

Fundamentals of **ORTHOPEDICS**



Mohindra • Jain

Fundamentals of Orthopedics

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Words of Wisdom

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Forewords

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Dedicated to

*My parents for their blessings, my wife, Bhumika for her
unconditional love and my family for always being there*

—Mukul Mohindra

*My parents, whose nurturing gave me courage to dream, my wife, Zeepee
who strengthened me to realize my dreams and my brother, Manish who has
always been there whenever I needed support*

—Jitesh Kumar Jain

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Osteoporosis



Words of Wisdom

“Hard work beats talent when talent doesn’t work hard” is a universal truth. The master key to success is determination, to do that extra bit and to go that extra mile. But effort should always be well disciplined. Discipline means persistence and perseverance—the ability to continue through bad times, obstacles and problems in a competent manner. This book is a diligent effort by a team of people to share the knowledge and experience they gained over the sleepless nights of hard work to give you the best. So get set to reach your goals with a mentor to guide and steer you through till you reach what you deserve.

Always remember the **6Ps** that demarcate the bridge between mediocrity and excellence.

Proper

Prior

Planning

Prevents

Poor

Performance



Deepak Chaudhary MS (ORTHO)

Director

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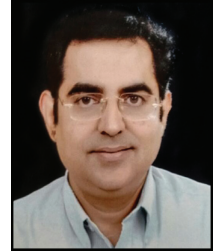
Foreword

Teaching methodology and orthopedics course curriculum have undergone plethora of changes in the past decade. The quantum jump in orthopedic technology witnessed in diagnosis and management of various orthopedic pathologies and procedures calls for a compact reading material, which keeps pace with the change.

“Fundamentals of Orthopedics” by Dr Mukul and Dr Jitesh has narratively and comprehensively explained the basic concepts, diagnosis and management of key orthopedic conditions which the undergraduates must know as part of their MBBS curriculum. The inclusion of excellent X-rays, clinical photographs and box depictions, besides elaborating high-yield points after each relevant pathology or concept are highly informative, with an eye on postgraduate entrance examination.

Having gone through a few chapters, I am fully convinced that this book with its lucidity yet in-depth elaboration of orthopedic pathologies will be an asset to every undergraduate student.

Dr Mukul and Dr Jitesh have worked with me at the Sports Injury Center, Safdarjung Hospital and VMM College and having an amazing clarity of clinical foundations of orthopedics. I strongly feel this book is a must on the shelf of every undergraduate student of medicine. I am sure the authors will further justify every subsequent edition, keeping in mind the fast changing orthopedic technology. I wish the book and the authors all the success in furthering the knowledge of orthopedics among the undergraduate students.



Himanshu Kataria MS (ORTHO) WHO Fellow (Liverpool)

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Foreword

We today live in an era where every individual has an inner desire to stay fit and look healthy. There is an aggression for speed in the young while the old tend to live longer as their life expectancy has increased. This has given an exponential rise to orthopedic problems in general population and hence it has become imperative for every undergraduate medical student to have a fair bit of orthopedic knowledge.

As an undergraduate student I always felt a lacuna that we never had any good book for orthopedic learning. Either the books used to be so vast to be covered in busy undergraduate training program or used to be too compact to even understand the basic concepts in the subject.

After so many years, I am feeling elated to write this foreword for the book “Fundamentals of Orthopedics” written by Dr Mukul Mohindra and Dr Jitesh Kumar Jain, which I believe is one of the best in recent times. I am certain that the key concepts given in this book would be beneficial not only to an undergraduate but also to the postgraduate students.

The authors have concised the vast knowledge of orthopedic problems in this book and depicted it in a very simple and easy language so that the undergraduate students can understand the important concepts in a much better way. The best part I would appreciate is the presentation of subject in an elaborative way but compacting all at the end of topics as high-yield points and synopsis. I believe reading this book would be a great fun and would enhance the orthopedic knowledge amongst young doctors and society as a whole.

I congratulate Dr Mukul and Dr Jitesh for writing this book.



Deepak Joshi MS (ORTHO)

Senior Specialist

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New Delhi, India

Foreword

It gives me immense pleasure to write a foreword for “Fundamentals of Orthopedics” written by Dr Mukul Mohindra and Dr Jitesh Kumar Jain. I believe that this book will fill the lacunae in undergraduate and postgraduate teaching. This book covers all the fundamental concepts in orthopedics in a simple language with excellent illustrations. First time, I have come across a book which shows all the fancy signs in orthopedics being clearly illustrated in figures and radiographs. Important tables and figures in color, lot of radiographs makes reading easy, matter easy to remember and has high recall value. All the topics have high-yield points keeping in mind the need for postgraduate entrance examination.



Both Mukul and Jitesh have a flair for teaching and it is appropriate that they have come up with this excellent book. I hope that all the undergraduates and postgraduates students will find it useful and it will find a place on reading shelves of all the orthopedic surgeons. I wish the authors and book success in enlightening all of us.

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Preface

“When the going gets tough, the tough gets going” This perspective well holds its worth even in today’s era where the examination system has undergone a paradigm shift. To keep pace with the growing expectations of the varied examiners, what is required from a medical student today is extreme versatility. Not only is it important to acquire sound principles to attempt the subjective papers and pass the clinical examination, it is equally mandatory to build an elaborative knowledge-bank that is accurate and up-to-date with the current trends to score well in the objective exams. This book is just a perfect answer to this tough task that time has posed to a medical aspirant.

The book has been written to offer an all-in-one package to conquer every version of the examination system. The information given in the book is elaborative yet it is concise and to the point. A number of contributors have shared their knowledge and concepts to ensure the material delivered is highly accurate. Considering the paucity of time that lies with an aspirant, the contributors have specially worked hard to ensure complete delivery of material in topics that lie sandwiched between orthopedics and other branches.

Since we have been actively involved in teaching for many years, we were well-versed with the changing trends. All topics have an incredible touch of simplicity yet they are comprehensive. An amazing feature of the book is the vast collection of images. Almost every clinical sign, clinical test, radiological sign, an instrument or an implant has been depicted in a well labelled figure. We remember well our times as undergraduates when looking at them we would ponder as what to look for. We are hopeful that this addition will not only enhance the practical skills of the readers but also help them steer through the increasing image based puzzles being put up in the online versions. This book also features the first ever introduced image based quiz section.

Keeping in mind the objective entrance pattern, well sorted statements have been added at the end of all the topics as “High-Yield Points” to facilitate answering the multiple choice questions. We have not only ensured that nothing is missed but also confirmed that information is highly accurate, for we understand well enough the worth every single correct answer holds in shaping your future.

When we sit back and share memories of times we used to prepare, we would often smile together at some common moments—that around 20 different subjects and all to be mastered for just one exam. It is indeed a herculean task for which we have jotted an excellent, well organized synopsis with efforts that spanned over sleepless nights. This chapter has all that you need to brush up a day before the exam when the adrenaline rush is high but the brain glucose low.

‘All is well that ends well’ a quote that needs no description. So to ensure the end to be just perfect a smartly prepared MCQ collection comprising both controversial and non-controversial questions from all recent exams have been sorted and jotted to rightly make the edition an “All in One” book. These MCQs are just the perfect feast for the hungry PG aspirants.

And to sum up we will share with you a quote well said, “You seldom improve when you have no role models but yourself to copy”. This book has been written to give you just a perfect mentor that will teach you precise concepts and practices of orthopedics, make you versatile to an extent the trend demands and simply, make you the best what you really deserve to be, for you have proven you are different from the lot by choosing a profession that is most noble.

Mukul Mohindra MS (ORTHO) DNB MNAMS

Jitesh Kumar Jain MS (ORTHO)

Acknowledgments

“Rome was not built in a day”. To accomplish a herculean task there are always a handful of people who stand strong behind the stage. This book was a dream project started by us but a long list of people got involved along, in one way or the other. It is our pleasure to acknowledge their efforts as without their support this project would have never reached its final destination.

Our journey started together in Sports Injury Center, Safdarjung Hospital where the seeds of this book were sown. It was the vision of our Director, Dr Deepak Chaudhary, to motivate us to begin this journey. Problems unfolded as we travelled the path but the guidance and blessings by our teachers Dr Himanshu Kataria, Dr Deepak Joshi and Dr Vineet Jain helped us pave our way through. Dr Ankit Goyal, Dr Nitin Mehta, Dr Pallav Mishra, Dr Himanshu Gupta, Dr Ajay Lal, Dr Vivek Shankar and Dr Ashutosh Jha were all a source of motivation whenever we got into any dilemma. Our co-fellows, Dr Mohd. Shafi Bhat, Dr Navdeep and our colleague Senior Residents, Dr Darsh Goyal, Dr Rahul, Dr Manoj Arya, Dr Shiv Chouksey, Dr Parth Chaudhary, Dr Sanjay Ramavat, Dr Rakesh Daripa, Dr Himanshu Bhargava, Dr Brahma Prakash, Dr Pawan Sharma, Dr Utkarsh, Dr Atul Mahajan, Dr Pankaj, Dr Sunny, Dr Rajat and Dr Prashant all deserve special thanks for adjusting with us for the duties and taking over the responsibilities so that we could work on the book.

I, Dr Mukul, would take this pleasure to thank my teachers whom I owe what I am today. Orthopedics for me started with Dr Mohammad Yamin, Head of Orthopedics Department at Dayanand Medical College and Hospital, Ludhiana and other faculty members from the department who made it interesting to a level that I could make it my choice. The Department of Orthopedics at PGIMS, Rohtak carved a stone into a structure which had a meaning. I am short of words to thank Prof Dr SS Sangwan (former Vice chancellor, University of Health Sciences, Rohtak) who was not just my guide but my mentor and Senior Professors Dr RC Siwach and Dr NK Magu for they have always been my role models. And thanks to Dr ZS Kundu, Dr A Devgun, Dr Roop Singh, Dr R Gupta and Dr R Rohilla for getting the right concepts and the right surgical skills into me. I would be failing in my duty if I do not thank Prof. Dr A Dhal, Head of Department of Orthopedics at Maulana Azad Medical College, New Delhi and Professors Dr AK Gupta, Dr VK Gautam, Dr Lalit Maini, Dr Vinod Kumar, Dr Manoj, Dr Sumit Sural and Dr Dhananjay Sabat who gave me the space to grow and allowed my skills to flourish. I would also extend my thanks to my motivators, Dr Sumer Sethi, Dr Tushar Mehta and Dr Pritesh Singh, my friends Dr Kamal Bali, Dr Chandan Jasrotia, and my seniors Dr Sanjay Arora, Dr Gaurav Saini, Dr Neerav and Dr Abhishek Jaipuria for their ever available support.

Prima facie, I, Dr Jitesh would be grateful to Lord Mahavira and Shiva for catering me good mental and physical health that made timely completion of this book possible. I owe my success to Department of Orthopedics, JN Medical College, Aligarh for sculpturing me into an orthopaedic surgeon and shaping me what I am today. I would extend my gratitude to my teachers, Dr Professor M Zahid, Dr Professor MKA Sherwani, Dr Professor Mazhar Abbas, Dr Professor Naiyer Asif, Dr AQ Khan, Dr Lateef Z Jeelani, Dr S Ahmad, Dr Owais A Qureshi, Dr Yasir S Siddqui, Dr Zulfqar, Dr Hatif and Dr Matloob Rehman for seeding in me the aptitude and the ethics of this field. I owe my practising skills to my mentor Dr JVS Vidyasagar, Head of the Department, Global Hospital Hyderabad and Dr Rajeev K Sharma, Senior Consultant at Indraprastha Apollo Hospital, New Delhi. I also thank my close inmates, Dr Sachin Khurana, Dr Kushesh Gupta, Dr Himanshu Gupta and Dr Varun Mittal for always being a backing to fall on. I would like to include a special note of thanks to my friend Nitesh Patni and Dr Praveen Sharma in encouraging me to start, endure and finally publish this book. I fail in my duty if I do not thank Dr Gaurav Gupta, Dr Faizan, Dr Ravish Chabra, Dr Nitin Agarwal, Dr Deepak Raghav, Dr Sachin Ingole, Dr Hiren Patel and Dr Matad Lokeshwaraiah Chetan for their valuable help and critical comments.

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Last but not the least we extend our thanks to our little artist Dr Shivali Arya, for her amazing sketches that gave real shapes to our weird ideas and words and to Ms Ritu, Ms Preeti and the staff at Sports Injury Center who helped us even beyond the working hours.

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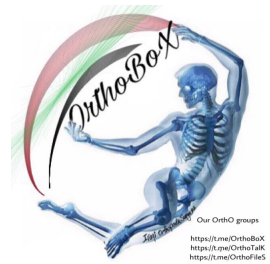
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CHAPTER

1

General Orthopedics



ORTHOPEDICS—HISTORY AND EVOLUTION

INTRODUCTION

It will be interesting to know that “orthopedics” was born as specialty for deformity correction in children. In 1741 Nicholas Andry (Fig. 1.1) coined the word “orthopaedics”, which was derived from Greek words for “correct” or “straight” (orthos) and “child” (paidion). Both “orthopaedics” and “orthopedics” are accepted spellings and in vogue worldwide. Until the end of 18th century “orthopedics” was limited to correction of deformity in children and fracture treatment was largely restricted to traction, splints and bandages.

In 19th century three landmark discoveries in surgical field which made surgeries safe, painless and enthusiastic were development of principles of antisepsis by Sir Joseph Lister (Fig. 1.2), the discovery of ether anesthesia in 1846 by William Morton (1819–1868) and the invention of X-rays by Wilhelm Konrad Roentgen (1845–1923). Discovery of X-rays revolutionized the way of making diagnosis in orthopedic cases. Another vital contribution which modernized the management of fractures was invention of plaster of Paris (POP) bandage by Antonius Mathysen in 1851. In 20th century World War I and II contributed a lot to development of core orthopedics. World wars produced countless number of patients requiring amputation, debridement, fracture management, tendon surgeries, etc. In fact many

great orthopedic surgeons were military surgeons like Sir Robert Jones, Gerdhard Kuntscher, Antonius Mathysen to name few of them. In world war II, there were less numbers of amputations, fewer infections, less gangrene cases and better fixations of fractures because of the lessons learnt from World War I. Now the scope of orthopedics has extended beyond fracture fixation and deformity correction and many specialty branches have emerged like spine surgery, orthopedic oncology, pediatric orthopedics, sports medicine, reconstructive orthopedics (joint replacement), etc.

SOME ORTHOPEDIC LEGENDS AND THEIR CONTRIBUTION

Galen (129–199 bc): Father of sports medicine. He is also credited with describing for first time the use of longitudinal traction for effecting reduction of overlapping bone fragments.

Nicholas Andry (1658–1759) (Fig. 1.1): He published the book “L’Orthopédie” in 1741 which conferred him the title of “**Father of Orthopedics**”. For correction of curvature deformity of tibia he suggested bandaging the limb to an iron plate (Fig. 1.3). This is the famous engraving of the “crooked tree” which has become the symbol of orthopedics.

Percival pott (1714–1788): Pott’s fracture. Potts paraplegia.



Fig. 1.1: Nicholas Andry (1658–1759).

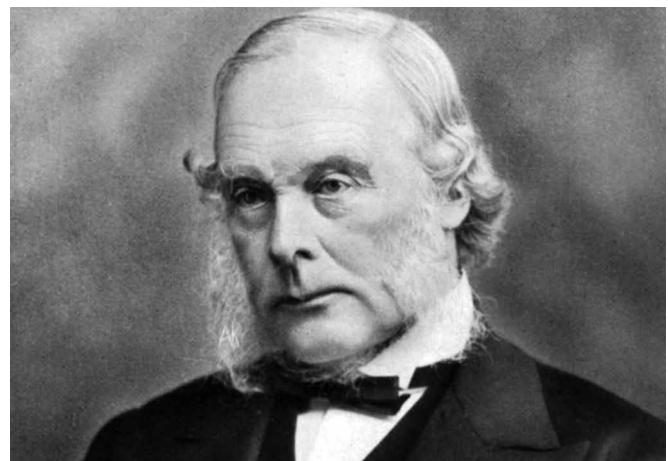


Fig. 1.2: Sir Joseph Lister (1827–1912).

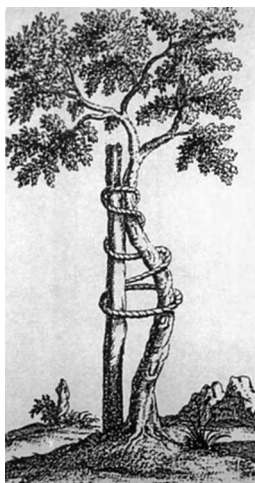


Fig. 1.3: Famous engraving of “Crooked tree” from the book of Nicholas Andry.

Jean-Andre Venel (1740–1791): He is considered by some as **“Father of Orthopedics”**. He established the first Orthopedics institute in the world in Switzerland.

Hugh Owen Thomas (1834–1891): He devised Thomas splint and Thomas test for flexion deformity of hip. He is also known as **“Father of British Orthopedics”**.

Sir Robert Jones (1855–1933): He was the nephew of great Hugh Owen Thomas. He is known as **“Father of Modern Orthopedics”**. He described the Jones fracture, Robert Jones bandage. He published first report of use of X-ray in orthopedics.

Albin Lambotte (1866–1955): He coined the term osteosynthesis and regarded as the **“Father of Internal Fixation”**. He also devised first external fixator.

Martin Kirschner (1879–1942): Who gave the very simple but very useful “K wire” to orthopedics.

Lorenz Böhler (1885–1973): **Father of trauma surgery.**

Kenji Takagi (1888–1963): **Father of arthroscopy.**

Austin T Moore (1899–1963): He performed the first metallic hip replacement. He gave the Austin-Moore prosthesis, which is still used today.

Gerhard Kuntscher (1900–1972): His big contribution to orthopedics is intramedullary nail which revolutionized the treatment of diaphyseal fractures of long bones.

Sir Raginald Watson Jones (1902–1972): He devised the Watson Jones approach (anterolateral approach) to hip joint. He was the student of Sir Robert Jones. He was the first editor of Journal of bone and joint surgery (British).



Fig. 1.4: Sir John Charnley (1911–1982).

Paul Randall Harrington (1911–1980): Harrington invented the Harrington Rod, a device that has helped more than 1 million patients of scoliosis to keep the spine straighten.

Sir John Charnley (1911–1982) (Fig. 1.4): **Father of total hip arthroplasty.** He was the great innovator of the modern total hip replacement and use of bone cement in total hip replacement.

Gavril Abramovich Ilizarov (1921–1992): He gave the famous Ilizarov theory that bone would grow if gradually distracted. His work pioneered the new way of treatment of one of most difficult cases of orthopedics; infected non-union, deformity correction and limb lengthening.

Masaki Watanabe (1911–1995): **Father of modern arthroscopy.** He performed first arthroscopic partial meniscectomy.

William F Enneking (1926–2014): **Father of Orthopedic oncology.** He gave a classification for bone tumors.

HIGH-YIELD POINTS

- Nicholas Andry is also known as father of parasitology.
- First intramedullary steel nail was introduced by Gerhard Kuntscher. However first interlocking intramedullary nail was performed by Modny and Bambara in 1953.
- First reamed intramedullary nailing was done by Fischer.

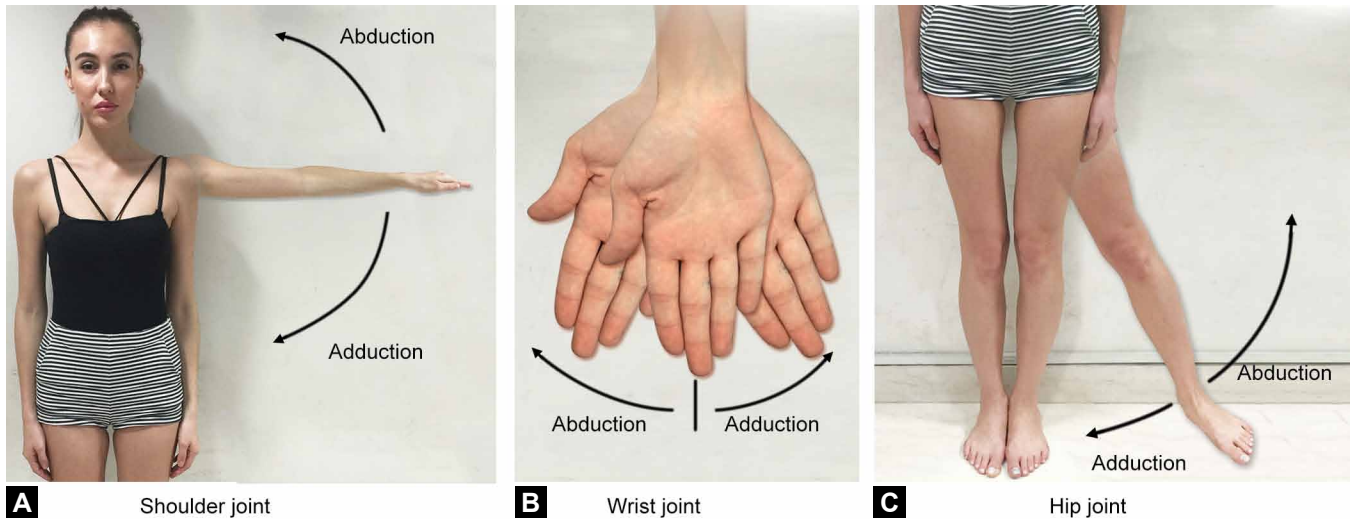
ORTHOPEDIC TERMINOLOGY

Abduction (Figs. 1.5A to C)—Movement of limb away from mid-sagittal plane of body.

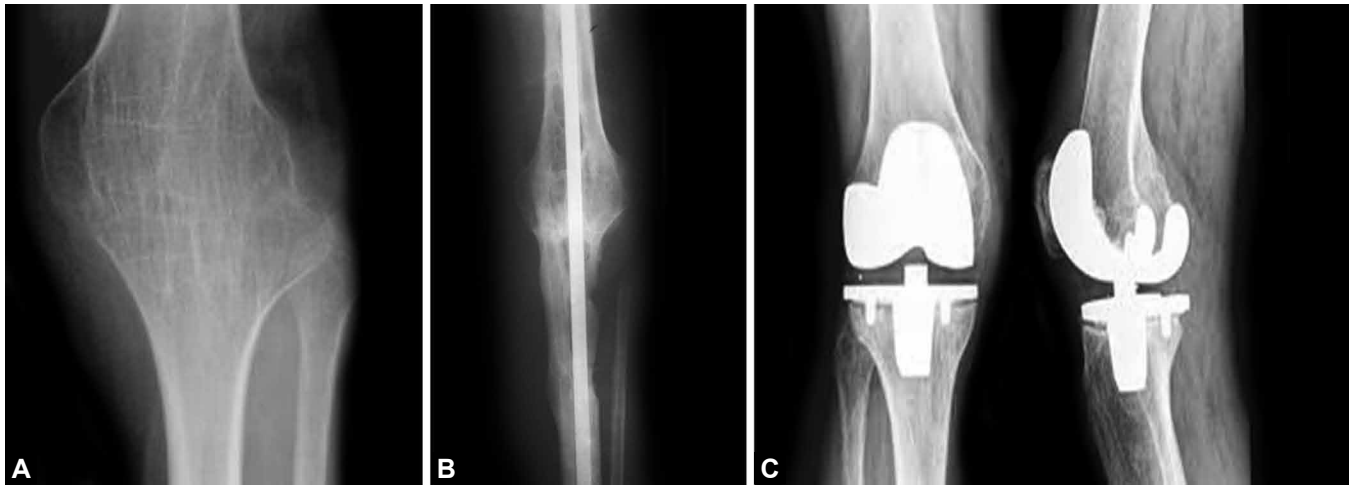
Adduction (Figs. 1.5A to C)—Movement of limb towards the mid-sagittal plane of body.

(Abduction and adduction movement occurs in coronal plane)

Ankylosis (Fig. 1.6A): Stiffness or fusion of a joint due to abnormal adhesions between two joint surfaces.



Figs. 1.5A to C: Abduction and adduction movements.



Figs. 1.6A to C: X-ray of knee showing (A) ankylosis, (B) arthrodesis and (C) arthroplasty.

Arthrocentesis: Joint aspiration (withdrawing synovial fluid/blood from the joint).

Arthrodesis (Fig. 1.6B): Surgically induced fusion of two joint surfaces.

Arthroeresis: It refers to an operation carried on a joint to restrict an undue mobility.

Arthrography: X-ray examination of joint after injecting contrast material (It has largely been replaced by MRI).

Arthropathy: A disease of a joint.

Arthroplasty (Fig. 1.6C): Replacement of a joint with a prosthesis.

Arthrosis: Degenerative wear and tear of cartilage of the joint (Osteoarthritis).

Arthrotomy: A procedure where surgeons cut into the joint (usually done to drain pus from joint).

Calcaneus: Foot fixed in dorsiflexion deformity at ankle joint.

Calcification: Deposition of amorphous calcium phosphate.

Cavus: Exaggeration of longitudinal arch of foot.

Clonus: Successive rhythmic involuntary muscular contraction and relaxation (pathological hyperreflexia of normal deep tendon reflex). More than 5 beats are significant.

Chemonucleolysis: Injection of chymopapain (an enzyme that dissolves part of the disk) into disk space to dissolve the disk (as a treatment of prolapsed disk)

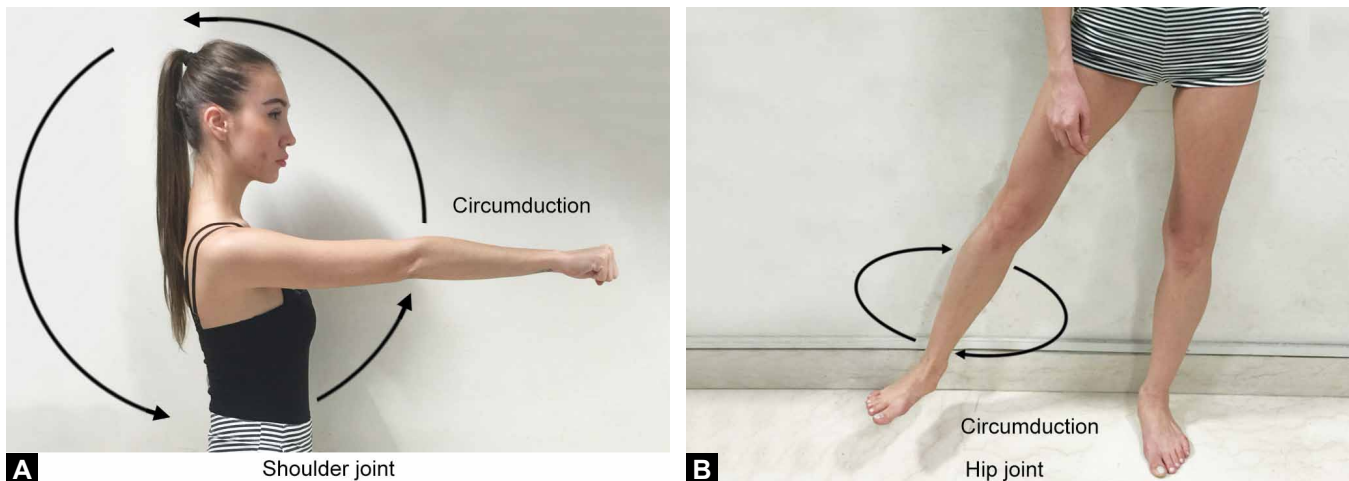
Circumduction (Figs. 1.7A and B): It is a combination of flexion, extension, abduction and adduction. In this movement distal end of a limb makes a conical movement and the apex of the cone is at the proximal end of the limb.

Dorsum: Upper surface of an animal (dorsal surface of hand is surface opposite the palm) or back of human.

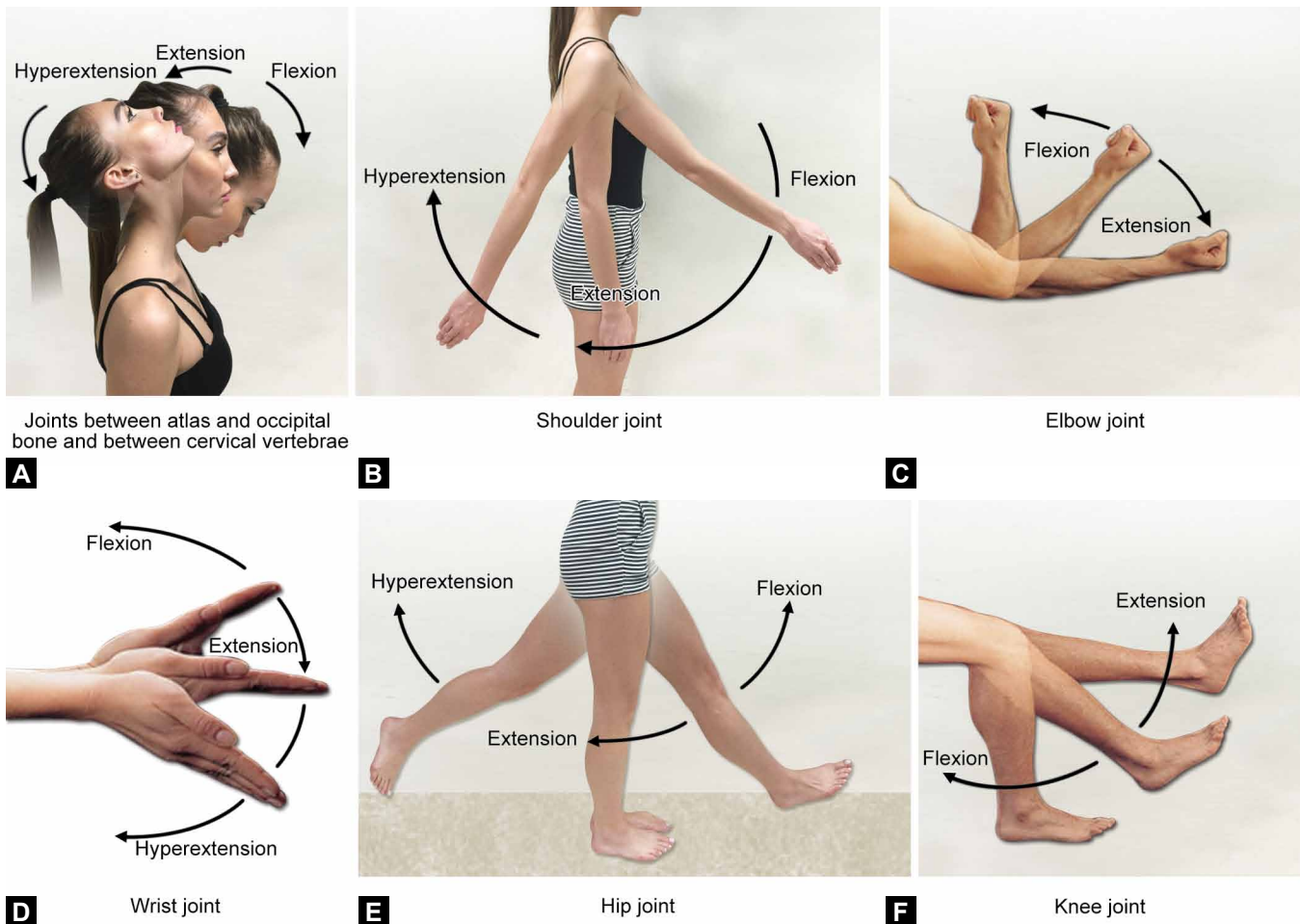
Epiphyseal plate/growth plate or physis: Hyaline cartilage present above the proximal metaphysis and below the distal metaphysis separating metaphysis from epiphysis.

Epiphysiodesis: Surgically induced fusion of epiphyseal plate or physis to metaphysis or/and epiphysis.

Equinus: Foot fixed in plantar flexion at ankle joint.



Figs. 1.7A and B: Circumduction movement (A) shoulder (B) hip joint.



Figs. 1.8A to F: Extension and flexion movements.

Extension (Figs. 1.8A to F): Movement in sagittal plane which increases angle between two body parts.

Eversion (Fig. 1.9): Plantar surface (sole) of foot rotates away from mid-sagittal plane.

Flexion (Figs. 1.8A to F): Movement in sagittal plane which decreases angle between two body parts.

Genu: Pertaining to knee.

Hemarthrosis: Bleeding into joint space.

Impacted fracture: When fracture fragments are driven into each other.

Interosseous membrane: A fibrous sheath that separates two bones (between two forearm bones or two leg bones).

Inversion (Fig. 1.9): Plantar surface of foot (sole) rotates towards the mid-sagittal plane.

Kyphosis: Normal backward convex curvature of spine in thoracic and sacral region.

Laminectomy: Removal of spinal lamina (usually to decompress spinal cord or nerves).

Lordosis: Normal backward concave curvature of spine in cervical and lumbar region.

Laminotomy: Removal of a part of lamina.

Manus: Pertaining to wrist/distal portion of forearm.

Myositis: Inflammation of the muscles.

Neurolysis: Interruption of the transmission of nerve signal (usually for pain relief) by application of physical agents (heat or freezing) or chemicals (such as phenol or alcohol) to a nerve.

Neurorrhaphy: Surgical suturing of a divided nerve.

Open reduction: Reduction of fracture fragments by surgical exposure and under direct vision. In open reduction fracture hematoma is drained.



Fig. 1.9: Eversion and inversion movements of foot.

Opposition (apposition) of thumb (Fig. 1.10): A movement unique to thumb in which thumb rotates around its long axis and its palmar surface comes in contact with palmar surface of little finger.

Orthotics: Orthotic is a device that aids/supports a body part and enhances the structural and functional characteristics of the skeletal system.

Ossification: Laying down of new bone or deposition of crystalline calcium phosphate to form new bone.

Osteoclasia: Surgically induced fracture of bone (to correct deformity).

Osteogenesis: Bone formation.

Osteometric devices: These are used to measure bone length.

Osteonecrosis: Death of bone tissue.

Osteosynthesis: Stabilization and internal fixation of fracture.

Osteotomy: A surgical procedure in which bone is cut in order to correct deformity.

Plantar surface: Inferior surface of foot which comes in contact of ground.

Plantaris: Equinus that occurs at the fore foot is called plantaris.

Pronation (Figs. 1.11A and B): Rotation of forearm and hand so that palm faces downward. Pronation of foot is combination of eversion, abduction and dorsiflexion.

Prosthetics: The art and science of developing artificial replacements for body parts.

Recurvatum: Excessive extension deformity of joint (genu recurvatum is hyperextension deformity of knee joint, i.e. knee bends backwards). It is opposite to flexion deformity.

SLAP lesion: Tear of superior labrum of shoulder anteriorly and posteriorly.

Spondylitis: Inflammation of vertebrae.

Spondylolisthesis: Anterior or posterior translation of one segment of spine in relation to the vertebrae below.

Spondylolysis: A defect in pars-interarticularis of vertebral arch. It may progress to spondylolisthesis.

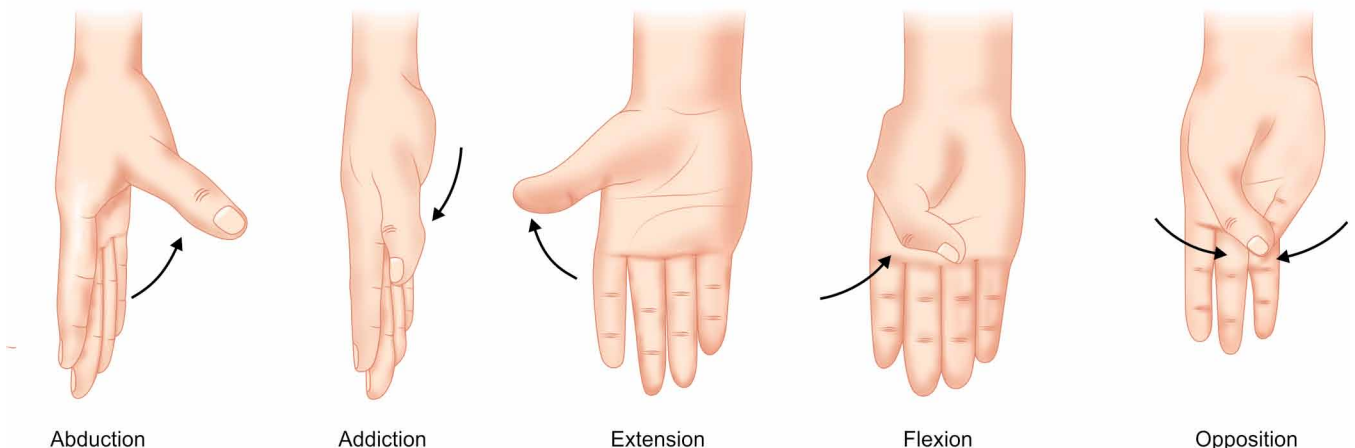
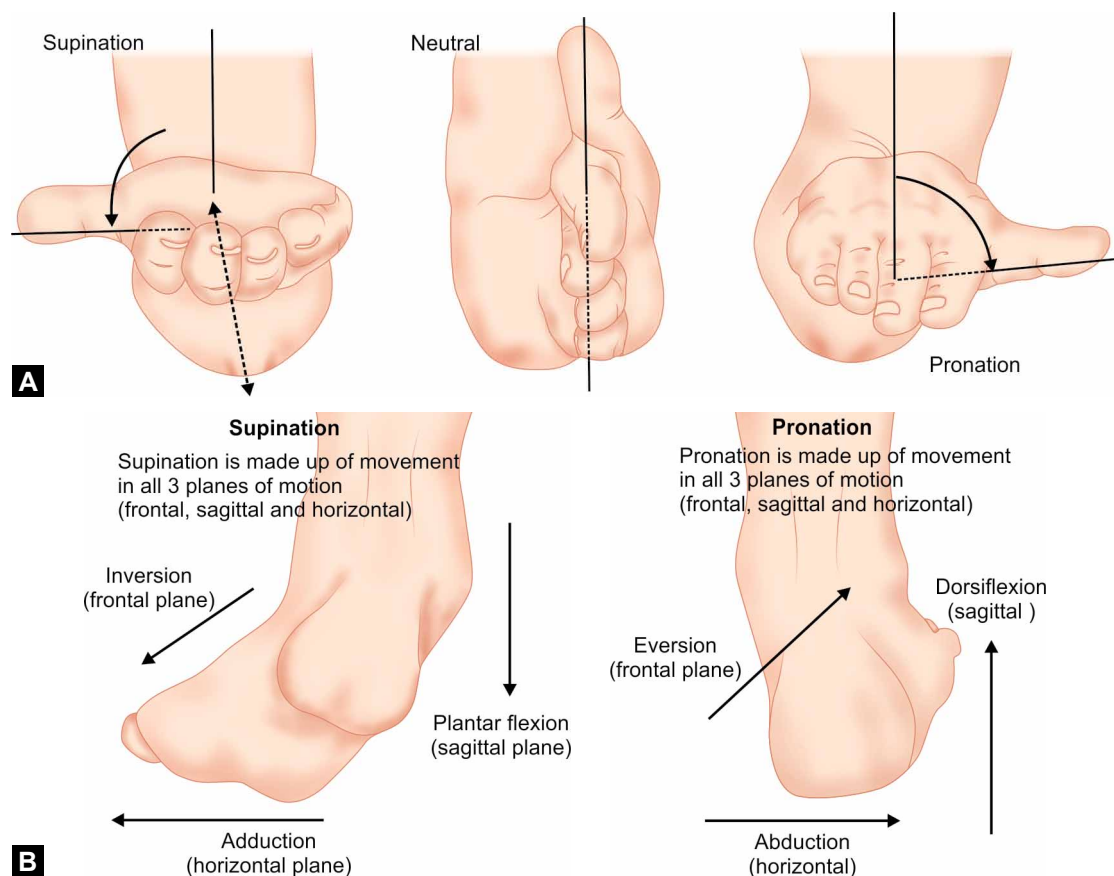


Fig. 1.10: Thumb movements.



Figs. 1.11A and B: Supination and pronation movements (A) wrist and forearm (B) foot.

Subluxation: Incomplete dislocation of a joint (articular surfaces remain in contact).

Supination (Figs. 1.11A and B): Rotation of forearm and hand so that palm faces upward. Supination of foot is the combination of inversion, adduction and plantar flexion.

Synovitis: Inflammation of synovium.

Tenodesis: Surgical suturing/anchoring of tendon to bone.

Tenolysis: Surgical release of a tendon from adhesions.

Tenotomy: Surgical division of a tendon.

Tenosynovitis: Inflammation of a tendon and its sheath.

Valgus: Position of distal end of long bone or a joint more lateral than it should be.

Varus: Position of distal end of long bone or a joint more medial than it should be.

(Note: Varus and valgus are coronal plane deformities)

Volar: Pertaining to palm or sole (palmar aspect of hand, plantar aspect of foot).

ANATOMY AND COMPOSITION OF BONE AND BONE GROWTH

BONE ANATOMY AND PHYSIOLOGY

Introduction

Bone is the basic unit of the skeletal system of the body. Bones along with ligaments and cartilage provide a strong yet flexible framework on which muscles attach through tendons to generate coordinated movements of the body. Human skeleton is divided into axial and appendicular parts.

Axial skeleton: Skull, vertebral column and thoracic cage.

Appendicular skeleton: Shoulder girdle and upper limbs, pelvic girdle and lower limbs.

HIGH-YIELD POINTS

- The largest internal organ in body is skeletal muscles.
- Adult skeleton has 80% cortical and 20% trabecular bone.
- Porosity of cortical bones mostly falls in range of 5% to 10% while that of cancellous bones ranges between 75% and 95%. Vertebrae have cortical to trabecular bone in a ratio of 25 to 75 (maximum in body).
- Cortical bone has an outer periosteal surface and an inner endosteal surface. Bone formation is more than bone resorption on the periosteal surface and

bone resorption is more than bone formation on the endosteal surface, so with aging bones normally increase in diameter and marrow space expands.

- Endosteum is the most metabolically active part of the bone, also the maximum remodeling occurs at the endosteal surface.
- Adult human body has average 206 bones of which 80 bones are present in axial skeleton and 126 bones constitutes the appendicular skeleton.
- Clavicle, scapula and pelvis belong to appendicular skeleton. Ossicles of the middle ear, the hyoid bone of the throat, are part of axial skeleton.
- By definition long bone is defined as one which is longer than its width. Phalanx followed by metacarpal/metatarsal is the shortest long bone.
- Although clavicle is classified as a long bone, it has no medullary (bone marrow) cavity.

Functions of Skeleton System

- *Shape and movements:* Skeleton framework gives shape to body and in coordination with muscles it allows for body movements.
- It protects vital organs as ribcage provides protection to lungs and skull provides protection to the brain.
- Bone is a store house of minerals specially calcium and phosphorus and plays vital role in the calcium metabolism (mineral homeostasis) in the body.
- In adults flat bones such as the pelvis, sternum, cranium, ribs, vertebrae and scapulae contain the red bone marrow and are the main site of blood production.

Structure of Bone

Bones are made up of bone cells (osteoblast, osteoclast and osteocytes) and intercellular matrix. Bones are densest tissue in the body due to deposition of minerals in the intercellular matrix. Deposition of minerals in the intercellular matrix makes the bones hard but light weight, strong but elastic so that it can efficiently support the movement, walking and running without bending or breaking.

Bone matrix consists of organic and inorganic components. Organic component includes collagen fibers (mostly Type I collagen). Inorganic matter is composed mainly of calcium and phosphorus in a crystalline form called “hydroxyapatite”. Bone also contains other minerals in small amount, i.e. magnesium, potassium, strontium and ferrous salts, etc. Organic matter gives the bones its flexibility and elasticity while inorganic matter gives the strength and hardness to the bones. Composition of bone is given in Box 1.1.

Bone cells: There are three types of bone cells—(1) osteoblast, (2) osteoclast and (3) osteocytes.

Osteoblasts: These are bone forming cells which derive from mesenchymal precursors in the bone marrow. These

are mononuclear cells which have well-developed rough endoplasmic reticulum and a large Golgi complex. Osteoblast lays down new matrix which is known as osteoid (uncalcified matrix). These are rich in alkaline phosphatase and produce type I collagen and other noncollagenous bone proteins. Osteoblasts are activated by parathyroid hormone and they control osteoclastic activity. Osteocytes are terminally differentiated stage of osteoblasts which get embedded in osteocytic lacunae.

Osteoclast: These are bone reabsorbing multinucleated giant cells derived from mononuclear precursors of macrophage lineage (specifically monocytes) in the marrow. These cells are activated by osteoblast. Their main function is to resorb bone and is thus involved in bone remodeling. Active osteoclasts are present in excavations in bone formed by them after erosion of matrix, the excavations being called as “Howship’s lacunae”.

A typical long bone derives its blood supply from nutrient artery, epiphyseal vessels and periosteal vessels. Nutrient artery supplies the diaphysis and metaphysis and epiphyseal region is supplied by epiphyseal vessels. Periosteum is richly supplied by periosteal vessels which also supply the outer cortex. If nutrient artery is damaged periosteal vessels are usually sufficient to nourish the bone. Bones can be classified based on anatomy and structure (Table 1.1).

Cortical bones are long bones of the body like femur or humerus and the small bones of hand and foot like metacarpals and metatarsals. Long bones of a child (Fig. 1.12) are divided into epiphysis, physis or growth plate, metaphysis and diaphysis. Epiphysis, physis and metaphysis are present at both ends. In mature bone epiphysis fuses with metaphysis and growth plate gets replaced by bone.

Box 1.1: Composition of bone (Dry weight based)

- **Inorganic matrix:** 65% (mainly calcium and phosphorus)
- **Organic matrix:** 35% (of which 80% is Type I collagen, non-collagenous proteins exist in small amount and include—osteocalcin/bone Gl a protein, osteopontin, osteonectin and alkaline phosphatase and cells make 5%)

Table 1.1: Classification of bones

Based on anatomy	<ul style="list-style-type: none"> • Long—Tubular bones of upper and lower limbs • Short—Short bones of foot and hand (tarsals and carpals), patella and sesamoid bones. • Flat—Bones of skull, pelvis, sternum, etc. • Irregular—Facial bones and vertebrae • Sesamoid—Which is present within a tendon or a muscle, i.e. patella in quadriceps tendon and pisiform in flexor carpi ulnaris tendon • Accessory bones: These are extra bones which have failed to fuse during development, i.e. accessory navicular
Based on structure	<ul style="list-style-type: none"> • Cortical (compact) and cancellous (trabecular) bones • Woven and lamellar bones

Parts of a growing long bone:

- **Epiphyses:** Epiphyses are present on the ends of the bones. It consists of cancellous bone covered by a thin layer of compact bone. On its ends it is covered by articular cartilage and forms the joint. In long bones epiphysis is present on both the ends; it is present on only one end of metacarpal, meta-tarsals and phalanges.
- **Physes:** Physis or growth plate is a thin region of actively growing bone cells between the epiphysis and the metaphysis in a growing bone. This is present on both the end of the long bones and responsible for the longitudinal growth of the bones. It consists of four zones (Fig. 1.13):
 1. Germinal zone/Resting zone
 2. Proliferative zone
 3. Hypertrophic zone
 4. Zone of endochondral ossification.

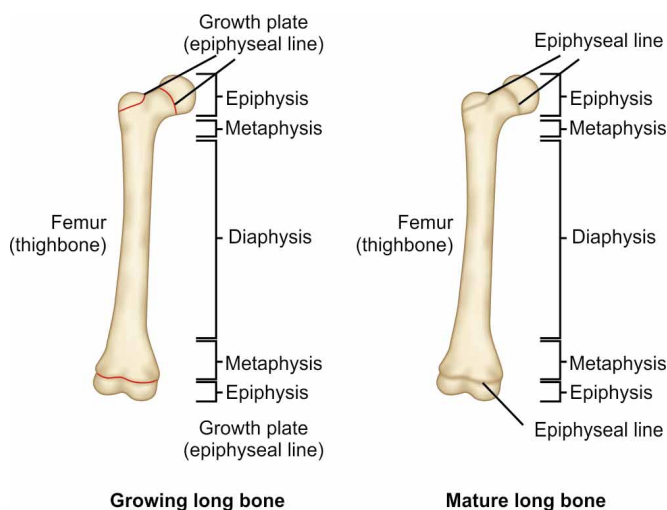


Fig. 1.12: Parts of growing and mature bone.

Germinal zone provides the developing chondrocytes which divide and get organized into columns in proliferative zone. Both germinal and proliferative zones are rich in extracellular matrix. In hypertrophic zone chondrocytes stop mitoses and undergo hypertrophy. This is the weakest zone of physis and most physeal injuries occur through this plane.

Physis is connected to epiphysis and metaphysis by the zone of Ranvier and perichondral ring of LaCorix. Zone of Ranvier contains germinal cells, which is responsible for circumferential growth of physis. Ring of LaCorix is a fibrous structure that is connected with zone of Ranvier and periosteum of metaphysis.

- **Metaphysis:** It is the junction between the growth plate and the diaphysis. It consists of both cancellous and cortical bone.
- **Diaphysis:** It is the region between the two metaphyses. It consists of compact cortical bone and has a medullary canal which consists of marrow. This portion of the bone is responsible for the strength of bone for weight bearing and movement.

Cancellous bones or trabecular bone: Small bones of the wrist, bones of the hind and mid-foot like calcaneum, talus, etc. and the epiphyseal and metaphyseal areas of long bones, flat bones (pelvis, ribs, skull, etc.), and vertebrae are cancellous bones. Cancellous bones are more porous, more vascular and have larger surface area than compact bone. It contains sheets of bone called trabeculae which connect open spaces of cancellous bone giving a honeycomb appearance. Red marrow fills the spaces around trabeculae. Trabeculae contain bone cells osteoblasts, osteocytes and osteoclasts. Osteoblasts are the bone-forming cells which secrete hard tissue of bone around them. When they are completely surrounded by layers of hard matrix they get converted into osteocytes which are present into small space called lacuna.

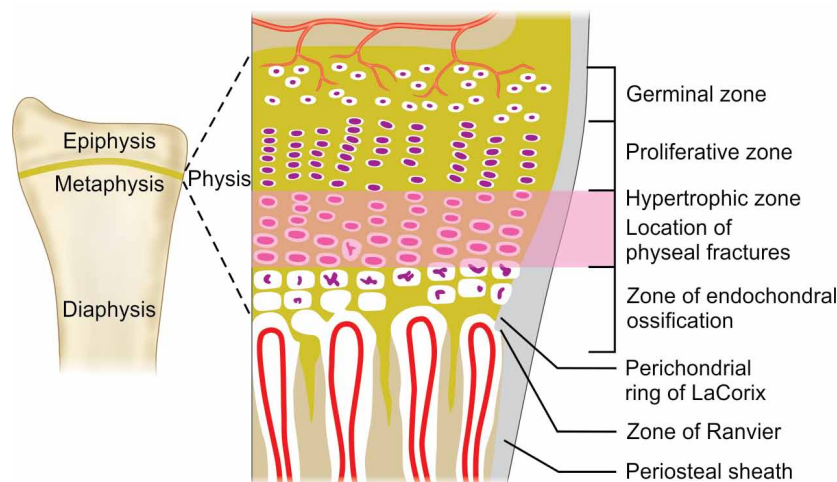


Fig. 1.13: Structure of physis.

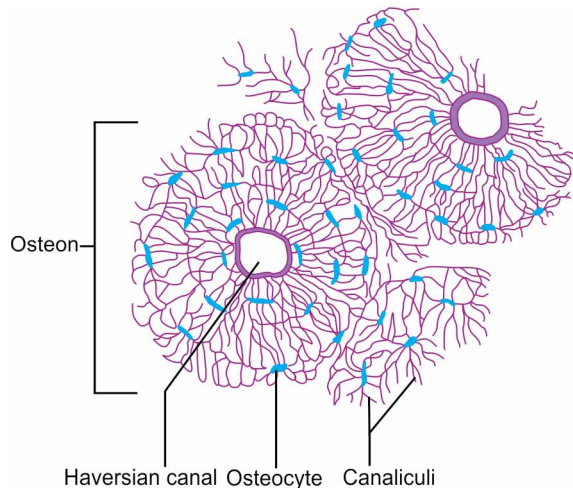


Fig. 1.14: Structure of compact bone.

Microscopic Structure of Cortical Bones (Fig. 1.14)

Cortical bone consists of a number of columns of cells called “osteon”. Each osteon has layers of bone cells like osteoblasts, osteocytes and osteoclasts around a central canal called “Haversian canal”. The outer border of an osteon is lined by a cement line which is a region of collagen-poor bone matrix.

The Haversian canal surrounds the blood vessels and nerves cells throughout the bone and communicates with the osteocytes in the lacunae through canaliculi.

“Volkmann’s canals” run perpendicular to the “Haversian canals”. They interconnect the Haversian canal with each other and the periosteum. These canals allow for the transfer of nutrients.

Woven bone and lamellar bone: Woven bone is relatively weak and is characterized by random organization of collagen fibers. It is immature bone which is not stress oriented (lamellar bone is stress oriented as it has parallel arrangement of collagen fibers). Woven bone is present in all fetal bone and in initial stage of healing (later it gets replaced by lamellar bone). Woven bone is quickly produced and it has high rate of turn-over compared to lamellar bone. In contrast to woven bone lamellar bone is mechanically stronger as it has a parallel alignment of collagen into sheets (lamellae). Both mature cortical and cancellous bones are lamellar bone.

HIGH-YIELD POINTS

- Adult skeleton has 80% cortical and 20% cancellous bone. Vertebrae have cortical to cancellous bone in a ratio of 25 to 75 (minimum in the body)
- The porosity of cortical bone mostly falls in range of 5%-10% while cancellous bone porosity mostly ranges from 75%-95%.

- Like lamellar bone, matrix in trabecular bone is also deposited in the form of lamellae. So trabecular bone is also lamellar bone but it does not contain Haversian systems.
- Periosteum is attached to bone by Sharpey’s fibers.
- Osteoid is uncalcified matrix
- Physis or growth plate is a temporary primary cartilaginous joint.
- With bone formation and resorption the levels of following substances increase in urine or serum:

Markers of bone resorption:

- Urine and serum cross-linked N telopeptides
- Urine and serum cross-linked C telopeptides
- Urine hydroxyproline
- Urine deoxypyridinoline
- Urine hydroxylysine glycosides
- Serum TRAP (Tartarate resistant acid phosphatase)
- Serum bone sialoprotein

Markers of bone formation:

- Serum bone specific alkaline phosphatase
- Serum osteocalcin
- Serum carboxy terminal extension peptide of procollagen-1
- Serum type I collagen extension peptide
- Osteocytes are most abundant cells in bone tissue.
- Osteocalcin is a protein that is exclusively produced by osteoblasts and its concentration in blood is a measure of osteoblastic activity.
- A number of growth factors have been identified that are produced by osteoblasts that regulate cell development and differentiation in bone. Bone morphogenetic proteins are one of them that have recently received a bit of attention. They have been synthesized in purified form from bone matrix and are commercially available for therapeutic use to enhance osteogenesis. Marshal Urist (1964) is credited with this invention.

GROWTH OF BONE

The process of formation of bone is called “ossification”. During the fetal stage it occurs either by “intramembranous ossification” or by “endochondral ossification”.

Intramembranous ossification: It occurs in flat bones and in clavicle. Here calcium hydroxyapatite is directly deposited into a preexisting membrane (primitive connective tissue) without any intervening cartilage model stage. During intramembranous ossification mesenchymal cells, derived from neural crest proliferate. Some of these mesenchymal cells differentiate into osteoblasts (ossification center) which secrete collagen and proteoglycan. Calcification occurs in this collagen matrix. During this process of calcification, bony (calcified) spicules are formed. A layer of mesenchymal cells that surround the calcified spicule forms the periosteum.

Endochondral ossification: Endochondral ossification is seen in long bones of the body. It involves the formation

of cartilage and its subsequent replacement by bone. During endochondral ossification some mesenchymal cells develop into chondrocytes. These chondrocytes proliferate and secrete extracellular matrix which is mineralized to form cartilage model. Now cartilage cells start dying and few cells surrounding cartilage become osteoblast (ossification center) and secrete bony matrix into degrading cartilage. In this way the whole cartilage gets replaced by bone.

Primary ossification centers appear in the cartilage during the fetal development. These are responsible for the formation of diaphysis of the bones. Secondary ossification centers mostly appears after birth and are responsible for the formation of epiphysis of the long bone and the extremities of flat and irregular bones.

Appositional (Increase in Width) and Interstitial Growth (Increase in Length)

In fetal life each long bone is represented by a rod of hyaline cartilage surrounded by perichondrium. Interstitial growth in this cartilage model occurs when chondrocytes within the cartilage divide and secrete new matrix and increase the length of cartilage model. Appositional growth occurs when chondroblasts in the perichondrium produce new matrix at the periphery and increase the width of cartilage model.

In contrast to cartilage, bone grows only by appositional growth. Longitudinal growth which occurs before maturity is due to cartilage proliferation in the epiphyseal and metaphyseal areas of long bones, before subsequently undergoing mineralization to form bone. Inner layer of periosteum (cambium layer) contains osteoprogenitor cells which develop into osteoblast. These osteoblast secrete new bone matrix and increase the thickness of bone.

HIGH-YIELD POINTS

- **Ossification centers (OC):** Ossification centers for the distal femur, calcaneum, talus and sometimes cuboid are present at term birth. OC for proximal tibia is either present at birth or appears within 2 months.
- The first bone to ossify in the human skeleton is the clavicle. It is only long bone to ossify by intra-membranous ossification. It ossifies at 5th week of intrauterine life and that is when the human skeleton starts forming. Clavicle is also the last bone to complete ossification. Mandible is the second bone to ossify after clavicle by intra-membranous ossification.
- All long bones tend to have a single primary center for the shaft that appears before birth. Then after birth a variable number of ossification centers appear for the ends that fuse with the shaft. Clavicle is the only long bone to have two primary centers of ossification.
- As per the law of ossification, the secondary center that appears first fuses last. The bone that does not obey this law is “fibula”.
- In 1st metacarpal secondary center of ossification present in base but in heads in all other metacarpals.
- **Ossification of carpals:** Carpal bones ossify by rule from one center only. Capitate is the 1st carpal bone to ossify (at 2 months) and before three years only capitate and hamate ossify in a child's hand.
- **Chondrodiastasis:** This implies the gradual physal distraction (without producing fracture) and opening of the growth plate (Salter and Harris type I epiphyseal detachment). It is a recently introduced method to achieve limb lengthening and deformity correction.

FRACTURE TYPES AND CLASSIFICATIONS

FRACTURE TYPES AND CLASSIFICATION SYSTEMS

A fracture is a break in the continuity of bone (even a single cortex) with or without displacement. There are many ways to classify fractures (Table 1.2). Classification systems have evolved from description of clinical appearance of fracture (before invention of X-rays, i.e. colles fracture) to radiology based fractures description.

Why a Classification is Needed?

- It guides the treatment—a common treatment approach is usually followed for same injuries, i.e. interlocking nailing for diaphyseal fracture of femur or tibia.

- It explains prognosis—open fractures are more likely to carry poor prognosis than close fractures, high chance of avascular necrosis in some fracture, i.e. fracture proximal pole of scaphoid and basal fracture neck of femur.
- It makes easy to describe a fracture, i.e. to give details of fracture to other surgeons.

Mechanism of injury and fracture pattern (Table 1.3): A fair idea of mechanism of injury can be inferred from X-ray appearance of fracture.

Symptoms and Signs of Fracture

Pain, swelling, tenderness and abnormal mobility are present at the site of fracture. There may be varying soft tissue injury around the fracture. Displaced fracture presents

Table 1.2: Classifications of fractures





Based on displacement	<ul style="list-style-type: none"> • <i>Undisplaced fractures</i>: Bone only breaks but fracture fragments do not displace. • <i>Displaced fractures</i>: Minimally to completely displaced fractures. • <i>Impacted fracture</i>: When fracture fragments are pushed into each other. It is usually seen in distal radius and proximal femur fracture.
Based on communication with environment	<ul style="list-style-type: none"> • <i>Close</i>: No contact with external environment. • <i>Open fractures</i>: Where fracture communicates with environment. In open fractures, fracture hematoma is drained out of wound (See Chapter 2 for detail).
Based on completeness	<ul style="list-style-type: none"> • <i>Complete fracture</i>: Complete loss of bone continuity. • <i>Incomplete fractures</i> (only one cortex is broken), i.e. greenstick fracture.
Based on etiology	<ul style="list-style-type: none"> • <i>Traumatic fracture</i>: Which is sustained due to injury. • <i>Pathological fracture</i>: Which occurs in diseased bone due to trivial trauma or no injury. • <i>Stress fracture</i>: Which occurs in normal bone due to excessive stress/overload. • <i>Fragility fracture</i>: A type of pathological fracture which occurs due to osteoporosis.
Based on radiology	<ul style="list-style-type: none"> • <i>X-ray features based</i>: Most currently used classifications are X-ray based, i.e. Garden classification of fracture neck femur. • <i>CT scan based</i>: Sanders classification of calcaneus fracture.
Based on fracture pattern	<ul style="list-style-type: none"> • Transverse, oblique, spiral, comminuted and segmental.
Based on location	<ul style="list-style-type: none"> • <i>Intraarticular fractures</i>: Which involve the articular surface. • <i>Extraarticular fractures</i>: Diaphyseal and metaphyseal fractures.
Other types	<ul style="list-style-type: none"> • <i>Avulsion fracture</i>: A small chunk of bone is torn away from the bone due to pull of ligament or tendon. • <i>Periprosthetic fractures</i>: Fractures around joint replacement prostheses.

with deformity at fracture site. Patient is not able to use his fracture limb, i.e. weight bearing is not possible on fractured tibia or femur. Crepitus can be elicited at fracture site but is often very painful. Any fracture (especially high velocity injury) may be associated with injury to surrounding vital structures (vessels and nerves).

HIGH-YIELD POINTS

- Tenderness is the most common sign of fracture and pain is most common symptom of fracture.
- Abnormal mobility and loss of transmitted movements is the surest sign of fracture.
- In transverse fracture forms an angle less than 30° with horizontal. In oblique fracture it is more than 30°.

Table 1.3: Mechanism of injury and fracture pattern

Type of force	Geometry of fracture	
1. Bending	<i>Transverse/oblique</i> : In transverse fracture, fracture line runs transversely to the long axis of bone.	
2. Twisting/torque	<i>Spiral</i> : Fracture line spirals along the long axis of bone in more than one plane	
3. Moderate axial compression combined with bending and torsion	<i>Oblique</i> : Fracture line runs oblique to the long axis of the bone. The two cortices of each fragment are in the same plane.	
4. High energy force and direct impact	<i>Comminuted</i> : More than three fracture fragments.	

- Occult fracture is a general term applied to those subtle fractures where clinical examination points to a fracture but the fracture is not visible on an X-ray. Fatigue and insufficiency fractures many a times present as occult fractures. The investigation of choice for occult fractures is MRI more than CT. Occult fractures are seen on X-rays after 2–4 weeks when there is evidence of new bone formation.

AO classification (Muller AO/OTA classification): This is a unique and comprehensive classification (Boxes 1.2 and 1.3) which can be applied to fracture of all bones. It is an alphanumerical classification, i.e. numbers and alphabets are used to classify a fracture. Recently a pediatric version has also been published.

In AO classification each major bone is given a number (Fig. 1.15) like humerus, forearm bones, femur and leg bones have been assigned 1, 2, 3 and 4 respectively. Each long bone is divided into three parts or segments; proximal segment, diaphysis and distal segment which are assigned 1, 2 and 3 number respectively. Each part is further divided into types (Table 1.4).

Types of proximal and distal segment fractures are classified as:

- A—Extraarticular
- B—Partial articular
- C—Complete articular

Types of diaphyseal fractures are classified as:

- A—Simple
- B—Wedge
- C—Complex

Each type is further divided into groups and subgroups which differ from bone to bone.

Box 1.2: Systematic approach to classify a bone fracture by AO classification

AO classification a unique and uniform pattern of answering five questions to classify a fracture:

1. Which bone?
2. Which part (segment) of bone?
3. Which type?
4. Which group? and
5. Which subgroup?

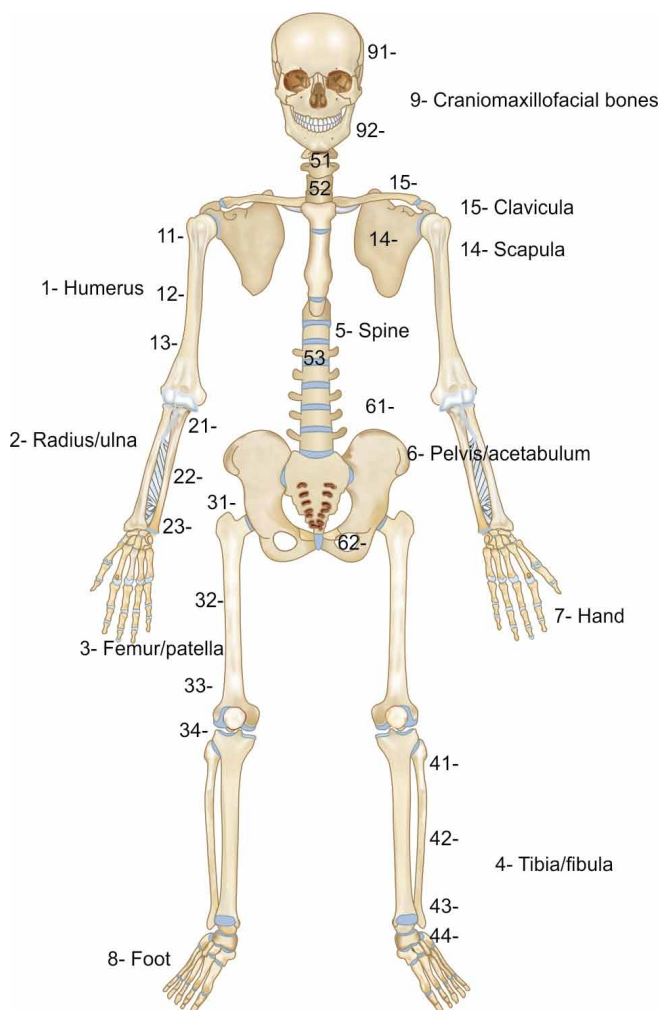


Fig. 1.15: AO classification—each major bone is assigned a number.

Box 1.3: Example of AO classification

How will you classify a proximal metaphyseal humeral fracture which is comminuted with no contact of articular surface with diaphysis?

- Which bone—humerus (1)
- Which part—proximal segment (1)
- Which type—complete articular (C)

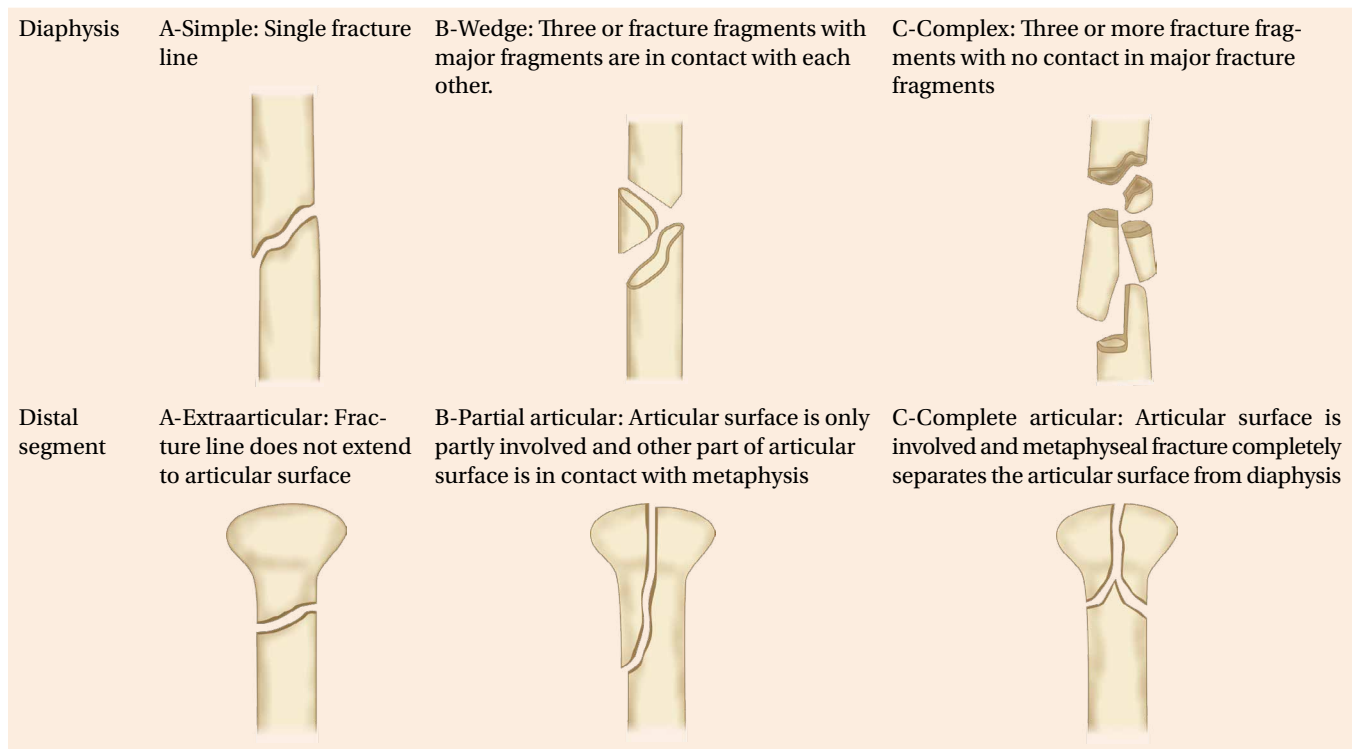
So this will be classified as fracture 11-C.

Table 1.4: AO classification—each part/segment is divided into three types A, B and C

Proximal segment	A-Extraarticular: Fracture line does not extend to articular surface	B-Partial articular: Articular surface is only partly involved and other part of articular surface is in contact with metaphysis	C-Complete articular: Articular surface is involved and metaphyseal fracture completely separates the articular surface from diaphysis

Contd...

Contd...



BIOLOGY OF FRACTURE HEALING

DELAYED UNION AND NONUNION

There is no universal definition of fracture nonunion which is applicable to all fractures. Arbitrarily nonunion fracture is one that has not united and is not expected to unite without intervention. In nonunion fracture gap is filled by fibrous tissue or fibrocartilage.

Delayed union of fracture is defined as when fracture takes more than usual time to unite depending on the type and site of fracture, but shows some progression towards union over time. Most orthopedic surgeons do not consider nonunion of fracture of shaft of long bones to happen before 6 months.

United States Food and Drug Administration panel definition of nonunion: "When union does not take place in 9 months after fracture and fracture shows no visible progressive signs of healing for 3 months".

Etiology

Causes of nonunion are multifactorial and may be related to patient, injury, fracture or treatment.

Patient or host factors:

- Age: Old age
- *Malnutrition:* Albumin less than 3.5 and lymphocytes less than 1,500 cells/mL indicates poor healing potential

- Smoking/tobacco abuse
- Alcohol abuse
- *Systemic diseases:* Diabetes, cancer, metabolic bone diseases, osteomalacia, cushing disease.
- *Drugs:* Nonsteroidal anti-inflammatory drugs (NSAIDs), antineoplastic drugs, corticosteroid therapy and bisphosphonates
- Radiation therapy
- Infection

Local factors (related to injury):

- Open fractures (excessive periosteal stripping and soft tissue damage)
- Intraarticular fracture
- Denervation of bone
- Bone loss, segmental fracture
- High velocity injury/severely comminuted fracture
- Intact fellow bone (intact fibula may prevent apposition of fracture fragments in case of fracture tibia)
- Soft tissue interposition

Factors related to treatment:

- Inadequate reduction (Fig. 1.16)
- *Inadequate internal fixation:* Implant too short, construct too stiff.
- *Inadequate immobilization:* Excessive motion at fracture site leads to disruption of early bridging callus
- *Wrong surgical technique:* Excessive periosteal stripping.

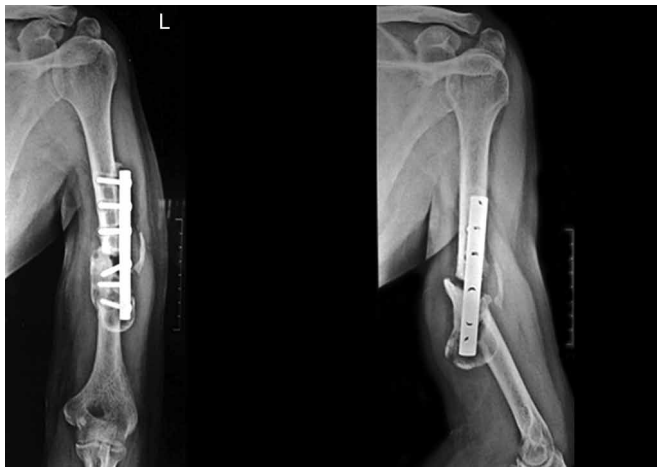


Fig. 1.16: X-ray humerus AP and lateral showing nonunion following inadequate reduction.

Box 1.4: Fractures prone to nonunion

- Fracture neck of femur
- Fracture proximal pole and waist of scaphoid
- Fracture body of talus
- Fracture lateral condyle in children
- Fracture proximal fifth metatarsal
- Nonunion is also common in fracture distal one-third of tibia and distal one-third of ulna.

Fracture specific factors:

- *Vicarious blood supply:* Some fractures are prone to nonunion due to vicarious blood supply of the bone (Box 1.4).
- Pathological fractures have poor healing potential
- Neuropathic fractures.

CLINICAL FEATURES

Patient who has been waiting for union of fracture for long time after fracture presents with persistent pain and tenderness at the fracture site with functional disability (inability to use limb). Instability (frank mobility, crepitus) may be present. Patient should be evaluated for signs of infection like swelling, increased local temperature, discharge, etc.

Radiology

X-ray of fracture nonunion may show following signs (Fig. 1.17): Persistent fracture line, paucity of callus, sclerotic and rounded fracture ends with obliteration of medullary canal and osteopenia in surrounding bone. CT scan may show persistent fracture line in doubtful cases. Scintigraphy helps to distinguish between biologically active (rich blood supply) and nonresponsive nonunion (poor blood supply).

HIGH-YIELD POINTS

- Fractures which are prone to malunion are:
 - Supracondylar humerus fracture in children



Fig. 1.17: X-ray leg AP and lateral views showing X-ray signs of nonunion.

- Intertrochanteric fracture of femur
- Colles fracture

All these are metaphyseal fractures. Metaphysis is cancellous bone and hence rapidly unites but often malunites

- Union—on two orthogonal X-rays (AP and lateral) healing of three out of four cortices without pain is considered union.
- Most common site of nonunion is fracture of distal one-third of tibia and most common cause of nonunion is inadequate immobilization.
- Hypertrophic nonunion is usually seen where immobilization is not adequate and abundant callus formation occurs in an attempt to attain stability.
- Indium111-labeled leukocyte imaging is very sensitive and specific in diagnosing infected nonunion.
- Excessive motion and very rigid fixation (no motion) both may lead to nonunion whereas micro motion at fracture ends promotes callus formation and is a desirable factor.

Types

Fracture nonunion is classified based on the blood supply of fracture ends (Table 1.5).

PSEUDOARTHROSIS (FIG. 1.18A)

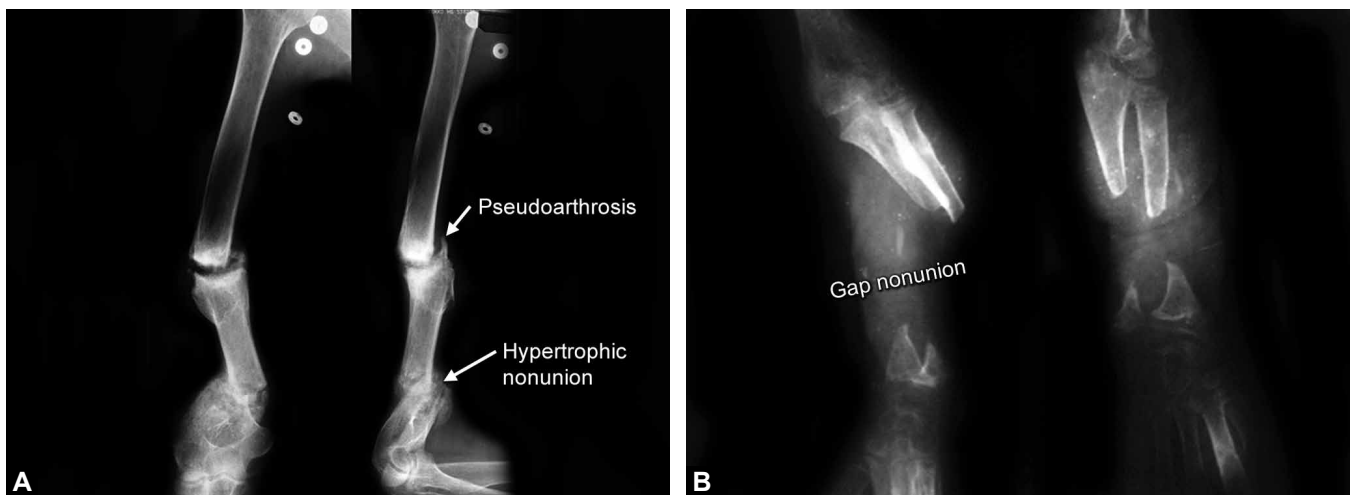
It is a type of nonunion, characterized by fluid filled cavity (clear fluid) which is lined by a membrane (synovial like cells), between fracture ends. Bone scan shows vascularized bone ends. It occurs due to insecure fixation where excessive motion leads to false joint formation.

Treatment

In hypertrophic nonunion stable internal fixation may promote union but treatment of oligotrophic and atrophic noninfected nonunion is open reduction, debridement of

Table 1.5: Types of nonunion (Figs. 1.18 and 1.19)

Hypertrophic nonunion	They are characterized by vascularized bone ends. Callus formation is generally seen and may be abundant but this callus is nonbridging in nature.	<ul style="list-style-type: none"> • Elephant's foot—rich in callus—it results from insecure fixation and early weight bearing in a reduced fracture • Horse's hoof—less abundant callus—it is seen in moderately unstable fracture fixation • Oligotrophic—minimal or no callus but vascularized bone ends. It is seen in distracted/displaced bone ends.
Atrophic nonunion	Characterized by absence of callus. Bone scan shows avascular fracture ends. Fracture ends become atrophic and osteoporotic.	<ul style="list-style-type: none"> • <i>Torsion wedge</i>: Characterized by avascular intermediate fragment between fracture ends which has united to one main fracture end. • <i>Comminuted</i>: Characterized by presence of one or more avascular fragments between fracture ends • <i>Defect (gap) nonunion</i> (Figs. 1.18A and B): Characterized by loss of bone between fracture ends.



Figs. 1.18A and B: (A) X-rays of humerus AP and lateral views showing pseudoarthrosis and hypertrophic nonunion; (B) X-ray forearm AP and lateral views showing defect nonunion leading to atrophic and osteoporotic bone ends.



Fig. 1.19: X-ray of leg AP and lateral views showing sclerosed fracture ends and scanty callus formation with obliterated medullary canals—typical of atrophic nonunion.

sclerotic fracture ends and bone grafting. Nonunion with bone loss, shortening and deformity are difficult cases and require distraction osteogenesis using ring fixator based on the Ilizarov's principles (page 29).

Box 1.5: Biophysical methods used in treatment of nonunion

- Low intensity pulsed ultrasound
- Electrical stimulation
- High-energy extracorporeal shock wave therapy

Apart from surgical methods biophysical methods (Box 1.5) have also been used in treatment of delayed and nonunion with varying success.

BONE GRAFTING

A bone graft is a transplanted bone. Its use is indicated to stimulate bone union, to replace lost bone or to assist in revascularization of avascular segments.

Types

A graft transplanted from one site of skeleton to another site within the same individual is called an autograft/autogenous bone graft.

- Autogenous bone graft is gold standard. Fresh grafts that are transferred directly from the donor to the recipient site are usually autogenous grafts.

- Allografts are harvested from one individual and transplanted into different individual of the same species. Allografts are preserved and treated (freeze drying, irradiation, chemomodification, etc.) before transplantation to reduce graft rejection.
- Xenografts are transplanted from one species to a member of a different species.
- An isograft is transplanted from one monozygotic twin to the other.

Additionally, the graft may be described as cortical, cancellous, corticocancellous and osteochondral (bone and cartilage piece).

The graft may be vascularized with its own blood supply (vascularized bone graft) or it may be nonvascularized (free grafts). The vascularized bone grafts can be harvested in two ways. One is to take a bone (usually fibula) and keep its blood vessel intact (free vascularized bone graft) and anastomose the same to a vessel at the recipient site. The other is to take a bone along with an attached pedicle of muscle such that the vessel of the muscle is kept intact (muscle pedicle bone graft). This bone can be transplanted to a nearby site and the muscle's vessel continues to supply the bone.

Properties of Graft

Osteoinduction: Process of inducing pluripotent/primitive mesenchymal cells to differentiate into bone forming cells osteoblasts.

Osteoconduction: Graft acts as scaffold for the growth of new bone on its surface and deep down into pores, when placed in contact with native bone.

Osteogenesis: Graft itself provides bone forming cells osteoblasts.

HIGH-YIELD POINTS

- Autologous cancellous grafts are usually harvested from the iliac crest (most common site), the fibula, proximal tibia, the distal radius, the olecranon, the greater trochanter and distal femoral condyles. Best site for cancellous bone graft is posterosuperior iliac spine.
- Iliac crest is also a source of tricortical graft. Other sources of cortical graft are fibula and ribs.
- Cancellous bone grafts serve the purpose of osteoinduction and osteoconduction and also provide for osteoprogenitor cells. Cortical grafts are poor in osteoinduction and do not provide for osteoprogenitor cells.
- Cancellous bone graft is slowly replaced by new bone by a complex process technically known as "creeping substitution".
- **Demineralized bone matrix (DBM):** It is an allogenic bone graft prepared by acid extraction of cortical bone. It is rich in collagen I, noncollagenic protein and has some bone morphogenetic proteins (BMPs). BMPs convey osteoinductive property in DBM.

BONE GRAFT SUBSTITUTES

Limited availability of autologous bone graft, donor site morbidity limits the use of autogenous bone graft. Allogenic bone grafts have limited potential of osteoinduction and inferior mechanical strength as compared to autologous bone graft due to freeze-drying used in its storage and sterilization. They also carry a small risk of disease transmission. These shortcomings led to developments of bone graft substitutes. Table 1.6 summarizes the different bone graft substitutes used in orthopedics.

FRACTURE HEALING

Fracture healing is a remarkable process that aims at the restoration of exact anatomy of bone. Although it is a continuous process but divided into five phases which overlap each other. Depending upon the type of fracture and method of fracture fixation and immobilization fracture healing is of two types primary and secondary.

Primary Fracture Healing or Direct Fracture Healing (Healing without Callus)

It is less common mode of fracture healing. It is seen in rigid internal fixation of fractures (compression plating) and in unicortical fractures (Greenstick fracture). It is direct attempt of bone to restore its continuity without forming fracture callus. It is of two types, gap healing and contact healing. Gap healing occurs when there is minimal gap in between rigidly fixed fracture ends. Woven bone (immature bone having random arrangement of collagen fibers) is initially formed in transverse orientation between fracture gaps which is later replaced by lamellar bone (regular parallel alignment of collagen into sheets/lamellae).

Contact healing is seen when fracture ends are closely approximated to each other without any gap. Osteoclasts at one end of fracture cause bone resorption to form so called cutting cones such that the fracture gap widens initially. In these cones osteoclast cut by osteoclasts lay down new bone.

Table 1.6: Bone graft substitutes

Type	Example	Properties
Ceramic based	Calcium phosphate and its collagen composites, hydroxyapatite, tricalcium phosphate, bioactive glass, etc.	Osteoconductive
Polymer based	Biodegradable polymers	Osteoconductive
Growth factors based	BMPs and platelet rich plasma (PRP)	Osteoinductive
Cell based	Bone marrow aspirate	Osteogenic potential

Secondary Fracture Healing or Indirect Fracture Healing (Healing by Callus Formation)

This is more common method of fracture healing. It is seen in absence of rigid fixation (cast immobilization, intramedullary nailing and bridge plating for comminuted metaphyseal fractures). It is divided into five phases (see Box 1.6):

1. *Stage of hematoma formation:* It starts within few hours of fracture with hematoma formation. Periosteal and intramedullary vessel disruption produces a hematoma at fracture site.
2. *Stage of granulation tissue/inflammatory phase:* Hematoma accumulates beneath periosteum and between fracture ends and act as a source of growth factors and cytokines that initiate cellular events of healing. Inflammatory response peaks at 24 hours with accumulation of neutrophil, platelets, lymphocytes, macrophages, endothelial cells and fibroblasts. These cells produce a number of growth factors and cytokines like fibroblast growth factors (FGFs), vascular endothelial growth factors (VEGFs), transforming growth factor- β (TGF- β), platelet-derived growth factor (PDGF), interleukin-1 and interleukin-6 (IL-1 and IL-6), tumor necrosis factor- α (TNF- α) and bone morphogenetic proteins (BMPs). These factors act as chemoattractants for mesenchymal stem cells derived from periosteum and bone marrow and also induce their differentiation into chondroblast, osteoblast, fibroblast and angioblast.
3. *Callus formation:* It starts within few days of the end of inflammatory phase and lasts for few weeks. The

Box 1.6: Approximate timing of various phases of fracture healing.

- Hematoma organizes by 2-3 days
- Granulation tissue is fully formed by 2-3 weeks.
- Provisional callus/Soft callus is seen first around 3 weeks.
- Woven bone/Hard callus is seen by 3 months or bone consolidates (clinical union) by 3 weeks.
- Remodelling continues to occur over 2-3 years.

stem cells that have differentiated into osteoblasts synthesize new bone to effect repair (Repair phase). The phase consists of intramembranous ossification, chondrogenesis and endochondral ossification. As healing progresses P^H gradually becomes alkaline from acidic pH of inflammatory phase. In the initial stage of this phase the healing tissue is composed of mixture fibrous connective tissue, cartilage, some woven bone and osteoid called as provisional callus or soft callus. This callus is pliable and weak good enough to prevent shortening at fracture site but not angulation or rotation. Callus becomes visible earliest on radiographs by 3 weeks.

4. *Stage of consolidation:* Cells from the cambium layer of periosteum are the earliest to produce bone and osteoblast at the periphery of callus also produce bone by intramembranous ossification. Simultaneously chondrocytes derived from stem cells simultaneously lay down cartilaginous matrix. Mineralization of this cartilaginous matrix takes place by these chondrocytes. Ultimately at the end of this phase whole callus is composed of woven bone (mineralized callus but lacking a lamellar structure, also called as hard callus). This woven bone or hard callus is rigid and strong and when it is formed bone is said to have clinically united.
5. *Remodeling phase:* This phase continues for the years and this aims at restoration of exact architecture of bone. Some biologists call it the modeling phase where special units called as bone remodeling units consisting of both osteoclasts and osteoblasts are formed on the surface of the bone. The osteoclast reabsorb the woven bone and osteoblast deposit more and more osteoid. In this way the whole woven bone is eventually replaced by lamellar bone. Thicker lamellar bone is laid in the area of high stresses (these are compression sites having more of osteoblastic activity) while in areas with no stress (these are tension sites having more of osteoclastic activity) unwanted bony buttresses are curved away to make the bone attain anatomical shape (Wolf's law).

Figure 1.20 is showing in series radiological progress in a uniting bone.

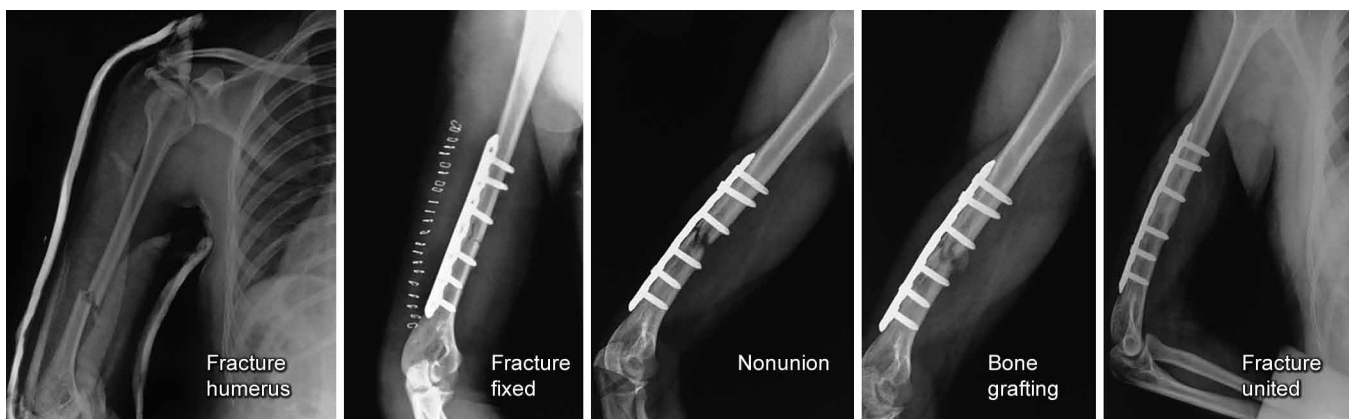


Fig. 1.20: Fracture humerus as it unites in a 24-year-old male.

HIGH-YIELD POINTS

- Some authors divide the process of fracture healing into three phases: Inflammatory (hematoma formation and granulation tissue formation), reparative (soft and hard callus formation) and remodeling phase.
- The first radiological stage of union is callus (provisional callus/soft callus) but the first clinical stage of union is woven bone (hard callus).
- Tetracycline labeling is a special method used to estimate the rate of mineralization in newly laid osteoid or in other words it estimates rate of bone turn over. It is used in diagnostic situations in cases like osteomalacia, bone tumors, etc.
- Stage of remodeling is governed by Wolf's law. It states that bone is deposited only along the lines of stress. Extra bone is all reabsorbed to give a uniting bone its anatomical appearance.

- Better fracture remodelling is seen in younger patient, fracture nearer to growth plate and when deformity/angulation is in plane of joint movement.
- Bone is continuously in a remodeling state. In adult skeleton (after skeletal growth has ended) for bone deposition to occur a raw surface would be needed. This is prepared by osteoclasts (bone resorbing cells that are derivatives of monocytes). These cells resorb cortical bones by forming cones but they resorb cancellous bone by forming lacunae (Howship's lacunae).
- Bone apposition/formation is going to be best seen in Howship's lacunae followed by cutting cones prepared by osteoclasts in a normal adult bone. However, in a fractured bone (bone resorption is not needed) so the apposition would be best in the subperiosteal cambium layer.

FRACTURE CONSIDERATION IN CHILDREN AND PHYSEAL INJURIES

Pediatric bone is anatomically and biomechanically different from adult bone. It behaves differently from adult bone to injury and also during healing.

UNIQUE FEATURES OF PEDIATRIC BONE

- Periosteum is thicker than adult bone. Thicker periosteum requires more energy to disrupt than in adults. This is the reason for characteristic greenstick fracture pattern in children.
- Periosteum is more vascular. This helps in rapid healing of fractures.
- Pediatric bone is more porous than adult. It prevents peripheral extension of main fracture line, so comminuted fractures are rare in children.
- Pediatric bone has low bending strength and low modulus of elasticity compared to adult bone (more flexible).



Fig. 1.21: X-ray forearm lateral view showing greenstick fracture of radius.

Thus pediatric bone absorbs greater energy before failure and plastic deformation is common in pediatric bone.

- Pediatric bone has more remodeling capacity than adult bone. Deformity in plane of motion remodel to greater extent than deformity in other plane. Rotational deformity remodels less than angular deformity.
- *Open physis:* Physeal injury can cause partial or complete closure of physis or growth plate. This may cause growth deformity and shortening.
- Pediatric bone has low mineral density compared to adult bone.

CHARACTERISTIC FRACTURE PATTERNS OF PEDIATRIC BONE

- *Greenstick fracture:* Thicker periosteum resists the deforming forces more than in adult. This causes characteristic greenstick fracture in children. In greenstick fracture one cortex breaks and other cortex remains intact or only deforms (Fig. 1.21). Greenstick fracture is most commonly seen in forearm bones. *Treatment of greenstick fracture:* Traction is given to align the bone and reduction force is applied directly at the fracture. Overcorrection is often done, this may complete the fracture. After alignment fracture is immobilized in cast.
- *Torus/Buckle fracture (Fig. 1.22):* These fractures occur at junction of metaphysis and diaphysis. This is incomplete and stable injury with buckling of one cortex. These fractures result from axial loading with compression of trabeculae. Fracture line is usually not visible and sometimes angulation is the only clue to fracture. Splinting is usually all that is required for treatment.



Fig. 1.22: X-ray leg AP and lateral views showing torus fracture of distal tibial metaphysis.



Fig. 1.23: Plastic deformity—see the angulation without any break. Source: Reproduced from Chee Y (2009). Plastic deformity. EURORAD. DOI:10.1594/EURORAD/CASE.2791.

Table 1.7: Salter-Harris classification

Type	Description
I	Fracture plane passes through the growth plate
II	Fracture plane passes through the physis and metaphysis
III	Fracture plane passes through physis and epiphysis
IV	Fracture plane passes through the metaphysis, physis and down through the epiphysis.
V	Crushing injury of physis

Rarest, most difficult to diagnose.

*Thurston-Holland fragment is triangular piece of metaphysis that remains attached to epiphysis. It is characteristic of type II physeal injury (but also seen in type IV).

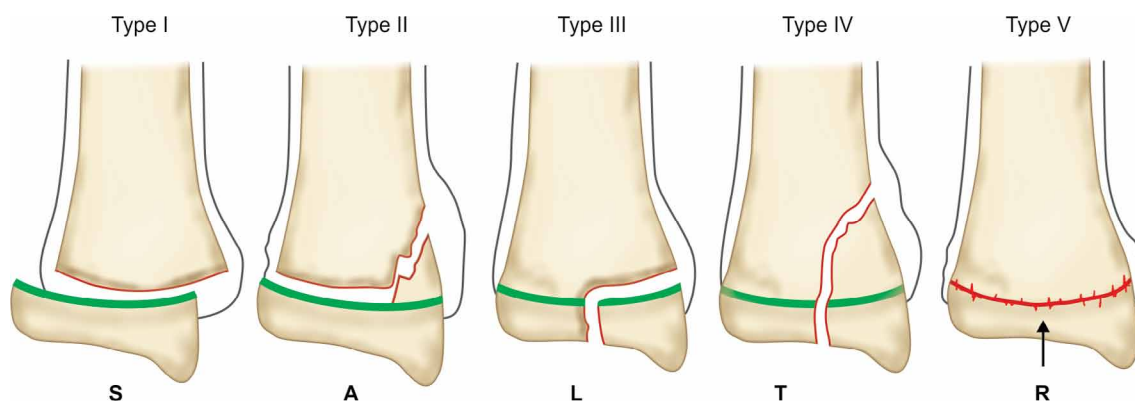


Fig. 1.24: Physeal injuries.

- *Plastic deformation* (Fig. 1.23): Bones in children are more flexible than in adult. When force is not sufficient to break the bone it may angulate or bend the bone permanently (beyond elastic limit). Plastic deformation is most common in forearm bone especially in ulna. Severe deformity (angulation more than 20° in older children) requires reduction and splintage.
- *Physeal injury*: Open physes are susceptible to injury in children. These are common injuries in children

especially in adolescents (12–14 years) nearing the growth spurts. Most common site of physeal injury is phalanx followed by distal radius. Salter Harris classification (Table 1.7) (Fig. 1.24) is most commonly used to classify physeal injuries in children. It is based on the location of fracture in one or more of epiphysis, physis and metaphysis. It also predicts the outcome/prognosis. Type I has the best and type V has the worst prognosis.

Table 1.8: Mnemonic for SALTER Harris classification- “SALTR”

Type I	Type II	Type III	Type IV	Type V
Slipped (slippage of epiphysis)	Above (Fracture passes up in the metaphysis)	Lower or below (Fracture passes below in epiphysis)	Through (fracture passes through the all; epiphysis, physis and epiphysis)	Rammed or cRushed physis

**Fig. 1.25:** X-ray of elbow showing displaced radial head epiphysis in a child.

Mnemonic SALTR is useful in remembering this classification (Table 1.8).

Diagnosis of physeal injuries: Child presents with pain and swelling around the joint. Diagnosis of physeal injuries can be made on routine X-rays (Fig. 1.25). Whenever in doubt comparison with X-ray views of normal joint and MRI are very useful.

Treatment: In children fractures heal at a faster rate so timely reduction of physeal injuries is of paramount importance. Attempt of reduction in cases presenting late can further damage the growth plate. In type I and II fractures reduction should not be attempted after 7–10 days, however type III and type IV fractures must be reduced as they involve the articular cartilage. Once reduced reduction can be secured with pins or/and cast.

Complications: Growth disturbance (angular deformity, shortening) is the single most important complication of physeal injury. Significant deformity may require osteotomy and/or limb lengthening procedures.

HIGH-YIELD POINTS

- Clavicle is the most common bone to be fractured at birth followed by humerus. See Box 1.7 to know some most common fractures in different scenarios.
- *Toddler's fracture:* It is undisplaced/minimally displaced spiral fracture of shaft of tibia usually seen in small children. Treatment is long leg cast immobilization for 2–3 weeks.
- *Growing fractures:* These are skull fractures seen mainly in infancy and early childhood characterized by progressive diastatic enlargement of the fracture

Box 1.7: Most common fractures

Most common fracture overall—clavicle > distal end radius

Age wise

Most common fracture at birth—Clavicle

Most common fracture in children—greenstick fracture of forearm bones

Most common fracture in elderly—vertebral fracture > distal end radius fractures

In a patient presenting with history of fall on outstretched hand

Most common fracture if patient is a child (especially less than 8–10 years)—Supracondylar humerus

Most common fracture if patient is a young adolescent—Scaphoid fracture

Most common fracture in adult (especially post-menopausal osteoporotic female)—Distal end radius

line. A complication can be a cystic mass filled with CSF, called as a “leptomeningeal cyst”. The weakest zone of growth plate that is ruptured in most physeal injuries is the hypertrophic zone.

- The largest and the fastest growing of all growth plates is the distal femoral physis (contributes 70% to femur length and 37% to leg length). It is the first physis in the body to ossify. Also it is the commonest physis to be injured around the knee. Injury can occur during birth in a breech delivery leading to Salter Harris type I lesion. More commonly it is injured in a child by knee hyperextension (distal fragment displaced anteriorly) or when there is a valgus force to the knee (distal fragment goes laterally). The former mostly causes a type II lesion and a risk to popliteal artery rupture while the latter mechanism is more commonly associated with a type III or a type II Salter Harris lesion. In either types characteristically multiple layers of the growth plate are injured (not just the hypertrophic zone)
- Rare types of physeal injuries are:
 - *Type VI:* Injury to the peripheral portion of the physis and a resultant bony bridge formation which may produce an angular deformity (added in 1969 by Mercer Rang).
 - *Type VII:* Isolated injury to the epiphyseal plate (VII–IX added in 1982 by JA Ogden).
 - *Type VIII:* Isolated injury to the metaphysis, with a potential injury related to endochondral ossification.
 - *Type IX:* Injury to the periosteum that may interfere with membranous growth.
- Other classification for physeal injuries that are less commonly used—Ogden classification, Poland classification and Peterson classification.

SPLINTS AND TRACTIONS

SPLINTS

Any “rigid” device “used to immobilize” the injured part of the body is called a splint. Almost any rigid material can be used to splint the injured limb in emergency (Fig. 1.26). The primary purpose of splinting is “preventing further trauma and reducing pain”, until diagnosis and primary management is done. Splints may also be used in “postoperative period for support”, rest or even as a definitive measure to treat an orthopedic injury/deformity in the form of a POP back slab/cast. There are a wide variety of methods to splint an injured limb depending on the site of trauma. A few commonly used splints/braces are mentioned in Table 1.9.

Plaster of Paris Splint (Fig. 1.27)

It is a commonly used splint which can be used to support any fracture. It can be molded according to shape of limb. When one molds it to cover three-fourths of circumference of a limb, this splint is called a POP slab. It

is often used to support the fractured limb for transportation of patient while the patient is awaiting definitive treatment.



Fig. 1.26: Use of wooden plank as an emergency splint.

Table 1.9: Commonly used splints and braces

<i>Name</i>	<i>Use</i>
Aeroplane splint	Brachial plexus injury
Aluminium splint	Fracture of phalanges
Anterior spinal hyperextension brace	Dorsolumbar spinal injury
Ankle stirrup splint	Ankle sprain, ankle fractures
Bohler-Braun splint	Lower limb fractures-tibia and femur
Buddy strapping	Phalangeal fracture
Cramer wire splint	Fractures of arm, forearm, and leg
Cock up splint	Radial nerve palsy
Denis Brown splint	CTEV
Figure of eight brace	Clavicle fracture
Four post collar, SOMI brace, Philadelphia collar	Cervical spine injury
Forearm sugar tong splint	Distal forearm and wrist fracture
Knuckle bender splint	Ulnar nerve palsy
Lumbar corset	Lumbar strain
Mallet finger splint/Stack splint	Mallet finger
Milwaukee/Boston brace/Lyon brace/Providence brace/Charleston brace/Wilmington brace/SpineCor brace	Scoliosis
Radial gutter splint	Fracture of radial side metatarsals
Sling and swathe	Shoulder and humeral injuries
Taylor's brace, crotel frame	Dorsolumbar spinal injury
Thomas splint	Lower limb fractures
Toe raising splint/AFO brace	Foot drop
Tri-point splint	Boutonniere deformity, swan neck deformity
Ulnar gutter splint	Fracture of ulnar side metatarsals, Boxer's fracture
Volkman's splint	Volkman's ischemic contracture
Von Rosen's splint	Congenital dislocation of hip

Thomas Splint (Figs. 1.28A and B)

It was designed by H O Thomas for tuberculosis of knee. It has one outer bar, one inner bar and one ring. Ring is at an angle of 120° to the inside bar and the outer bar has a curve to accommodate the greater trochanter.



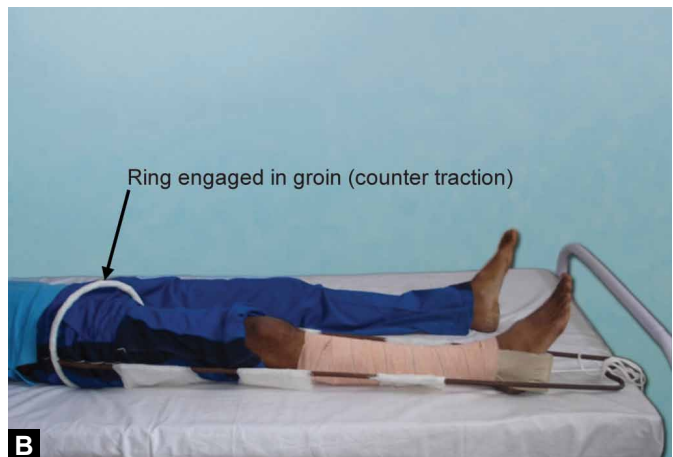
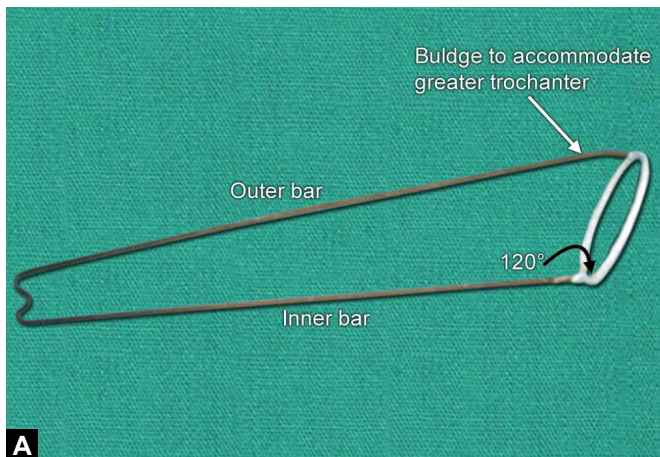
Fig. 1.27: Plaster of Paris splint.

Size and preparation of Thomas splint: Appropriate length of the Thomas splint should be chosen for proper splintage. Ring size is chosen by adding 2 inches to the thigh circumference at the highest point of groin. Length is measured by adding 6 inches to the length from highest point on the medial side of groin to heel. After having chosen the appropriate size Thomas splint is prepared by padding of it by cotton bandages and cotton. Ring should also be padded well to avoid impingement on the skin.

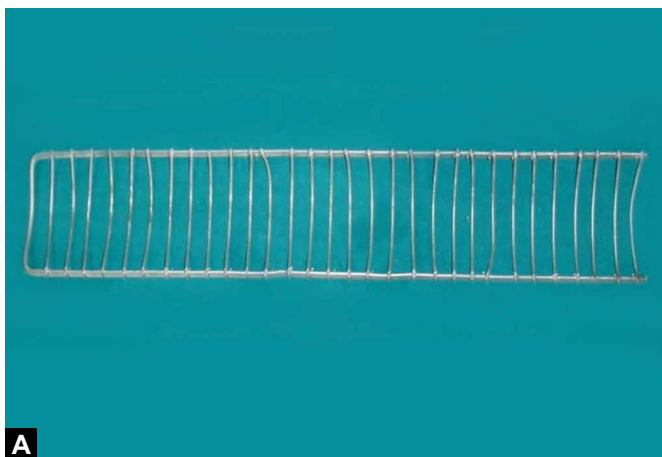
Use: It is used for immobilization of lower limb in hip and thigh injuries. It is efficient and easy to use tool for transportation of patients with lower limb injuries. Fixed and sliding traction can also be given on Thomas splint.

Cramer Wire Splint (Figs. 1.29A and B)

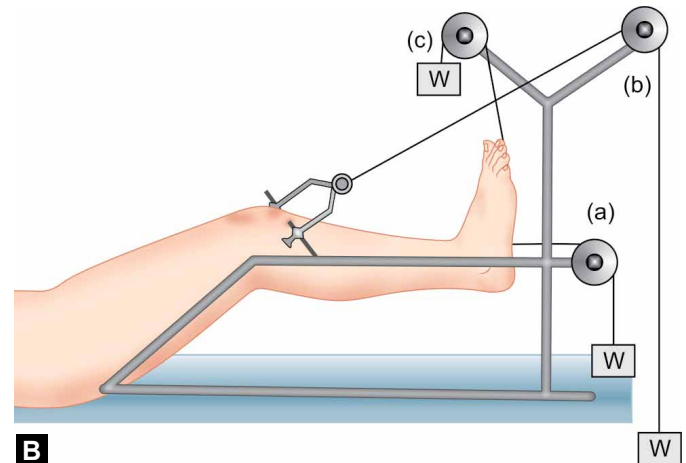
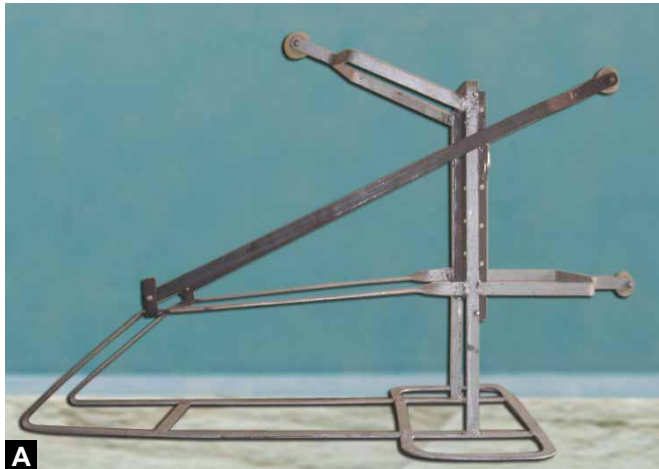
It is made up of two thick and parallel wires with many interlacing wires (ladder splint). It is a flexible splint which can be bent in different shapes to accommodate different body parts. It is used for temporary splintage of fractures of both upper and lower limbs during transportation.



Figs. 1.28A and B: (A) Thomas splint and (B) Fixed traction on Thomas splint.



Figs. 1.29A and B: (A) Cramer wire splint and (B) it can be easily bent to support fractures of limbs.



Figs. 1.30A and B: (A) BB splint and (B) traction on BB splint.

Bohler–Braun Splint (BB Splint) (Figs. 1.30A and B)

Bohler modified the Braun's splint which had only one pulley for tibial traction. Bohler-Braun splint has three pulleys for simultaneous tibial and femoral tractions and to change the angle of traction. Commercially available BB splint has three or four pulleys. It is used for both tibial and femoral fractures.

Functions of Pulleys

Pulley A—Calcaneal/tibial traction

Pulley B—Femoral traction

Pulley C—It is used to change the line/angle of traction. It is also used to prevent equinus deformity of ankle or foot drop.

One disadvantage of BB splint is that ambulation of patient is difficult on it.

HIGH-YIELD POINTS

- Two great surgeons are associated with Bohler-Braun splint. (1) Lorenz Böhler, the “father of traumatology”, and (2) Heinrich Braun, the “Father of local anesthesia”.
- *Tobruk splint*: Fixed traction of lower limb on a Thomas splint.
- *Fisk splint*: Modified Thomas splint to which a knee flexion piece is attached.

INDICATIONS

Splints are indicated in initial management of acute musculoskeletal injuries. They are used for short term before the definitive treatment is done. Splints are noncircumferential immobilizers and can accommodate swelling so they are best indicated for injuries where swelling is anticipated.

Indications for use of a splint are as follows:

- *Used for transportation*: Splintage of the injured limb provides and makes the transportation of the patient

easy and less painful before the definitive treatment. Thomas splint, cramer wire splint are particularly used for this purpose.

- *Used for Traction*: Some splints are used for preoperative traction of the fracture limb. This helps in reducing the pain and spasm, correcting deformity and maintaining limb alignment, e.g. BB splint and fixed traction on Thomas splint.
- *Therapeutic use*: Splints are also used to maintain deformity correction (e.g. Dennis–Brown splint in CTEV) and to prevent deformity (Cock-up splint in radial nerve palsy). Valgus knee splint is used in medial compartment osteoarthritis for pain relief.
- To provide rest to acutely inflamed joint as knee brace in TB knee and ankle brace in ankle sprain.
- They are also used in postoperative period in the form of immobilizers (especially at shoulder and knee) for helping in early cautioned mobilization of patients.

PRECAUTIONS AND CARE

- Always splint the joint above and below the site of trauma.
- Use appropriate amount and type of “padding to avoid pressure sores”. Properly pad bony prominences and high-pressure areas before application of a splint.
- Properly position the extremity before, during, and after application of splints/casts.
- Always assess the skin condition and dress the wound before splinting. Keep the limb elevated and document the neurovascular status of the affected limb before splintage.
- *Assessment of compartment pressure*: Always have an eye on presence/development of compartment syndrome in injured limb. Diagnosis is made on clinical suspicion of tense swelling and pain on passive stretching of limb. Always keep the distal extremity uncovered for serial assessment of neurovascular status.
- Encourage active toe/finger movements to reduce swelling and cryotherapy postsplinting for pain relief.

TRACTION

Traction is defined as the application of a continuous, well-sustained pulling force on a limb or muscle group in order to achieve a normal anatomical orientation and correction of bony deformity which occurred due to the fracture or dislocation. Traction relieves pain by counteracting the muscle spasm and allows limb to rest in functional position. Commonly used traction systems in orthopedics are listed in Table 1.10.

Countertraction is the pull acting to offset or oppose primary traction force used for the reduction and to maintain the reduction. Depending on the force providing countertraction the traction may be:

- **Fixed (Fig. 1.28B):** When the countertraction is produced by the traction system itself. A part of traction system gets purchase on a part of patient's body. For example in Thomas splint ring gets purchase around groin and produces countertraction. Fixed traction cannot obtain reduction but maintain it.
- **Sliding/Balanced (Fig. 1.31):** Where the countertraction is applied by the horizontal component of body weight. Body is kept at an angle by raising the foot end of the bed and gravity/weight of the patient provides the countertraction. Roughly one inch elevation is required for each pound of traction weight.
- **Combined traction:** Uses both fixed and sliding tractions. Depending on the methods of application of traction they are of two types:

Skin traction/Buck's traction (Fig. 1.32): It is a noninvasive method used where minimal force (no more than 10 lb) would suffice. It is commonly used in children as muscle mass and spasm is less. It should not be used to obtain or maintain reduction. It can be applied by two methods, adhesive skin traction and nonadhesive skin traction (vent-foam skin traction).

Contraindications to skin traction: It cannot be used where skin condition is poor (wound, allergy, dermatitis, impairment of circulation, venous ulcers, impending gangrene) or in cases of marked shortening/overriding of bony fragments.



Fig. 1.31: Figure showing sliding traction on BB splint where foot end of bed is elevated (arrow) to give countertraction by virtue of gravity.

Table 1.10: Commonly used traction system in orthopedics

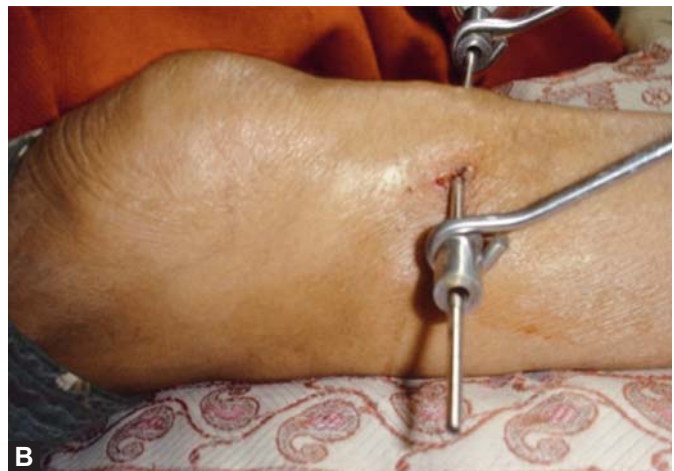
Traction	Use
Agnes hunt traction	Hip deformity correction
Bryant's traction, Gallows traction, 90-90 traction, Fisk traction	Fracture shaft femur
Buck's traction/skin traction	Preoperatively in femoral fractures, to give rest to the infected joint of lower limb, Undisplaced/minimally displaced fracture of acetabulum, after reduction of dislocated hip joint.
Calcaneal traction	Preoperatively used in tibial fracture
Crutchfield tongs, head halter traction, Gardner well tongs, halo-pelvic traction	Cervical spine injury
Dunlop traction, smith traction	Supracondylar fracture humerus
Halo-pelvic traction	Spinal deformities (scoliosis)
Halo-ring traction, crutchfield tong traction	Cervical vertebral fracture
Head Halter traction	Neck pain
Lower tibial traction	Tibial fracture
Metacarpal traction	Comminuted forearm fractures
Olecranon traction	Supracondylar humeral fracture or comminuted distal humeral fracture
Perkin's traction	Tibial and femoral fractures
Pelvic belt traction	Low back ache (given on OPD basis)
Russel's (split/Hamilton) traction	Trochanteric fracture, femoral shaft fracture
Supracondylar femoral traction	Proximal femoral and shaft fracture
Upper tibial traction	Femoral fracture
Well leg traction	Correction of adduction or abduction deformities of hip joint.



Fig. 1.32: Nonadhesive skin traction.



Fig. 1.33: Upper tibial skeletal traction on BB splint.



Figs. 1.34A to C: Common orthopedic tractions: (A) lower tibial traction; (B) upper tibial traction and (C) calcaneal traction.

Complications: Excoriation of skin from slipping of the adhesive strapping, pressure sores around the bony prominences and rarely common peroneal nerve palsy are a few complications.

Skeletal traction (Figs. 1.33 and 1.34): It is more definitive form of traction. It is applied by a pin (Steinmann or Denham) through bone and Bohler stirrup. It is used for reducing or maintaining the reduction of a fracture.

Usual sites of skeletal traction are upper third tibia, distal third tibia, supracondylar femur, and the calcaneum in fractures of the lower limb. Olecranon, second and third metacarpals are usual sites in upper limb for passage of pins for skeletal traction.

Complication: Pin site infections, distraction at fracture site, skin necrosis at entry site, damage to the epiphyseal plate in children and rarely osteomyelitis are the few complications of skeletal traction.

Indications of Traction

- To regain “anatomical alignment” and relation in cases of fractures and dislocations when surgery is delayed or not possible due to medical reasons.
- To “reduce muscle spasm”, deformities and relieve pain, e.g. poliottic/spastic limb, TB hip, psoas abscess.
- For “decompression of nerve root impingement” (sciatica, spondylolisthesis, compression fractures of spine).

Contraindications

- “Active” stage of inflammatory (rheumatoid) or infective arthritis
- Spinal instability
- Signs of “vascular disease”, i.e. ischemia
- Increased pain or worsening of symptoms with traction
- Fractures with metastatic bone disease
- Pregnancy.

Precaution and Care

- Limb should be “comfortably placed” and “adequate weight” should be applied depending on the site of fracture/deformity and the built of the patient. Up to 20 kg weight can be put on skeletal traction.
- The “weight” should “never touch the ground” and counter should always be in place if the traction is sliding. The ropes should be in the pulley only.
- Proper “pin site care” and daily cleaning and dressing is must to minimize chance of pin site infection.
- Good nursing care is very important to avoid complications of recumbency, i.e. frequent turning in bed to avoid pressure sores, active and passive physiotherapy to avoid joint stiffness and muscle wasting.
- Frequent documentation of neurovascular status is very important. Swelling of toes may indicate tight skin

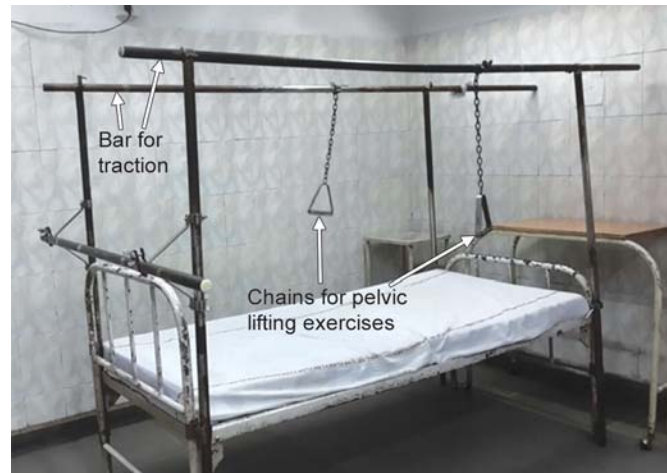


Fig. 1.35: Balkan beam's frame.

traction. Any tingling/paresthesia may indicate towards excessive traction causing traction palsy of nerve.

- Regular X-ray of the limb should be done to see the reduction of fracture.

HIGH-YIELD POINTS

- The first use of traction for correcting over riding of bone fragments was described by Galen.
- *Perkin's traction*: It is skeletal traction without splint.
- *Beds and frames*: Ideal orthopedic bed for patient with multiple injuries is one with adjustable height, i.e. Bradford frame. It allows for change of bed pan and linen without moving the patient.
- Balkan beam frame (Florschutz frame) (Fig. 1.35) is still used in orthopedic wards where Bradford frame is not available. It is an overhead frame attached to patient's bed consisting of overhead bars with pulleys attached to them.

GENERAL PRINCIPLES OF FRACTURE FIXATION

PRINCIPLES OF FRACTURE MANAGEMENT

Management of a fractured bone should aim not only at restoration of bony anatomy but functional rehabilitation of the limb also. Diagnosis of a fracture with modern diagnostic modalities is usually straightforward. Management of a fracture can be summarized in the following headings:

- *Resuscitation*: Based on advanced trauma life support (ATLS) guidelines
- Management of soft-tissue injury
- Fracture reduction
- *Maintenance of reduction by fracture immobilization*: Cast immobilization, internal fixation or external fixation
- Rehabilitation

Orthopedic trauma patients are often victims of high-velocity road traffic accidents and may sustain multiple injuries. Some injuries may be life threatening and need immediate intervention before the definitive treatment of fracture is begun (save life, then save limb, then save joint, then save function). ATLS guidelines provide comprehensive and speedy management of such injuries (see Chapter 2 for detail).

Management of soft-tissue injury: Traumatic fracture of bone is almost always associated with injury to its soft-tissue cover.

Tscherne graded the soft-tissue injury associated with closed fracture in four grades (Table 1.11).

Soft-tissue injury does not mean injury to only skin and muscles. Look also for blood vessels injury (signs of

Table 1.11: Tscherne's classification of soft-tissue injury in closed fracture

Grade 0	No or minor soft-tissue injury
Grade I	Superficial abrasion or skin contusion
Grade II	Deep contaminated abrasions and localized skin or muscle contusions. There is always a risk of imminent compartment syndrome in this group.
Grade III	Extensive skin contusion, destruction of muscle or subcutaneous tissue avulsion (closed degloving). High chances of compartment syndrome and vascular injuries compared to other grades.

Box 1.8: Fractures requiring open reduction

- Where displacing muscle force is too much to reduce close; displaced lateral condyle fracture of humerus in children, displaced fracture patella
- Where restoration of anatomy is of utmost importance; displaced intraarticular fracture, displaced type III and IV epiphyseal injury in children
- Atrophic non-union requiring bone grafting
- Fractures with vascular injury
- Where closed reduction fails.

ischemia), nerve injury (paresthesia, sensory loss, motor weakness), ligament injury (joint instability), etc.

In Grade 0 or I injuries the focus is on treatment of fracture only. However in Grade II or III injuries outcome of fracture management depends upon timely and effective dealing with soft-tissue injury. Limb should be splinted to provide rest to injured tissues and put on traction to keep the fracture aligned. Elevation of the limb helps in subsidence of swelling. Appearance of wrinkles around fracture (Wrinkle sign) is a good sign of soft-tissue recovery and time for definitive fracture fixation. Always keep an eye with high suspicion on the development of compartment syndrome in both closed and open fractures. Out of proportion pain and pain on passive stretching of muscles are the earliest features. Timely management is the only key to save the limb in compartment syndrome. Management of open fractures is discussed in detail in Chapter 2.

METHODS OF FRACTURE REDUCTION

Not all fractures require reduction. Undisplaced or minimally displaced fractures are usually amenable to direct immobilization. Criteria for acceptable reduction depend on many factors like site of fracture, age, etc. As a general rule, acceptability criteria are more generous for children than adults and for extraarticular fractures than intra-articular fractures. In some fractures like clavicle fracture and fractured neck of humerus in elderly, conservative treatment often gives good outcome as slight malunion does not affect the function result.

Two main methods of fracture reduction are closed reduction and open reduction.

1. **Closed reduction:** In closed reduction, fracture site is not opened so fracture hematoma is retained. Reduction is done under general or regional anesthesia but sometimes IV sedation or local anesthesia may suffice. Manual traction is given to disimpact the fracture ends and then direct forces are applied in opposite

direction of displacement to bring the fracture ends in close approximation in both anteroposterior (AP) and lateral views which is confirmed in image intensifier.

Closed reduction by mechanical traction: In some fractures displacing force of muscles is too much to reduce the fracture manually, e.g. in fractured shaft of femur, cervical fractures, etc. These fractures require mechanical traction before manual manipulation for achieving reduction. Whatever be the reduction technique it must be gentle and atraumatic.

2. **Open reduction:** In open reduction, fracture site is opened so fracture hematoma is drained. Reduction is done under direct vision with help of reduction forceps and other instruments. Heroical efforts for anatomical reduction (excessive use of reduction forceps and other tools) may cause excessive periosteal stripping and may damage the blood supply to bone. So they should be avoided as they are actually detrimental to healing.

Fractures that mostly require open reduction are listed in Box 1.8.

IMMOBILIZATION METHODS

There are four methods of fracture immobilization and maintaining the reduction achieved.

1. **Cast immobilization:** Mostly used for fractures that have been reduced closed.
2. **Continuous traction:** Used in cases where one cannot apply cast or fix a fracture with an implant.
3. **External fixation:** Primarily a method of immobilization for open fractures.
4. **Internal fixation:** It is a rule for fixing fractures that have been reduced by open incisions. In special situations, implants are used to fix fractures reduced in closed manner (see below).

Cast Immobilization

Plaster of Paris cast immobilization is still the standard method of immobilization for most fractures that have been reduced closed. In acute fractures, casts are applied as slabs (plaster that covers three-fourths circumference of limb) and not as full circumference plasters due to risk of swelling and development of compartment syndrome. When swelling subsides usually after 1 week, slab is converted into full cast.

Fiber cast is now available, which is light weight, radiolucent and impervious to water but costlier than POP cast. In acute displaced fractures, plaster cast is preferred because molding of plaster cast according to body contours is easier than fiber cast.

Some common fractures where cast is usually a preferred method of immobilization are given in Box 1.9. Commonly used cast methods are tabulated in Table 1.12.

Wedging of a cast (Fig. 1.36): This is reduction technique used in long bone diaphyseal fractures with angular malalignment. In this technique, a window is cut in the cast at fracture level leaving a hinge intact on the apex of the deformity. For example in valgus deformity (distal fragment in valgus) window is cut on lateral side leaving

Box 1.9: Fractures where cast immobilization is commonly used

- Most pediatric fractures
- Adult fractures
 - Metacarpal and metatarsal fractures
 - Colles' fracture
 - Fracture of surgical neck of humerus in elderly
 - Stress fractures
 - Undisplaced fractures of carpal and tarsal bones
 - Undisplaced/minimally displaced ankle fractures

Table 1.12: Common cast and slabs

Bruner cast	Ligamentous injury of first metacarpophalangeal (MCP) joint
Burkhalter cast	Metacarpals and phalangeal fractures
Colles' cast	Colles' fracture
Cylindrical cast	Undisplaced patellar fracture, ligament injuries around knee
Hanging cast	Fractured shaft of humerus
Hip spica	Fractured shaft of femur in children
James slab	Metacarpals and phalangeal fractures
Minerva cast	Cervical spine injury
Patellar tendon bearing (PTB) cast	Fractured shaft of tibia
Risser's cast	Scoliosis
Scaphoid cast	Scaphoid fracture
Thumb spica	Fractures involving base of thumb
Turn buckle cast	Scoliosis
U slab	Fractured shaft of humerus

a hinge on medial side and varus force is applied distal to the fracture. Once correction is obtained, more cast is applied to maintain the reduction.

Precautions and Care of Cast

- Adequate padding of cotton or stockinette and synthetic wool should be done before applying cast.
- Plaster cast is a circumferential splint and well-fitted cast does not accommodate swelling. If swelling appears after casting it can hamper arterial blood flow. Keep a careful watch for signs and symptoms of compromised circulation. Excessive swellings of digits and out of proportion pain are alarming signs and if present plaster should be cut and limb should be assessed for development of compartment syndrome.
- Limb should be kept elevated to prevent development of swelling.
- There should not be any indentations on the cast as it may impinge upon underlying soft tissues. Similarly edges of the cast should not impinge upon skin.

HIGH-YIELD POINTS

- **Rule of two for cast application:** A cast for any fracture should always immobilize one joint above and one joint below the fracture site.
- Charnley popularized the concepts of fracture reduction and cast immobilization for many fractures.
- **Cast syndrome (superior mesenteric artery syndrome):** It is rare complication of body cast or hip spicas that is characterized by gastric dilatation due to partial or complete obstruction of the duodenum. Obstruction occurs as there is compression of the duodenum between the superior mesenteric artery anteriorly and the aorta and spinal column posteriorly. It is treated by removal of cast and nasogastric decompression, fluid replacement, proper positioning and hyperalimentation. Surgery is rarely needed.

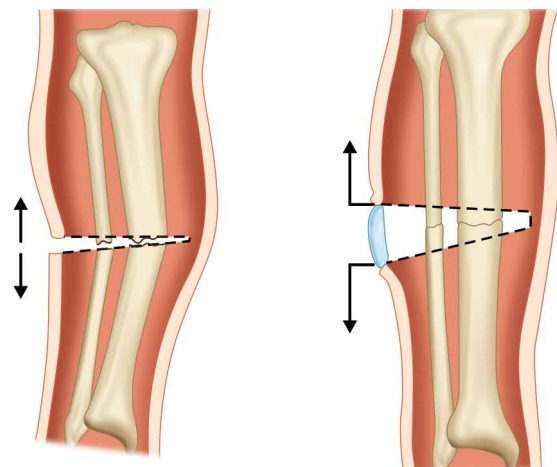


Fig. 1.36: Wedging of a cast.

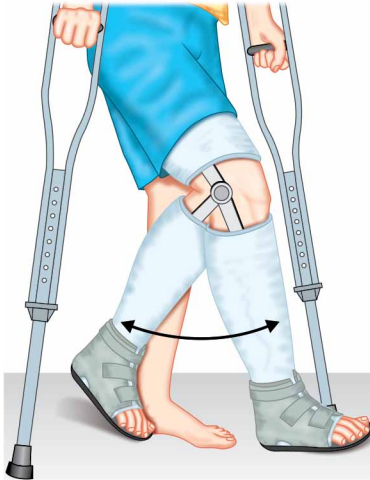


Fig. 1.37: Functional bracing for tibial diaphyseal fracture.

- *Fracture disease (term given by James Paget):* It is name given to constellation of symptoms which occur following immobilization in a cast. It is characterized by pain, swelling, stiffness, muscle atrophy, etc. Early physiotherapy should be encouraged to prevent it. As per some workers, this term is a part of reflex sympathetic dystrophy syndrome (see page 72).

Functional Cast Bracing (Fig. 1.37)

Functional cast bracing concept was popularized in late 1960s by Sarmiento. Initially functional cast bracing was done for tibial fractures but later on for fractured femur and upper limb fractures also. The technique of functional cast bracing consists of applying a splint (called brace) to the fractured limb that while supporting the fracture allows early weight bearing and movement of nearby joints. Early mobilization in this manner encourages the osteogenesis, union and tissue healing. Functional bracing cast is accurately molded around limb in segments which are connected by hinges around joint to allow joint motion while conventional cast bracing immobilizes joints above and below the fracture and restricts their movement.

Functional cast bracing provides less support to fracture than conventional cast so it is applied after 2–3 weeks when fractured ends become sticky and pain and swelling subsides. Early weight bearing is allowed with painless minor movement at fracture site. Thus functional cast bracing prevents joint stiffness, speeds-up rehabilitation and promote osteogenesis and union.

Continuous Traction

Role of traction for immobilization in modern orthopedic practice is very limited. Only valid indication for which continuous traction is still widely practiced is cervical fractures and dislocations. In some fractures like fractured shaft of femur, proximal femoral fractures, acetabular

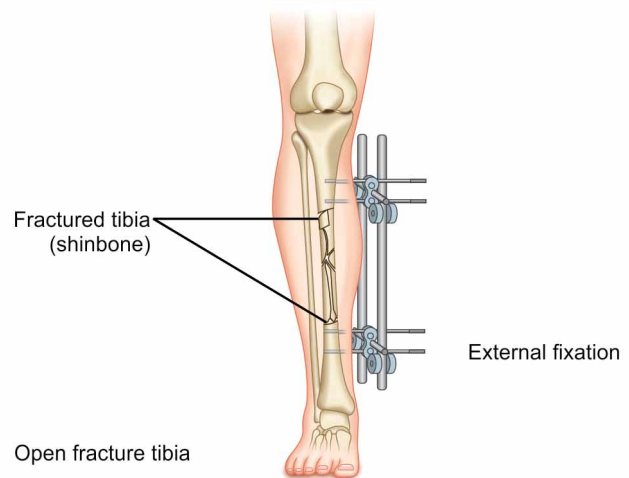


Fig. 1.38: External fixator assembly being used in treating open fracture of tibia.

fractures, comminuted pilon fractures and fracture dislocation of hip joint, if surgery is delayed or postponed due to medical reasons and no other options are available, patient is put on continuous skeletal traction to maintain the limb aligned and achieve union in acceptable position. Cast immobilization is not able to hold the fragments in proper positions in these fractures.

Immobilization by External Fixation

In this method, fractured fragments are anchored to an external bar with help of pins inserted into proximal and distal fragments of bone. Two or three pins are inserted into each fragment and connected to a rod or bar with help of clamps (Fig. 1.38). This method is mainly applied in cases of open and infected fractures where internal fixation carries a high risk of infection or its exacerbation. External fixator in this situation provides a stabilizing assembly that simultaneously allows dressing of the wound and since most of its assembly is outside the skin, there are least chances of infection. Commonly used external fixator frames are one plane (monolateral) frame, two plane (bilateral) frame and ring fixator.

Ilizarov Ring Fixator

Russian surgeon, Gavriil Ilizarov pioneered the revolutionary technique of bone and soft-tissue regeneration based on distraction osteogenesis in 1960s.

Principle: It is based on the principle of distraction histogenesis which states that gradual distraction of bone at the rate of 1 mm/day, regenerates new bone at the distraction site. At the site of distraction, fibroblast-like cells become metabolically active and secrete collagen. Dormant mesenchymal cells at the site get converted into osteoblasts and secrete osteoid. Growth changes are also seen in soft tissues with cellular hypertrophy and hyperplasia in myocytes and capillary formation and

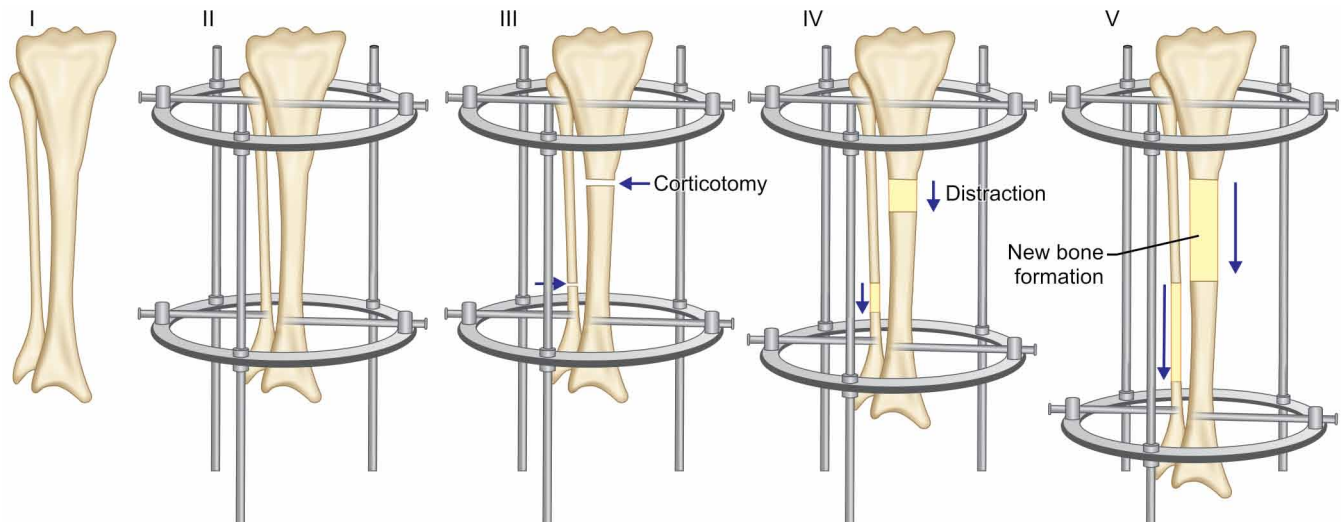


Fig. 1.39A: Limb lengthening by Ilizarov ring fixator.



Fig. 1.39B: Ilizarov ring fixator.

development of nerves in direction of tension vector, so all tissues including bone are lengthened.

Assembly and technique (Figs. 1.39A and B): The Ilizarov external fixator is a special modified external fixator that has a complex assembly of metal rings, threaded rods, and Kirschner wires. Wires are passed through skin and soft tissue and drilled through both bony cortices. Wires are attached under tension to half and full metal rings encircling the bone. Assembly is completed by connecting the rings to threaded rods. Assembly can be angulated using hinges if deformity correction is planned. After fixation of the assembly, corticotomy (cutting the cortices of bone while leaving a posterior hinge of periosteum intact for vascular supply) is done in the bone to be lengthened. Corticotomy is usually done at metaphysis because of high potential for osteogenesis in metaphyseal cancellous

Box 1.10: Use of Ilizarov method

- In treatment of infected non-union and gap non-union
- In deformity correction, malunion, burn contracture
- To gain length of limb
- In joint arthrodesis
- Proximal focal femoral deficiency
- Chronic osteomyelitis
- Chronic dislocations
- Neglected club foot: For distracting posteromedial side of foot

bone. Gradual distraction is started after few days of corticotomy. Few days are given as a latency period for hematoma to form and organize at site of corticotomy. Rate of distraction is kept slow at 1 mm/day at a rhythm of 0.25 mm every 6 hours. New bone is formed by gradual distraction at the corticotomy site.

Uses of Ilizarov method are given in Box 1.10.

HIGH-YIELD POINTS

- Taylor spatial frame is also used for limb lengthening, in treatment of non-union and deformity correction. It is easier to apply than Ilizarov fixator but costlier.
- Intramedullary devices are also available for limb lengthening but not for deformity correction.
- Even up to 10 cm of bone has been reported to be lengthened by use of Ilizarov.

Complications: Ilizarov technique is a complex procedure and should be done by experts only.

- Patient compliance: Ilizarov frame needs to be kept for long time (approximate 1 cm of bone is formed per month). This often leads to social isolation of the patient and also it is cumbersome to carry the heavy frame.
- Complications related to procedure are muscle contracture, neurovascular insult, pin site infection, and premature or delayed consolidation at corticotomy site.

Pin site infection is most common complication. Daily pin care with saline cleaning and betadine dressing of the pin tract should be done. In severe infection, pin is removed and new pin is inserted elsewhere. Thorough knowledge of neurovascular anatomy is necessary to avoid neurovascular injury during pin insertion. During distraction if sensory symptoms appear, rate of distraction is slowed or even stopped until symptoms disappear. Proper splinting and physiotherapy is necessary to prevent soft-tissue contractures. Regular radiological examination of the whole limb should be done to judge the consolidation at corticotomy site and also for earliest detection of subluxation or dislocation of adjacent joints.

Internal Fixation

In modern orthopedic practice, trend has been changed in favor of internal fixation (fixing fracture with implants applied inside the skin) of most fractures. Benefits of internal fixation are early mobilization preventing joint stiffness and more anatomical fracture alignment.

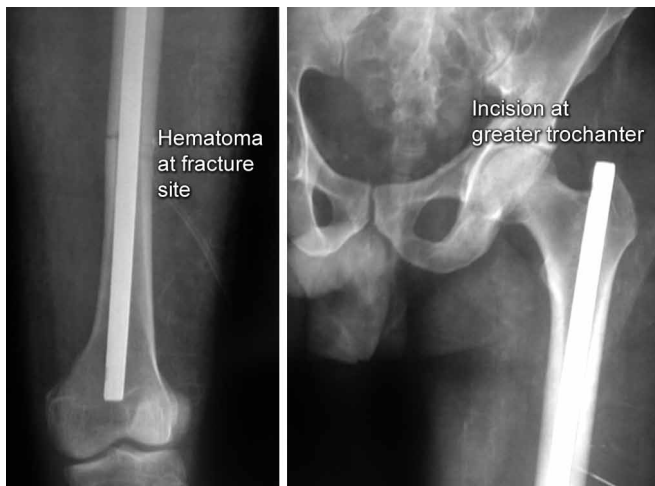


Fig. 1.40: Depicting a shaft femur fracture fixed with intramedullary nail.

Internal fixation is the rule for all fractures that are treated by open reduction where the complete treatment is called as open reduction and internal fixation (ORIF).

However, in some special situations internal fixation can also be done in some fractures that have been reduced closed [e.g. while nailing a long bone (Fig. 1.40)]. Here the treatment is called as closed reduction and internal fixation (CRIF) as skin incision being away from fracture site does not drain the hematoma (so closed reduction) while the fracture is fixed with an implant that lies inside the skin (internal fixation).

Classical examples of closed reduction (hematoma not drained) and internal fixation (implant inside the skin) include:

- *Nailing of a long bone*
- Fixing of a neck femur fracture with multiple screws*
- Pinning (putting K wires) in supracondylar humerus fractures*

**In the latter two situations the skin incisions are minimal such that hematoma is not drained so closed reduction but since an implant has been put within the body to fix fracture, it is internal fixation.*

Various methods of internal fixation available include:

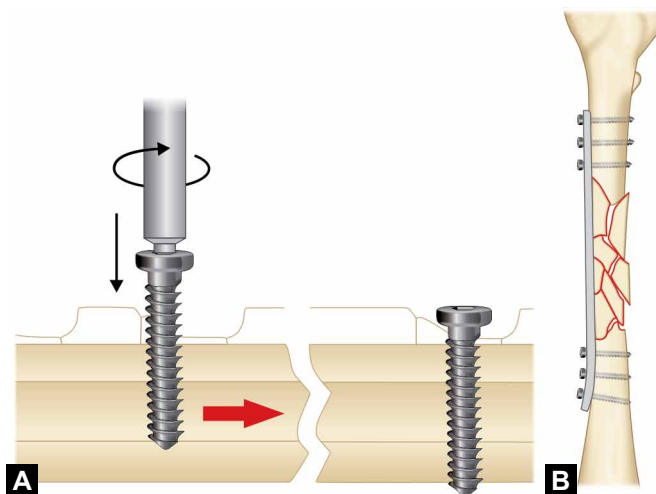
- **Screws:** They are inserted either directly across the fracture (lag screw) to compress it or put through the plates to fix a fracture. Common types of screws are cortical, cancellous and locking screws (see page 406 for details).
- **Kirschner wires (K wires):** These are stainless steel wires which are available in 1–3 mm in diameters. These are used mainly in pediatric fractures or in fractures of small bones of hands and feet.
- **Plates:** These are available in different designs and contour for different fractures. Five basic principles on which plates work are listed in Table 1.13.

Some Special Plates

Dynamic compression plate (Fig. 1.41A): In dynamic compression plating tightening of eccentrically placed

Table 1.13: Principles of plate fixation

		Example
Compression plate	This plate produces compression across the fracture when it is fixed across the fracture with screws.	Transverse or oblique forearm fractures
Neutralization plate	Its main function is to link the bones above and below the fracture without producing any compression across fracture. It is used to protect the lag screw which is used to compress the fracture.	Butterfly fracture (fracture with a separated wedge-shaped chip of bone) of metaphysis or diaphysis
Buttress plate/antiglide plate	It is a plate with broad surface area that it uses to prevent displacement of large fracture fragment mostly in an articular fracture.	Tibial plateau or distal radial fracture
Bridge plate (Fig. 1.41B)	It is used to bridge the comminution in metaphyseal and diaphyseal fractures. It is a less rigid fixation than compression plating.	Comminuted diaphyseal and metaphyseal fractures
Tension band plate (Fig. 1.42)	This plate converts tensile/distracting forces at fracture site into compression force. It is applied on the tension side/convex side/distracting side of a fracture. For example in fracture of shaft femur, the outer surface is the tension surface.	Olecranon fracture, fractured shaft of femur



Figs. 1.41A and B: (A) Principle of dynamic compression plate (B) Bridge plating.

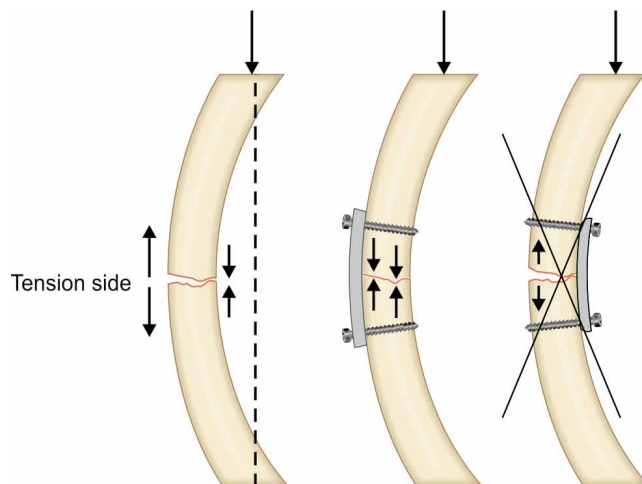


Fig. 1.42: Tension band plating for fracture femur.



Fig. 1.43: Tension band wiring of patella fracture (Q—pull by quadriceps and LP—pull by ligamentum patellae).

screws across plate cause axial compression of fracture. In dynamic compression plate slots for compression have a sloping surface at one end. Centrally placed screw compress the plate against bone. Now in opposite fragment screws are placed eccentrically and when tightened plate moves and compresses the fracture (Newton's third law of motion).

Locking plate: In this plate, screw heads have threads which get locked into plate holes at different angles thus providing angular stability. It is particularly useful for comminuted metaphyseal fractures, osteoporotic fractures and periprosthetic fractures where screw hold in bone may not be good. Here the screws hold to the plate by virtue of them getting locked to it and provide reasonably good stability.

- **The tension band principle:** Tensile/distractive forces are converted into compressive forces by applying device (either plate or tension band wire) on convex surface or tension surface of a fractured bone (Fig. 1.43). Here the patellar fragments are being distracted by quadriceps above and ligament patellae below. A wire has been tied on the convex side of patella. This will get stretched due to patellar distraction by quadriceps and just like a stretched rubber band it will reciprocally exert compression pull upon this stretch to compress the fracture (Newton's third law of motion).

Fractures where tension band principle is commonly used are listed in Box 1.11.

Intramedullary nail: First human intramedullary nail was done by Gerhard Küntscher in 1939. It was a V-shaped

Box 1.11: Fractures commonly fixed by tension band principle

- Fracture of patella
- Fracture of olecranon
- Fracture of greater trochanter of femur
- Fracture of medial malleolus
- Fracture of greater tuberosity of humerus.

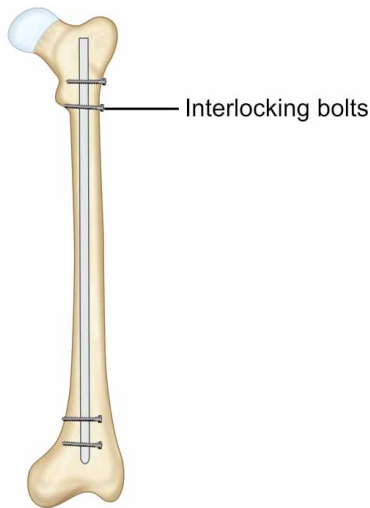


Fig. 1.44: Figure showing interlocking nail.

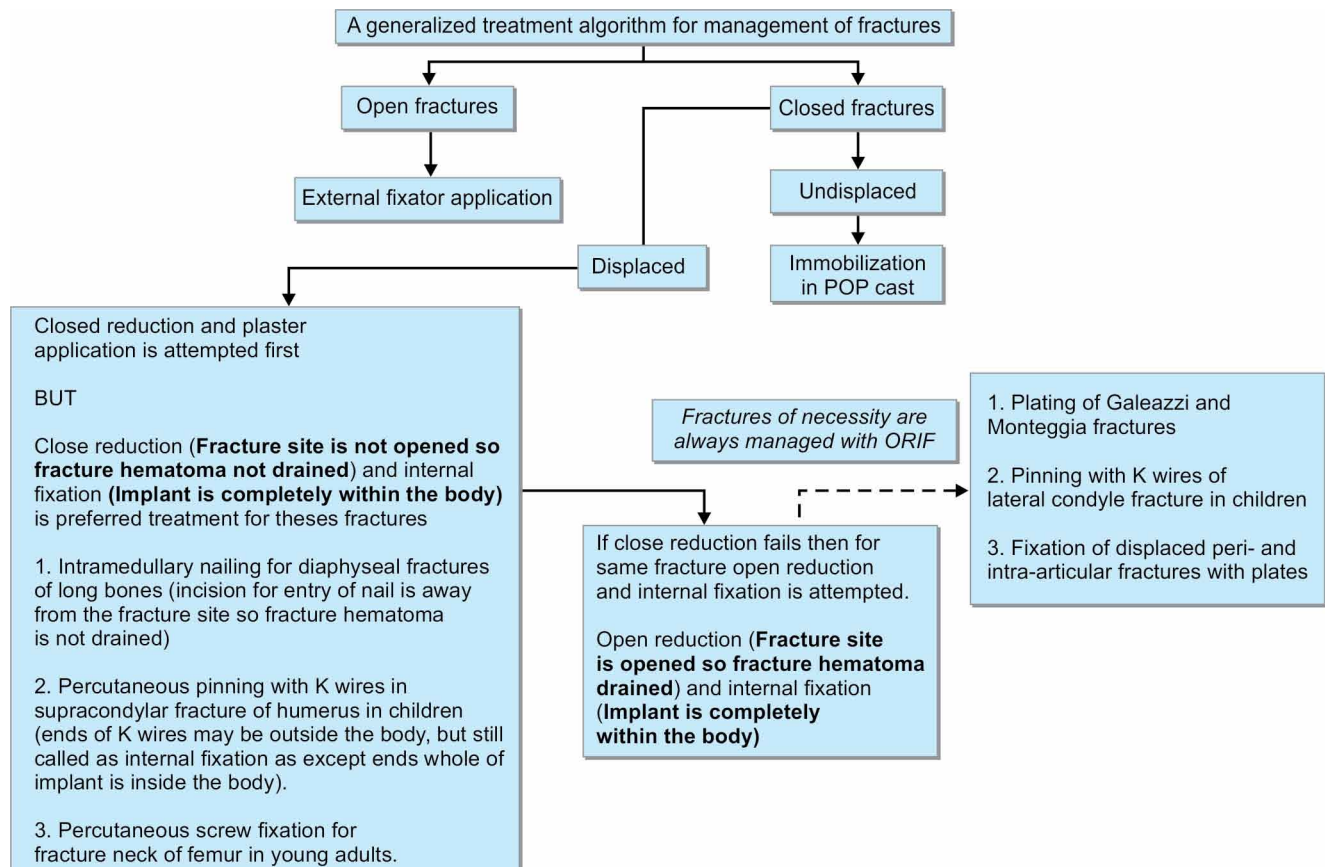
steel nail which was later changed to hollow clover leaf model. This nail relied on a frictional fit between nail and bone. Since then intramedullary nailing has seen many changes in design as well as in technique. In 1942, Fischer introduced the use of intramedullary reamers to increase the contact area between the nail and host bone thus increasing the stability of fracture. Later Modney invented the interlock nails that get locked in bones to provide additional rotational stability in case of comminuted fractures (Fig. 1.44). Then in the 1960s, development of image intensifiers allowed surgeons to do intramedullary nailing with better confidence and with closed reduction (as explained in Fig. 1.40).

Principle of intramedullary nailing: Fracture is reduced under image intensifier and after reaming of medullary cavity nail is inserted into the medullary cavity which act as an internal splint to resist bending. Interlocking nails are provided with slots for locking bolts which prevent rotation and shortening.

Advantages of intramedullary nailing: It is ideal implant for long bone diaphyseal fractures. It can be implanted by minimally invasive technique without exposing the fracture hematoma. Thus it is a biological method of fracture fixation.

A treatment algorithm for management of fracture is given in Flowchart 1.1.

Flowchart 1.1: A general algorithm for deciding treatment for any fracture.





Figs. 1.45A and B: (A) X-ray of wrist joint AP and lateral views showing fixation of distal radius fracture by external fixator (tightened ligaments are shown by broken white lines). (B) Clinical picture of distractor used for distal end radius fracture.

HIGH-YIELD POINTS

- The first internal fixator device as well as the first external fixator was devised by Malgaigne. However, the credit for pioneering the modern internal fixation devices rests with Lambotte who is called father of modern internal fixation.
- A plate is considered to be a load bearing device. It bears all the weight if loaded before a fracture unites and hence cracks. A nail is a load sharing device. It allows vertical translation of bone ends and shares the load with the bone. So even if fracture is not united, it does not fail under load. Hence in weight bearing bones (lower limb) fractures are mostly nailed while in upper limb bones, fractures are mostly plated (better stability).
- *Ligamentotaxis:* In this technique, an external fixator is applied in distraction around the fracture site. Here length and alignment of fracture fragments is achieved indirectly by tightening of ligaments surrounding the fracture site. Management of comminuted distal

radius fractures by external fixator (distractor) is based on principles of ligamentotaxis (Figs. 1.45A and B). This is one of the places where an external fixator is used in a closed fracture.

- *Direct and indirect reduction:* Direct reduction means fracture fragments are manipulated directly by instruments or hands. In indirect reduction, fracture is reduced without exposing the fracture. Reduction is achieved either by traction/distraction or by applying forceps on the soft-tissue envelope and not directly on the bone.
- *Fractures of necessity:* These are the fractures which essentially require ORIF for their management.
 - Adult forearm fractures (Galeazzi fracture, Monteggia fracture)
 - Lateral condyle fracture of humerus in children
 - All displaced intraarticular fractures (displaced intraarticular fractures need absolute anatomically reduction to prevent joint arthritis so they are always openly reduced).

STRESS FRACTURES, PATHOLOGICAL FRACTURES AND PERIPROSTHETIC FRACTURES

STRESS FRACTURES

Stress fractures occur when normal bone is subjected to excessive and unaccustomed stress of lower magnitude than required for acute traumatic fracture (abrupt increase in duration and/or frequency and/or intensity of work). Stress fractures are common in lower limb bones in dancers, runners, jumpers, gymnast and military recruits. Stress fracture of nonweight bearing bones (upper limbs)

may also occur following repetitive stress, i.e. olecranon is the most common site of stress fracture in baseball players. Box 1.12 shows common sites of stress fractures.

Pathophysiology

Repetitive cyclical loading alters bone's microstructure and causes microfractures which lead to increase in osteoblastic and osteoclastic activity. When repetitive loading

Box 1.12: Common sites of stress fractures

- Tibia: Posteromedial compression injuries in distal (Fig. 1.46) or proximal thirds (most common stress fractures)
- Shaft of second/third metatarsal (March fracture, second most common stress fracture)
- Other metatarsals
- Medial malleolus: In jumpers and runners
- Distal fibula (Runner's fracture) (Fig. 1.47)
- Femoral neck (Fig. 1.48): Inferomedial cortical breaks (compression side) are more common than superior (tension side). However, tension side breaks are more dangerous and often progress to complete fracture without fixation.
- Femoral shaft: Posteromedial or medial cortical breaks.
- Navicular: In central third of bone in runners/sprinters, ballet dancers, football players
- Calcaneus: Tuberosity fractures in military recruits and in runners
- Ribs: Fractures of middle ribs (4th–9th) common in rowers due to traction by serratus anterior
- Pubic rami stress fractures in female long distance runners.



Fig. 1.47: X-ray of distal leg showing stress fracture of distal fibula (Runner's fracture).

occurs at a rate at which body does not have time to recover, bone formation (osteoblastic activity) lags behind the bone resorption (osteoclastic activity). If the stress continues, fatigued bone may fail.

Risk Factors for Stress Fracture

- *Alteration in training program:* Sudden increase in duration/intensity/frequency of training
- *Alteration in biomechanics:* Stiff ankle (decreased ankle dorsiflexion), increased hip external rotation
- Limb length discrepancy.

Clinical Features

After a period of stressful activity (athletic training, unaccustomed activity), patient presents with complaints of gradual development of pain at the site of stress fracture.



Fig. 1.46: X-ray of leg AP and lateral views showing stress fracture of distal third of tibia (arrow marks, in AP view periosteal reaction can be seen due to healing of stress fracture).



Fig. 1.48: Compression side femoral neck stress fracture, see the periosteal new bone formation at the site of stress fracture (arrow mark).

Patient describes it as activity-related pain and that he gets relief with rest. On examination focal bony tenderness suggests the diagnosis of stress fracture. Little swelling over affected region may be present.

Radiology

It takes 2–3 weeks for the stress fracture to become visible on X-ray. Low-density cortical area (gray cortex) is the earliest sign. Later a radiolucent line extending across the cortex appears at the site of fracture. Periosteal new bone formation, linear sclerotic line or frank fracture line are late stage features (appear 2–3 months after the stress fracture). Bone scan [technetium-99m methylene diphosphonate (MDP) bone scan] shows increased activity and can show stress fracture in early stage. MRI is the investigation of choice (IOC) for detection of stress fractures.



Fig. 1.49: Growth arrest lines (should not be confused with stress fracture).

Stress fractures must be differentiated from Harris lines/Park lines/growth arrest lines (Fig. 1.49) which are bilateral symmetrical dense trabecular metaphyseal lines mostly seen in rapidly growing bone ends.

Treatment

Activity modification is enough for most of the stress fractures. For stress fractures of foot bones (metatarsals, navicular), nonweight bearing below knee cast immobilization for 4–6 weeks is the treatment of choice. High-grade (MRI showing wide or transcortical increased signal intensity) tension-side (superior) femoral neck stress fracture requires prophylactic internal fixation with cancellous screws.

HIGH-YIELD POINTS

- Stress fractures are overuse injury caused by abnormal stress whereas insufficiency fractures are caused by normal stress in bones with low mineral density (osteoporosis).
- Tibia is the most common site of stress fracture (proximal or distal thirds).
- Navicular is the most common tarsal bone to sustain stress fracture. Shaft of metatarsals are most common site of stress fracture in foot.
- Use of running shoes, shock absorber inserts in shoes and modification of running mechanics (increase in cadence and decrease in stride length) are simple measures to prevent lower limb stress fractures.
- MRI has equal sensitivity and more specificity than bone scan and it is the IOC in detecting stress fractures. Bone scan is IOC for bilateral stress fracture.

PATHOLOGICAL FRACTURES

Pathological fracture (Fig. 1.50) occurs in a bone which is abnormally weak either by systemic affection or by a localized disease. Trivial trauma/stress which would have

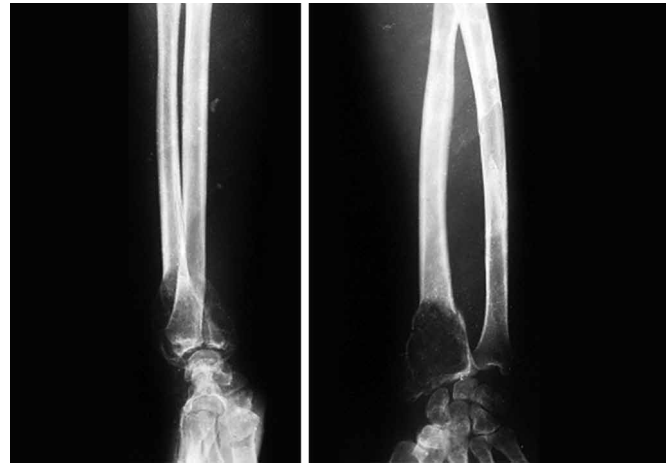


Fig. 1.50: X-ray wrist with forearm AP and lateral views shows pathological fracture in a giant cell tumor (GCT) of distal end of radius.

Box 1.13: Causes of pathological fractures

- *Reduced bone mass:* Osteoporosis
- *Neoplastic:* Primary bone tumor (benign and malignant), metastatic bone lesions.
- *Tumor-like lesions:* Simple bone cyst, aneurysmal bone cyst, fibrous dysplasia, nonossifying fibroma
- *Metabolic and hormonal imbalance:* Osteomalacia, rickets, scurvy, Cushing's syndrome, hyperparathyroidism
- *Developmental disorders and bony dysplasias:* Osteogenesis imperfecta, osteopetrosis, achondroplasia, diaphyseal alacalis (multiple exostosis), Ollier's disease
- *Defect of bone remodeling:* Paget's disease, osteopetrosis
- *Infections:* Osteomyelitis, hydatid disease of bone
- *Marrow cell disorders:* Histiocytosis, Gaucher's disease.

left the normal bone intact can cause pathological fracture in weak bone. Osteoporosis is the most common cause of pathological fracture in elderly. Box 1.13 shows the causes of pathological fractures.

HIGH-YIELD POINTS

- Metastatic carcinomas are the most common cause for destructive bone lesion in adults.
- Thoracic spine is the most common site for metastasis and femoral neck fracture is the most common site of pathological fracture.
- Lung, liver followed by bones are the three most common sites for metastasis.
- Common cancers which metastasize to bones are:
 - Osteoblastic: Prostate, breast
 - Osteolytic: Renal cell carcinoma, thyroid, lung
 - Mixed: Breast
- Breast cancer is the most common cancer which metastasizes to bone, overall and in females. In males, it is prostatic carcinoma.
- Metastasis from follicular carcinoma thyroid and renal cell carcinoma are pulsatile.
- Most common presentation of pathological fracture is fracture itself.

Box 1.14: Workup of a patient with suspected pathological fracture

- **Blood investigations:** CBC, ESR, CRP, renal function tests, liver function tests, thyroid function tests
- Bone densitometry (DEXA)
- **Metabolic profile:** Serum calcium, serum phosphorus, serum alkaline phosphatase, PTH
- **Search for occult primary:** Tumor markers, plasma protein electrophoresis, immunoelectrophoresis, clinical examination of breast, thyroid and prostate, mammography, etc.
- **Radiology:** X-ray of involved bone, CT scan of chest, pelvis and abdomen, MRI to know the local spread, PET scan, bone scan for the occult metastasis.

(CBC: Complete blood count; ESR: Erythrocyte sedimentation rate; CRP: C-reactive protein; DEXA: Dual-energy X-ray absorptiometry; PTH, parathyroid hormone; PET: Positron emission tomography).

Diagnosis

Pathological fracture should be suspected when fracture occurs:

- In an elderly who is a known patient of cancer
- Spontaneously or after trivial trauma
- In a patient with history of irradiation
- With complaint of pain or limp preceding the fracture
- With unusual fracture pattern.

A detailed workup (Box 1.14) of the patient with suspected pathological fracture should be done including search for occult primary. If investigations fail to reveal the cause of pathological fracture, biopsy should be done to establish the diagnosis.

Pathophysiology of Bone Metastasis

Metastatic bone lesions are both osteoblastic and osteolytic. Tumor cells in some cancers (prostate) produce some signaling molecules that stimulate bone formation by increasing osteoblast activity. They include TGF- β , BMPs, and endothelin-1. Whereas in other metastatic cancers like breast cancer, tumor cells secrete parathyroid hormone-related protein (PTHrP) and IL-6, which are powerful mediators of osteoclast activation and participate in osteolysis by stimulating the production of receptor activator of nuclear factor kappa-B ligand (RANKL) by osteoblasts and stromal cells.

HIGH-YIELD POINTS

- The term “fragility fracture” is used for low-energy fractures of osteoporotic bone. Vertebral fractures, proximal femoral fractures and wrist fracture (Colles’ fracture) are three most common fragility fractures.
- Bisphosphonates inhibit the osteoclast-mediated bone resorption by inducing osteoclast apoptosis, inhibiting osteoclast maturation and decreasing their activity. They hold important place in medicinal treatment of bony metastasis.
- Although bisphosphonates are mainstay of treatment of osteoporosis but long-term treatment (> 5 years) can cause subtrochanteric fracture of femur due to severe suppression of bone turnover.

Table 1.14: Mirel’s criteria for prophylactic fixation of impending pathological fractures

Mirel’s criteria (score > 8 warrants prophylactic fixation)			
Score	1	2	3
Site	Upper limb	Lower limb	Peritrochanteric
Pain	Mild	Moderate	Severe
Lesion	Blastic	Mixed	Lytic
Size	< 1/3rd diameter of bone	1/3rd to 2/3rd diameter of bone	> 2/3rd diameter of bone

Management

Management of pathological fracture should focus on pain relief, management of cause of pathological fracture, and fracture stabilization. Often a combination of NSAIDs and narcotics is required for adequate pain relief. Bisphosphonates and radiotherapy are also used for pain relief and to halt the progression of bone destruction in metastatic bone cancer. Radionuclide therapy is the recent addition in treatment for palliative pain relief from metastatic bone disease. Commonly used agents are phosphorus-32 orthophosphate and strontium-89 chloride.

Fracture management: Conventional methods (cast immobilization or ORIF) are usually enough for pathological fractures secondary to cystic lesions of bone, benign neoplasm and due to generalized systemic disease (osteoporosis, Paget’s disease, osteogenesis imperfecta, etc.). Fracture in case of osteomyelitis requires primary management of infection.

Metastatic pathological fractures often fail to unite and require internal fixation with intramedullary rod or long plate with addition of bone cement to fill the defect or replacement of affected bone with prosthesis. Joint arthroplasty is a favorable option for lesion near the joint. For involvement of large area of bone often replacement of whole bone with tumor prosthesis (megaprosthesis) is required.

Impending Pathological Fracture

A fracture is likely to occur in a large lytic lesion of bone. Prophylactic internal fixation of bone is warranted if risk of fracture is high. Mirel’s criteria (Table 1.14) are used to quantify the risk of impending fracture.

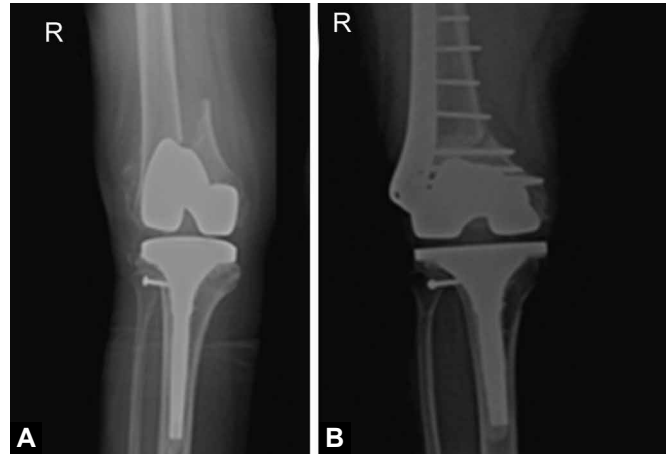
PERIPROSTHETIC FRACTURES

Fractures around joint replacement prostheses are called periprosthetic fracture. These usually result from low energy fall. Patients present with pain around prosthesis and difficulty in weight bearing following a fall. Diagnosis is made on X-rays (Figs. 1.51A and B).

Treatment of these fractures is challenging due to poor bone stock and presence of prosthesis poses difficulty in internal fixation. Displaced fractures with stable prosthesis are usually treated with ORIF with locking plates. Loose prosthesis needs to be replaced by revision arthroplasty.

HIGH-YIELD POINT

Incidence of periprosthetic fracture is much higher after revision arthroplasty than after primary arthroplasty.



Figs. 1.51A and B: X-ray knee AP view showing periprosthetic distal femoral fracture around total knee arthroplasty and its management with ORIF with distal femoral locked plate.

IMAGING IN ORTHOPEDICS

Radiology plays a pivotal role in management of orthopedic patients. X-rays, ultrasonography (USG), CT scan, MRI and nuclear imaging all have specific roles in different orthopedic pathologies.

X-RAYS

It was discovered by Wilhelm Conrad Röntgen in 1895. Electromagnetic radiations are produced when high-energy electrons strike the tungsten target in a special X-ray tube. These electromagnetic radiations are sent by X-ray machine through various tissues of body giving their images on X-ray films. Mostly the wavelength of these radiations ranges from 0.01 nm to 10 nm.

Uses of X-ray in orthopedics are given in Box 1.15.

- **Advantages:** Cheap, easily available even in peripheral centers.
- **Drawbacks:** Radiation risk (avoid in pregnant women), less sensitivity as compared to CT/MRI, minimal details about cartilage/soft tissues.

ULTRASOUND

These are high-frequency sound waves that are transmitted and received by a transducer. These are based on piezoelectric effect. USG transducers contain a piezoelectric crystal made of lead zirconate titanate (PZT), which changes shape when electric current is passed through it which results in production of sound waves. These sound waves are made to pass through body tissues and their differential passage through various tissues gives their images.

High-frequency high-resolution transducer is used (8–13 MHz) for musculoskeletal ultrasound. A Doppler ultrasound can identify vascular flow in channels and also measure the speed.

Uses of ultrasound in orthopedics are given in Box 1.16.

- **Advantages:** No radiation risk, easily available, high sensitivity for soft tissues, very good to detect presence of fluid in any plane, dynamic examination (patient can be asked to move a particular limb to see the status of specific muscles/tendons), useful in evaluating patients with metallic implants which limits the evaluation by CT and MRI.
- **Drawbacks:** Status of bone not well seen, operator-dependent investigation, limited field of view.

CT SCAN

It was discovered by Godfrey Hounsfield. It consists of a rotating X-ray tube and a series of detectors in a gantry, with a table that moves in and out of the gantry as required. It generates cross-sectional images of the scanned portion of body.

Uses of CT scan in orthopedics are given in Box 1.17.

- **Advantages:** Takes less time, high sensitivity for bone pathologies (but not for marrow), 3D reconstruction of datasets is possible (useful in planning surgeries), multiplanar reconstruction (coronal, sagittal, axial and oblique).
- **Drawbacks:** High radiation exposure, expensive, poor image quality and artifacts in metallic implants (due to beam hardening), poor resolution for soft tissues.

MRI

It images the body structures with the use of powerful magnets that produce radiofrequency pulses. The intensity of different organs appears according to their proton density.

Box 1.15: Use of X-rays in orthopedics

- Use in trauma:
 - Usually the first investigation in trauma
 - To see location and type of fracture:
 - A joint above and a joint below should be covered in X-ray of a fractured bone to rule out a possible dislocation/subluxation
 - At least two X-ray views are recommended to confirm a fracture
 - Glass pieces can be seen on X-ray due to presence of lead within them
 - Also used after fracture reduction by plaster fixation/nailing to confirm proper fixation of fracture fragments
- Use in infection (osteomyelitis):
 - Loss of soft-tissue planes is the first change in pyogenic osteomyelitis (OM) (24–48 hours)
 - Periosteal reaction is the first bone change (7–10 days):
 - No periosteal reaction in tuberculosis (TB) osteomyelitis
 - Chronic OM shows sclerosed dead bone (sequestrum) with thick onion peel type of periosteal reaction (differential diagnoses—Ewing's sarcoma)
 - Air pockets may be seen in soft tissues in spread of infection to soft tissues—necrotizing fasciitis
- Use in bone tumors:
 - Tumor location: Epiphyseal, metaphyseal or diaphyseal
 - Tumor matrix: Cartilaginous tumors have characteristic rings and arcs pattern of calcification, bone-forming tumors like osteosarcoma show osteoid tumor matrix
 - Periosteal reaction, adjacent soft-tissue involvement
- Use in degenerative arthritis:
 - Reduced joint space in involved joint (indicates cartilage damage as cartilage is not visualized on X-ray and forms the joint space)
 - Osteophytes, subchondral cysts, subchondral sclerosis—seen in osteoarthritis

Box 1.16: Use of ultrasound in orthopedics

- Infection/inflammatory arthritis
 - Useful for evaluation of soft-tissue infections, any abscesses, muscle edema and status of draining lymph nodes
 - Joint effusion can be noted—best for visualization of septations or internal echoes within the joint fluid that are often seen in septic arthritis
 - USG-guided aspiration of joint fluid to make diagnosis
 - Thickened synovium with increased vascularity (pannus formation) is seen in rheumatoid arthritis
- Trauma
 - Mainly used for evaluation of vessels by using color Doppler: Vascular injury with a localized hematoma can be well appreciated in short time.
 - Traumatic tendon tears: Acute or chronic tendon tears can be seen on USG, facilitated by dynamic evaluation.
- Degenerative
 - Tendon tears, muscle atrophy
- Also useful in evaluation of nerve compression in carpal tunnel syndrome.

- **Advantages:** Excellent soft-tissue details, marrow details, no radiation
- **Drawbacks:** Expensive, time consuming (high chances of motion artifacts)
- **Contraindications:** Permanent pacemaker, metallic implants (presently MRI compatible titanium implants are being used in most places), neurostimulators, metallic auditory implants, claustrophobic patients (open MRI is preferred in claustrophobic patients and MAVRIC MRI has recently been introduced to reduce artifacts in MRI scanning of patients with metallic implants).

Uses of MRI in orthopedics are given in Box 1.18.

Box 1.17: Uses of CT scan in orthopedics

- Trauma
 - Usually done after X-rays for better preoperative evaluation/3D reconstruction of joints or bones
- Tumors
 - MRI and X-rays are more often used to interpret bone tumors
 - CT scan has role in selected cases to show extent, pattern of tumor matrix calcification, status of adjacent bone cortex, periosteal reaction, presence of pathological fracture.

Basic MRI Pulse Sequences

- **T1W:** Useful for obtaining anatomic detail, detecting fat and hemorrhage. Fat and hemorrhage are hyperintense (bright) on T1W images.
- **T2W:** Useful for pathology—water is hyperintense on T2W (pneumonic: World War 2—WW2, water is white on T2) and thus sites of inflammation shine out.
- **PD-proton density images:** Useful for meniscal pathology and anatomic detail.
- **Gradient echo (T2) images:** Loose bodies and hemorrhage (appear hypointense) are better identified. Fibrocartilage—meniscus in knee and labrum in shoulder can be visualized better. 3D reconstruction can be made.
- **FAT-SAT images:** Marrow and soft-tissue pathology identification.

PET-CT

It is combination of two modalities—positron emission tomography (PET) and CT scan. A substrate molecule is infused and its uptake by sites of high metabolism is

Box 1.18: Uses of MRI in orthopedics

- Investigation of choice in soft tissue (marrow, brain, spine, muscles, tendons, ligaments, cartilage, nerves) pathology detection
- Trauma
 - Not routinely used
 - Investigation of choice for unilateral stress fractures (bone scan is investigation of choice (IOC) for bilateral stress fractures) and occult fractures
 - Bone contusions can be seen, even when cortex is intact
 - Traumatic tendon ruptures, hematomas
- Infection/inflammation
 - MRI is IOC in acute, subacute and chronic OM as it shows status of marrow of involved bone as well as adjacent soft tissues
 - Also the preferred modality in septic arthritis and soft-tissue infections like pyomyositis, necrotizing fasciitis
- Tumors
 - Useful in assessing intramedullary spread, skip lesions, soft-tissue extent, status of adjacent neurovascular bundles
 - Biopsy and histopathology is the gold standard investigation for tumors.

detected by CT imaging. ¹⁸F-FDG (fluorodeoxyglucose) is the most commonly used agent to study metabolism while ¹³N ammonia is most commonly used agent to study perfusion. In orthopedics PET-CT is mainly used for finding occult primary in suspected patients with bone tumors, in follow up of oncologic imaging to assess treatment response and for assessing distant/widespread metastasis.

BONE SCAN

Technetium Tc 99m-labeled methylene diphosphonate is usually used to scan the bones. Areas of uptake represent increased osteoblastic activity.

Activity in bone scan is recorded in two phases:

1. *Early perfusion phase*: Shortly after injection when the isotope is still in the blood.
2. *Delayed bone phase*: After 2–4 hours when isotope has been taken up by bone.

Uses of bone scan are given in Box 1.19.

HIGH-YIELD POINTS

- *Rule of two in imaging*: Always obtain an X-ray of one joint above and one joint below the site of injury, in any suspected fracture case.

Box 1.19: Uses of bone scan

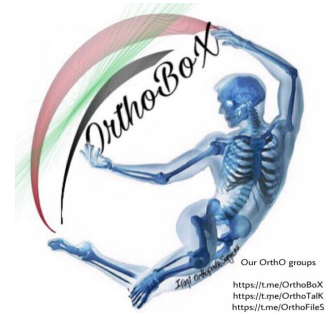
- *Hot spots (increased tracer uptake)*: Metastasis, trauma, neoplasm, infection
- *Cold spots (decreased tracer uptake)*: Multiple myeloma, histiocytosis X, metastasis from renal cell carcinoma/thyroid carcinoma (due to replacement of normal bone)
- *Bone marrow agents*: Tc 99m labeled sulfur colloid, Tc 99m minimicroaggregated albumin colloid (MMAA) are used for evaluating hematopoietically active marrow and marrow infiltrative diseases (e.g. glycogen storage disease)
- Hyperparathyroidism, renal osteodystrophy, widespread Paget's disease, diffuse metastasis show generalized increased uptake on bone scan (*superscan*)
- Highly sensitive for osteoblastic/sclerotic lesions (FDG-PET CT is more sensitive for osteolytic lesions/marrow involvement)

- USG is the IOC for screening of neonatal hip.
 - MRI is best investigation for developmental dysplasia of the hip (DDH) since it allows evaluation of complete disease spectrum, management and complications.
 - MRI is best radiological IOC for osteomyelitis.
- Bone scan is next in preference to MRI in osteomyelitis since it shows increased uptake due to osteoblastic activity at the site of infection.
- Investigation of choice for unilateral stress fracture is MRI and in bilateral stress fractures is bone scan.
 - MRI is IOC for occult (hidden) fractures.
 - Investigation of choice for osteoblastic/sclerotic metastasis is bone scan and osteolytic metastasis is FDG-PET.
 - Bone scan is indicative of only osteoblastic activity while PET-CT indicates any tumor cell activity.
 - Order of investigations in inflammatory joint swelling: X-ray → USG-guided aspiration of joint fluid → MRI.
 - MRI is the IOC for evaluating marrow extent, micro-metastasis, skip lesions and soft-tissue involvement in cases of bone tumors.
 - Biopsy is the IOC/gold standard for diagnosing any tumor.
 - In heterotopic ossification the earliest detection can be done by a bone scan. However, the screening investigation for the purpose is alkaline phosphatase levels and prostaglandin E2 level in 24 hour urine sample. A sudden increase in 24 hour urinary excretion of PGE2 is an indication for bone scan.

CHAPTER

2

Traumatology



MANAGEMENT OF THE POLYTRAUMA PATIENT

INTRODUCTION

Polytrauma patients are those patients who have sustained two or more severe injuries which endanger life. Road traffic accidents are among leading cause of polytrauma and death and mostly involve young and active population of society. Care of a polytraumatized patient should begin from the scene of accident. Highly coordinated team efforts are required to manage polytrauma victims effectively.

TRIAGE

This comes into operation in case of mass casualties when injured persons outnumber the helping medical experts. Simply this is a system deciding which patient should be treated first depending on how severely injured are they. Patients are sorted into four color-coded groups of priority based on their need for evacuation and immediate treatment.

1. Priority 1 (Red)—Immediate care needed
2. Priority 2 (Yellow)—Urgent care needed
3. Priority 3 (Green)—Delayed
4. Priority 4 (Black)—Dead.

Patients are rapidly assessed on the basis of “ABCDE” resuscitation system:

- Airway control with stabilization of the cervical spine.
- Breathing assessment—management of respiratory distress.
- Circulation—assessment of shock and management of external hemorrhage.
- Disability or neurological status—management of head injury.
- Exposure or undressing of the patient.

Priority 1 patients are those who are likely to deteriorate without medical help (requiring immediate intervention to save life). Likewise injured but walking patients with stable vitals are classified into delayed (priority 3) category.

ADVANCE TRAUMA LIFE SUPPORT

Guidelines for Care of Injured

Advance trauma life support (ATLS) is a periodically updated, evidence-based training course for physicians and surgeons

who are involved in care of trauma patients. Concept behind ATLS is that save the life by addressing the most dangerous threat to life first. It encompasses three components:

1. Primary survey and resuscitation
2. Secondary survey of detailed examination
3. Definitive care.

A rapid assessment by primary survey based on ABCDE (as mentioned above) of all injured is done. Catastrophic hemorrhage if any should be controlled before any (ABCDE) intervention. Patient may need resuscitation if airway/breathing is compromised or if he is in shock. These should be taken care of in primary survey. Check for any suspected injury to cervical spine and protect it before airway is being secured.

Secondary survey should include detailed physical examination. Expose the patient and look for any swelling or deformity. Fractures and dislocations should be reduced or aligned and splinted. Thorough neurological examination should be done and Glasgow coma score (GCS) should be calculated. A neurological referral may be warranted if consciousness level deteriorates i.e. if GCS is less than 8. Adjunctive helping tool to diagnosis like ultrasonography (USG), X-rays and laboratory investigations are done in secondary survey.

MANAGEMENT OF OPEN FRACTURES

An open fracture (old term—compound fracture) is one that communicates with external environment or in other words where the hematoma is draining out from the wound (Fig. 2.1). Open fractures are orthopedic emergencies. They carry increased morbidity due to severe soft tissue injury and risk for fracture contamination. Open fractures of tibia are the most common open long bone fractures. Gustilo-Anderson classification (Table 2.1) is most commonly used classification system for open fractures.

These are usually high velocity injuries and patient may require resuscitation in emergency room. Start intravenous (IV) antibiotics and give tetanus prophylaxis once resuscitation is complete. Active bleeding may require compression bandaging. Give IV analgesics or regional block for pain relief and remove the gross contamination.

Splint the fracture, place sterile saline dressing on the wound and shift the patient to operation theater urgently. Thorough surgical wound debridement should be done as soon as possible (ideally within 6 hours). All visible contamination and devascularized tissues should be removed. Vitality of muscles is assessed by color (pink), consistency (firm), contractility (should respond to pinch or electrocautery) and capillary circulation (actively bleeding). Patient may require serial debridement and low pressure saline lavage (Table 2.2) is most effective in reducing load of wound. IV antibiotics should be continued for 24 hours after wound closure in Gustilo type I and type II and for 3 days in Gustilo type III fractures. Temporary external fixation (mostly for Gustilo type II or beyond) or definitive internal fixation (mostly for Gustilo Type I) of fracture can be done depending on the soft tissue condition.

Early soft tissue coverage and wound closure is ideal. Patients of open fracture may require skin grafting or flap muscle coverage of wound. In few cases of Gustilo Type II and III primary closure may not be possible and decision of closure is taken after second relook debridement.



Fig. 2.1: Open or compound fracture.

CRUSH SYNDROME (TRAUMATIC RHABDOMYOLYSIS)

It is the systemic manifestation of extensive muscle injury due to severe crushing of muscles and subsequent release of cellular components of muscle cells into circulation. It is most commonly seen in victims of road traffic accidents with prolonged extrication.

Pathophysiology: Severe crushing causes lysis of muscle cells, leading to significant metabolic derangement and eventual organ failure. Crushing and compression open stretch activated channel and shuts down Na/K channel at cellular level causing increased intracellular calcium which in turn stimulates protease activity leading to cell lysis. After extrication restoration of blood flow to injured muscles causes reperfusion injury. Limb may swell up rapidly leading to compartment syndrome. Metabolic derangements include hyperkalemia, hypocalcemia and hyponatremia. With shifting of intravascular fluid into cells, patient frequently develops shock.

Renal symptoms are most serious complications. In addition to decreased intravascular volume release of myoglobin from damaged myocytes into circulation. It precipitates into proximal tubules and causes renal injury. Patients of crush syndrome are also likely to develop acute respiratory distress syndrome (ARDS) due to deregulated inflammatory mediators.

Treatment: It is largely supportive. Restoration of circulating blood volume to normalize urine output and normalization of metabolic derangements are the main goals of treatment. Up to one-third of patients develop acute renal failure and require dialysis. Impending compartment syndrome may necessitate fasciotomy.

Table 2.1: Gustilo-Anderson classification of compound fractures*

Type/Grade	Features
I	Fracture wound < 1 cm with minimal soft tissue injury and fracture comminution. Usually it is low energy trauma with clean wound.
II	Fracture wound > 1 cm without extensive soft tissue damage and fracture comminution. There is mild-to-moderate soft tissue injury and mild-to-moderate wound contamination.
IIIA	Fracture wound > 10 cm with extensive soft tissue injury and wound contamination but with adequate soft tissue coverage (atleast periosteum over bone is intact).
IIIB	Fracture wound > 10 cm with extensive soft tissue damage and contamination. Soft tissue coverage is inadequate (periosteal stripping occurs and bone may be exposed) and require skin or flap grafting
IIIC	Any size of open wound with major vascular injury requiring repair.

*Gun shot wounds with fractures and open segmental fractures are classified as type III Gustilo-Anderson injuries.

Table 2.2: Open fracture management

Type of fracture	Infection risk	Prophylactic antibiotics	Recommended saline irrigation	Wound closure
G-A type I	Increased (0%–2%)	1st generation cephalosporin	With 3 liters	Usually immediate after surgical intervention
G-A type II	Much increased (2%–10%)	1st generation cephalosporin plus aminoglycoside	With 6 liters	Immediate or early (within 24 hours to 72 hours)
G-A type III	Maximum (10%–50%)	1st generation cephalosporin plus aminoglycoside	With 9 liters	Immediate or early or delayed (after 72 hours)

DAMAGE CONTROL ORTHOPEDICS

This relatively new concept aims at reducing the immediate impact of high energy trauma by temporarily managing the fractures and soft tissue injury in a multiply injured patient thus improving patient's physiology, saving time towards more lifesaving procedures and reducing the mortality. Multiply injured patient may not be too stable to bear with major surgery and definitive fixation of fractures is not the rational option in them. Surgery itself is a kind of trauma and this second hit in an already polytraumatized patient may worsen his condition.

External fixator is one of the most important weapons of damage control orthopedics (DCO), in armamentarium of an orthopedic surgeon in care of polytrauma patient (Figs. 2.2A and B). It provides for rapid stabilization of fractures, reduces further tissue damage and helps in patient ambulation. Once the patient's condition is optimized (5–7 days later), definitive fixation of fractures can be undertaken.

TRAUMA SCORING SYSTEMS

These are used to classify trauma patients and to predict the outcome of multiply injured patients. These are broadly classified into anatomical, physiological and combination scores. Examples of commonly used physiological scores are revised trauma score (RTS) and acute physiology and chronic health evaluation (APACHE) and anatomical scores are abbreviated injury score (AIS) and injury severity score (ISS).

Injury Severity Score

It is an anatomical score and provides an overall score for patients with multiple injuries. Its value is directly proportional to mortality, morbidity and hospital stay. Each injury is assigned an AIS and six body regions [head, face, chest, abdomen, extremities (including pelvis), external] are taken into consideration.

Only the highest AIS score in each body region is used. The ISS score is the sum of squares of scores of three

most severely injured regions. AIS takes value between 1 to 6 and 6 is graded as unsurvivable, so highest ISS score can be $25 + 25 + 25 = 75$. If an injury is assigned an AIS of 6 (unsurvivable injury), the ISS score is automatically assigned to 75.

Mangled Extremity Severity Score (MES Score)

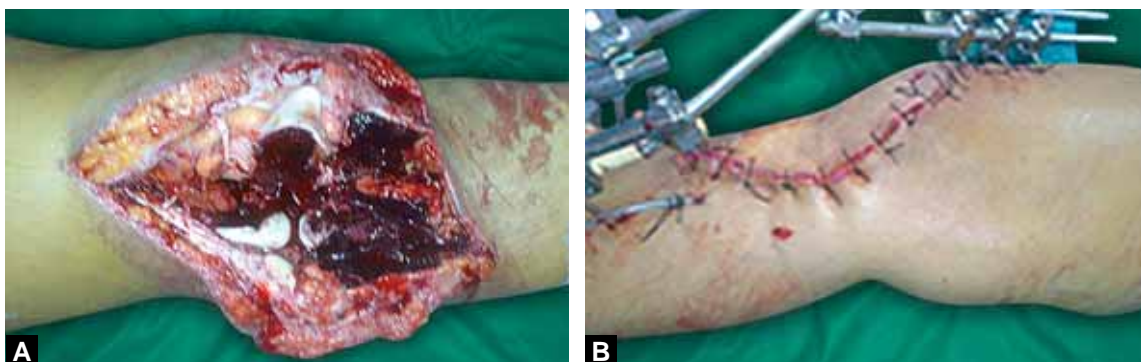
This score is used to predict the chances of amputation after severe extremity trauma. In cases of massive crushing of limb, this score helps to predict whether to go for limb salvage or to empirically amputate the limb to save the life of the patient. It consists of four variables and final score is sum of all four variables:

1. Skeletal and soft tissue injury (graded 1–4)
2. Ischemia of limb (graded 1–3, score is doubled for ischemia of more than 6 hours)
3. Shock (graded 0–2)
4. Age (graded 0–2).

Score of 7 or more is highly predictive of amputation. It is highly specific but less sensitive score in predicting fate of injured limb.

HIGH-YIELD POINTS

- The greatest priority step in treatment of contaminated open fractures is debridement followed by external fixation.
- In grossly contaminated wound local antibiotic delivery may be considered. Bead pouch technique with antibiotic mixed cement of polymethylmethacrylate (PMMA) is the most commonly used method.
- Vacuum assisted closure (VAC) is a useful adjunct to wound management when primary closure is not possible. This is a negative pressure dressing. VAC reduces edema, promote healthy granulation and increase local blood flow thus helping wound closure.
- EUSOL (University of Edinberg solution): It is made up of chlorinated lime (12.5 gm) and boric acid (12.5 gm) mixed in 1 liter of distilled water. It is used for wound dressing.



Figs. 2.2A and B: External fixator is very useful tool in damage control orthopedics.

INJURIES AROUND THE SHOULDER GIRDLE AND FRACTURE SHAFT OF HUMERUS

CLAVICLE FRACTURE

Clavicle is the most common fractured bone overall and during child birth and its fractures account for about 4–10% of skeletal trauma presenting to orthopedic emergency. A direct blow on the shoulder or direct fall onto the shoulder is the most common mechanism of injury. More than 80% of the fractures are located in the middle part of the clavicle (at the junction of the medial two thirds and lateral one third) followed by acromial and sternal part (least common).

The reasons for this location are:

- Peculiar anatomy: This is a junctional point of two curvatures
- There is a defect in this areas of bone as the nutrient artery has to enter at this point.

Surgical Anatomy

Clavicle is a horizontally placed S-shaped subcutaneous long bone which is convex forwards in the medial two-thirds and convex backwards in the lateral one-third. At its distal end it is connected to coracoid process and acromion by coracoclavicular (CC) ligaments (inner conoid and outer trapezoid) and acromioclavicular (AC) ligaments (Fig. 2.3). After fracture the medial fragment is elevated by unopposed pull of sternocleidomastoid muscle and distal fragment is displaced inferiorly and medially by pull of deltoid and pectoralis major muscles (Fig. 2.4). Supraclavicular nerve (superficial to clavicle) and subclavian vessels are at risk during operative repair. Brachial plexus is closest to clavicle at its mid portion.

Diagnosis

Patients present with history of trauma followed by swelling, tenderness, crepitus at site of fracture. Bone can be easily palpated for deformity, hematoma and crepitus. Patient must be examined for neurovascular deficit due to vicinity of vital structures to fracture site. Diagnosis is confirmed on an anteroposterior (Fig. 2.5) and Zanca view X-ray (15° cephalic tilt).

Management

Management is nonoperative in most of the cases as this bone almost always unites. Most surgeons prefer using

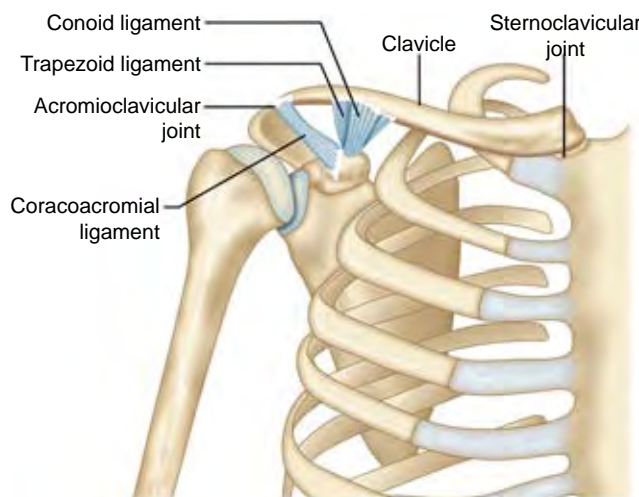


Fig. 2.3: Diagram showing the ligaments around the clavicle.

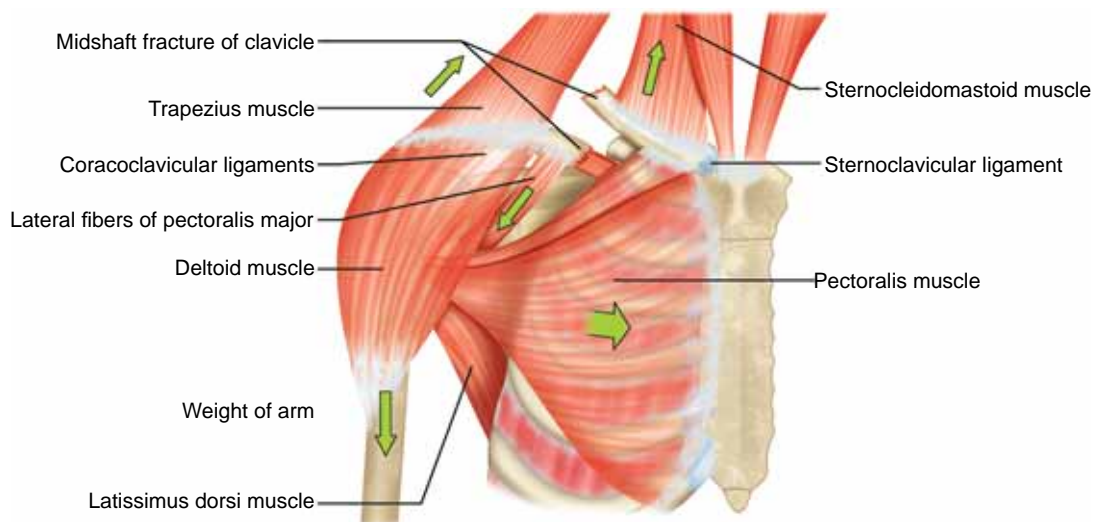


Fig. 2.4: Schematic representation of displacements in clavicular fracture.

ready made clavicular braces to provide some support. Figure of 8 bandage is outdated but may be used for infants. Immobilization with a simple sling (Figs. 2.6A and B) produces the same result with less pain compared to traditional figure of eight bandage or a clavicular brace. Active shoulder physiotherapy should be started as early as pain allows. Full range of shoulder motion can be expected in 6–8 weeks.

Indication for operative fixation (with plate or intramedullary pinning): Open fractures, associated neurovascular deficit, polytrauma patient, floating shoulder with ipsilateral scapular neck and clavicle fractures, displacement and shortening greater than 2 cm and displaced fracture of lateral end clavicle.

Complications: Malunion is the most common complication and may result in formation of an undue prominence that is a relative indication for surgery in patients having problem with cosmesis. However, surgery leads to formation of an unacceptable scar so patient has to be explained that. Other complications are neurovascular injury (acute as well as delayed due to encroachment of thoracic outlet by malunited or nonunited displaced fractures), nonunion and infection (following operative fixation and open fracture). Rate of nonunion is less than 1% and requires open reduction internal fixation (ORIF) with bone grafting.

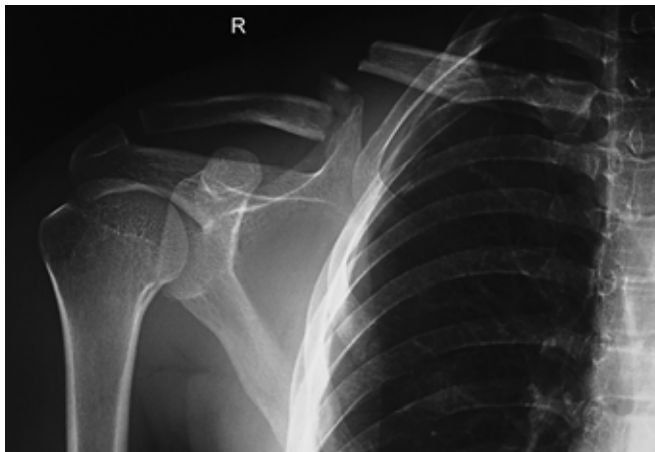


Fig. 2.5: Anteroposterior X-ray of the shoulder showing fracture clavicle.

HIGH-YIELD POINTS

- The clavicle is the first bone to ossify (fifth week of gestation) and the last ossification center (sternal end) to fuse, at 22 to 25 years of age.
- An undisplaced fracture of lateral end of the clavicle may be managed only with a broad arm sling.
- The most common neurological injury is to lower trunk of brachial plexus.

FRACTURE OF SCAPULA

Blunt trauma in road traffic accidents is the most common cause of this relatively infrequent fracture. More than 90% fractures are nondisplaced or minimally displaced and successfully managed with conservative treatment. Associated injuries are more important from clinical point of view. Rib fracture is the most common associated injury followed by head and chest injury (pneumothorax and pulmonary contusions).

Diagnosis

Patients present with history of trauma followed by swelling, local tenderness, crepitus and ecchymosis. Diagnosis can be made on X-rays—anteroposterior, lateral and axillary views.

Classification

These fractures are generally classified based on the anatomy. Body and spine fractures are the most common followed by scapular neck and glenoid cavity. Fracture of acromion and coracoid are less common.

Treatment

Nonoperative treatment is sufficient for majority of fractures. Scapula being surrounded all around by muscles has a very good vascularity and hence rapidly unites. Shoulder immobilization is required until pain alleviates. Early physiotherapy in form of pendulum and active range of motion exercises are started early. ORIF is required for significantly displaced fractures, fracture of coracoid with AC joint dislocation.



Figs. 2.6A and B: Immobilization in a simple sling or in clavicular brace is enough for most of the cases of clavicle fractures.

HIGH-YIELD POINTS

- Flail chest is defined as at least two fractures per rib (producing a free segment that does not contribute to lung expansion), in at least two or more ribs. It is a serious injury that has underlying pulmonary contusion in 50% cases and needs ventilatory support and management of underlying pulmonary injury apart from routine rib fracture management. These patients classically show paradoxical respiration.
- 5, 6 and 7th ribs are most commonly fractured ribs during CPR (cardio pulmonary resuscitation).
- Os Acromiale is a separate ossification center which fails to unite with main body of acromion.
- Scapulothoracic dissociation: This is a limb threatening injury where the upper limb is separated from the thorax with fractures in clavicle, scapula and first rib. There may be traction injury to the plexus leading to paralysis in the whole limb or at times intimal injury in the subclavian vessels leading to thrombosis and gangrenous changes in upper limb.

SHOULDER DISLOCATION

Dislocation of shoulder is the commonest dislocation in orthopedic practice comprising of almost 50% of all dislocations that present to an orthopedic clinic. It occurs at all ages but it more commonly affects young active males below 30 years of age.

Relevant Anatomy

The structure of shoulder joint can be imagined to be like a golf ball and a tee (Fig. 2.7). At any time only one fourth of a humeral head articulates with the glenoid. Hence the bony articulation is inherently unstable and the prime restraint to dislocation is provided by the soft tissue cover around the joint.

Important structures that stabilize the shoulder joint include the primary or static restraints and the secondary or dynamic restraints (dynamic because these can be build-up with exercises to improve joint stability).

Important static restraints are:

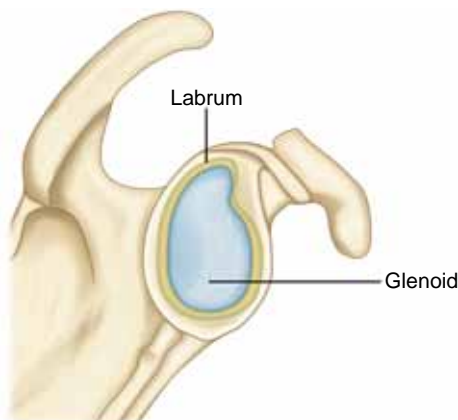


Fig. 2.8: Diagrammatic representation of glenoid labrum.

- *Joint capsule*: A strong capsule encloses the joint all around to keep it located.
- *Glenoid labrum* (Fig. 2.8): This is a fibrocartilagenous rim around the glenoid that encircles it to make it cavity shaped. Glenoid is deepened to almost 50% by the presence of labrum around it.
- *Glenohumeral ligaments* (Fig. 2.9): These are a group of ligaments (superior, middle and inferior) that run across the anterior and inferior aspect of shoulder from glenoid margin to the neck of humerus. They reinforce the anterior capsule adding to the anterior stability.
- *Negative intra-articular pressure*: The joint has minimal amount of synovial fluid such that there is a cohesion force between the opposing surfaces.
- *Bony articulating surfaces*: Their contribution as explained above is limited.

Important dynamic restraints (Figs. 2.10A and B) include:

- *Rotator cuff*: This is a group of four muscles viz. subscapularis, supraspinatus, infraspinatus and teres minor that encircle and surround the shoulder joint in front and back. The subscapularis originates from the coastal surface of scapula and extends anteriorly across the shoulder to insert into the lesser tuberosity of humerus. The other three muscles attach to the greater tuberosity of humerus and strengthen the anterosuperior and posterior aspects as shown in Figure 2.10A.

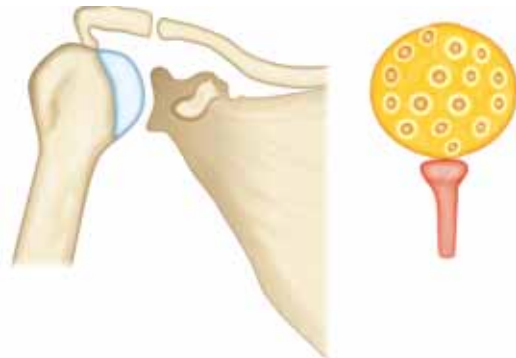


Fig. 2.7: Schematic representation of the shoulder joint showing the similarity to golf ball and a tee.

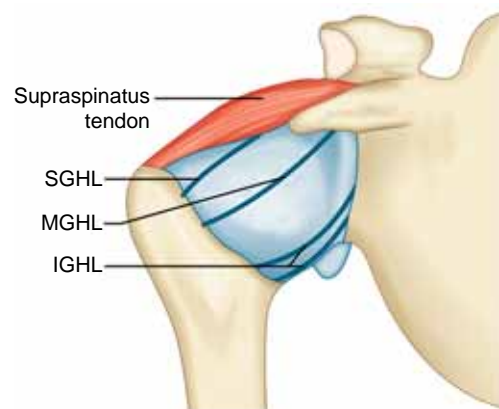
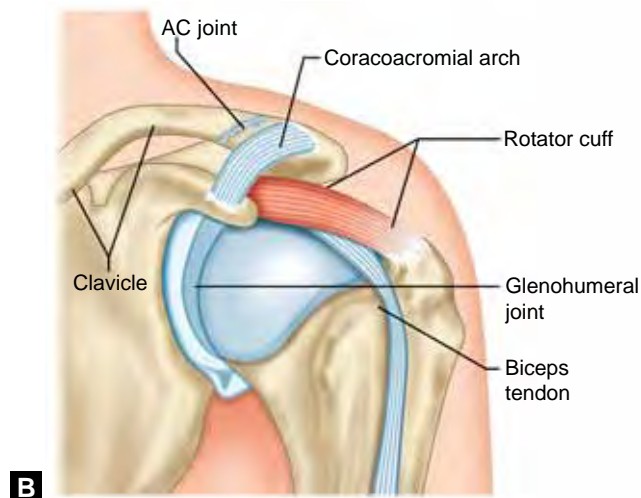
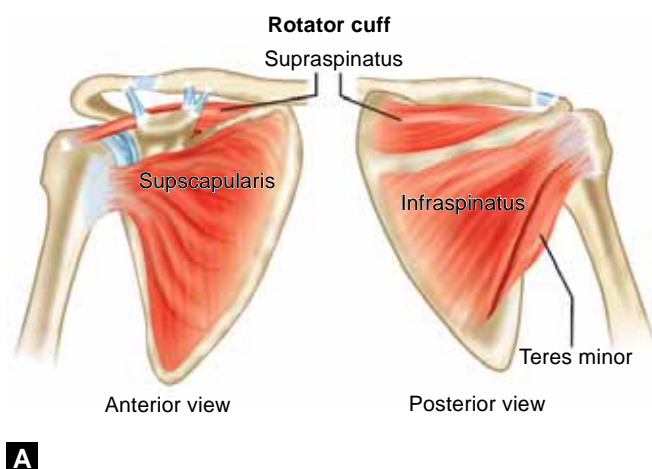


Fig. 2.9: The superior (SGHL), middle (MGHL) and inferior (IGHL) Glenohumeral ligaments.



Figs. 2.10A and B: (A) The rotator cuff muscles. (B) Diagram depicting the dynamic restraints that stabilize the shoulder joint.

- **Deltoid and biceps:** The anterior aspect of shoulder is well covered by the deltoid and if the muscle is strong it would not allow the joint to dislocate. Similarly, the tendon of long head of biceps (Fig. 2.10B) originates from the supraglenoid tubercle and travels in front of the humeral head to enter into the bicipital sulcus, reinforcing the anterior aspect of the joint thereby acting as another dynamic restraint.

Now from the knowledge of anatomy one can now well imagine that since this is a joint primarily stabilized by soft tissues, it would dislocate with minimal force and hence it is the commonest dislocation in orthopedic practice. Also most of the times the doctor reduces the joint, but the soft tissues fail to heal up. In all such cases when an important restraint is non-functioning the patients land up with the well-recognized complication of shoulder dislocation i.e. recurrent dislocations.

Classification

Dislocation of shoulder can be anterior, posterior or inferior (depending upon where the humeral head goes in relation to the glenoid). A superior dislocation is not seen as superiorly the presence of a strong coracoacromial arch prevents the head from riding up (Fig. 2.10B).

1. **Anterior dislocation (Fig. 2.11):** This is most common type (90%-95%). Dislocated head lies anteroinferiorly in relation to the glenoid.

Anterior dislocation is further subdivided into following sub-types (Fig. 2.12):

- **Subcoracoid**—It is most common sub-type. The head lies inferior to coracoid process.
 - **Subglenoid**—Next common sub-type. The head lies anterior and below the glenoid.
 - **Subclavicular**—The head lies below the clavicle.
 - **Intrathoracic**—It is very rare.
2. **Posterior dislocation:** These account for less than 5% of shoulder dislocation cases. Subacromial type in

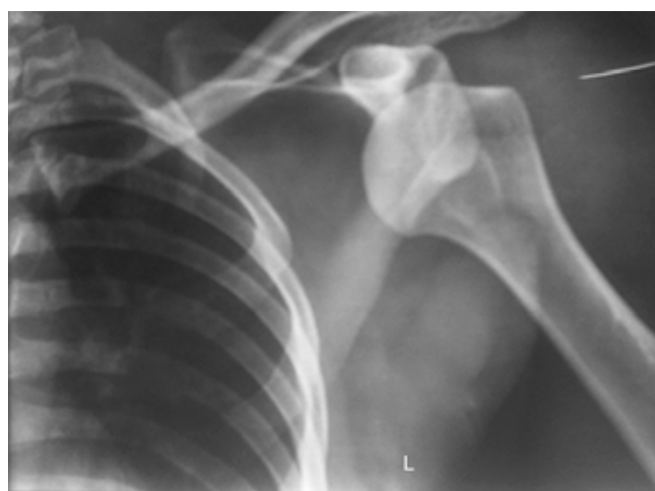


Fig. 2.11: Anteroposterior X-ray of shoulder showing anterior shoulder dislocation.

which the head lies posterior to glenoid and inferior to acromion is the most common subtype. Other two subtypes are subglenoid and subspinous.

3. **Inferior dislocation or luxation erecta:** This is a rare type in which the humeral head lies inferior to glenoid rim with a hyperabducted humerus (the arm locked in full abduction). Patient typically comes in emergency with abducted and locked shoulder supported by other hand over his head (Figs. 2.13A and B).

Mechanism of injury

A traumatic anterior shoulder dislocation mostly results from a fall on outstretched hand with abducted and externally rotated shoulder. Convulsive disorders and electric shock are the common causes for a posterior dislocation. Rarely can it occur following fall on out stretched hand with shoulder in adduction, flexion and internal rotation. Inferior dislocations result from hyperabduction injuries of the shoulder.

Diagnosis

Most first time dislocations of shoulder are traumatic in nature. Patients present with history of trauma and severe pain in the shoulder. Most patients sustain an anterior dislocation and keep their shoulder in abduction and external rotation. Following clinical tests may be useful to reach the diagnosis in doubtful cases:

Duga's test: In dislocated shoulder hand cannot be taken to opposite shoulder (due to inability to achieve full shoulder adduction and internal rotation).

Hamilton ruler test (Fig. 2.14A): In dislocated shoulder a straight ruler can touch the acromion process and lateral epicondyle of the humerus at the same time. In normal shoulder this is not possible due to deltoid bulge which is lost in dislocated shoulder.

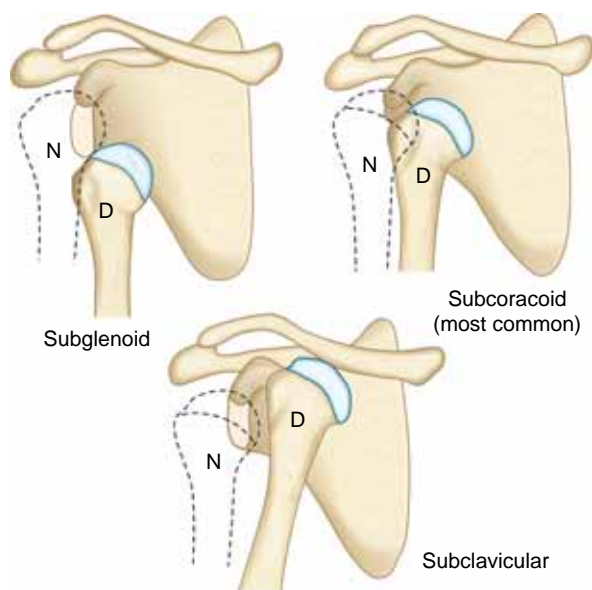


Fig. 2.12: Diagrammatic representation of sub types of anterior dislocation of shoulder. (N: Normal; D: Dislocated).

Callaway's test (Fig. 2.14B): As the head slips and occupies the axilla, girth from axillary base to shoulder top (i.e. the vertical circumference of axilla) increases as compared to opposite shoulder.

The patients who sustain posterior dislocation keep their shoulder in adduction and internal rotation. External rotation is limited. Coracoid process may be more prominent and humeral head may be palpable posteriorly. In routine anteroposterior X-ray posterior dislocation often is missed initially as the humeral head appears to be almost normally aligned with the glenoid. An important radiological sign that may suggest the diagnosis in such cases is the Light bulb sign (Fig. 2.15). In posterior dislocation of shoulder the humeral head remains in internal rotation and looks like a light bulb.

Another sign that may guide is the Rim sign. If on anteroposterior view space between anterior rim of glenoid and humeral head > 6 mm, it is highly suggestive of a posterior dislocation.

Inferior dislocation is the rarest but the classical attitude is generally diagnostic (Fig. 2.14A).

Treatment

Acute shoulder dislocation is reduced on urgent basis under sedation or general anesthesia and then arm is kept in a sling or a chest arm bandage for 3 weeks (to allow soft tissues to heal up). Gentle physiotherapy is started as soon as pain subsides.

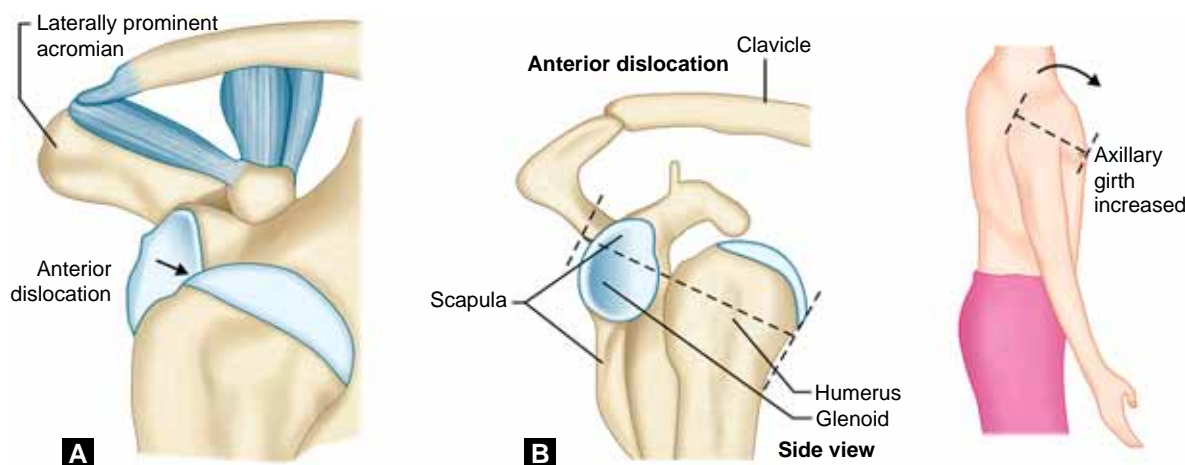
Methods of closed reduction of shoulder dislocation are as follows:

1. **Traction counter-traction methods:** Hippocratic method and Stimson's gravity method (Fig. 2.16B).

Hippocratic method (Fig. 2.16A): In supine position surgeon holds the patient hand with arm in 30-40 degrees abduction and gives sustained traction for about one minute. Counter traction is given by putting the surgeon's heel into patient's axilla. This acts as a fulcrum and arm is gradually adducted. Internal and



Figs. 2.13A and B: (A) Typical posture of a patient of luxation erecta (salute posture) and (B) X-ray of shoulder AP view showing inferior dislocation of shoulder.



Figs. 2.14A and B: Hamilton ruler test and Callaway's test.

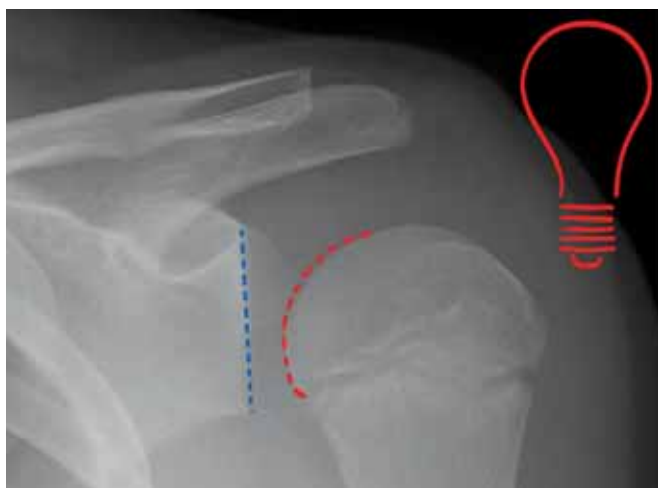


Fig. 2.15: Light bulb sign in posterior dislocation of shoulder (note the head is appearing in reduced position even though it is dislocated posteriorly).

external rotation of shoulder may aid in reduction. This is less favored nowadays as it is more painful method and brachial plexus and vessels are at risk during maneuver.

2. **Leverage methods:** Kocher's method (conventional method widely practiced), Milch's method (recently proposed to be more effective than Kocher's method). *Kocher's method* (Figs. 2.17A to D): In supine position arm is kept by the side of body and elbow is flexed to 90 degrees. Now slowly externally rotate the shoulder by grasping the wrist and supporting the elbow until resistance is felt (70-80 degrees). Now lift the externally rotated upper arm in the sagittal plane as far as possible. Now internally rotate the shoulder (bring the patient's hand towards the opposite shoulder). Humeral head slips back into glenoid with a palpable and audible click.
3. **Scapular manipulation:** In prone position patient's arm is kept in forward flexion and external rotation (suspended at the edge of table) and 8-10 kg weight or manual traction is applied to wrist. Now tip of scapula is pushed

medially with thumb while physician externally rotates the superior and medial aspects of the scapula. This method is claimed to be fast and relatively painless.

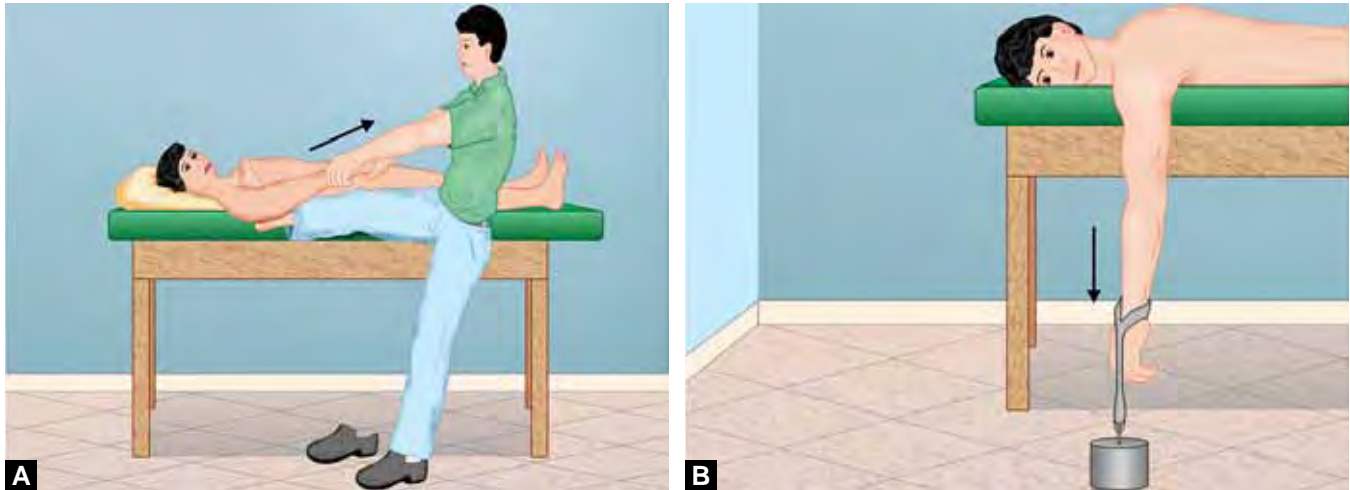
4. **Cunningham technique:** This is a newer method and claimed to be effective, painless and fast. Shoulder dislocation produces spasm of surrounding muscles which pull the dislocated humeral head and prevents its reduction. Cunningham technique involves massaging the trapezius, deltoid and biceps sequentially thus relieving the spasm and allowing for reduction. In sitting position support the arm and keep it adducted and with elbow flexed to 90 degrees or more. Now massage the trapezius and deltoid for 1 to 2 minutes gently and ask the patient to shrug his shoulder. Now massage the biceps at mid humerus level and keep the patient relax. As the patient relaxes and spasm relieves head of humerus slips back into the glenoid.

In most cases the doctor is able to achieve reduction by either of the methods mentioned above. In case one is unable to reduce closed (due to any intervening soft tissue structure), then without wasting any time the patient should be planned up for an urgent open reduction under anesthesia.

Complications

Complications post shoulder reduction show a bimodal age distribution. In patients aged 40 year and above most common complication is rotator cuff tear and shoulder stiffness. In young patients recurrent dislocation is the most common complication after 1st episode of dislocation. Infact, recurrent dislocation is overall the most common (long-term) complication and has been discussed in detail below. Osteoarthritis of glenohumeral joint can be another long-term sequel of shoulder dislocation.

All patients should be thoroughly examined for neurovascular injury. Axillary nerve injury (circumflex branch) is the most common acute complication and can be present in almost 7-10% of cases. It can be detected by absent deltoid contraction or better by loss of sensation over skin of small part of lateral upper arm (regimental badge sign,



Figs. 2.16A and B: (A) Schematic depiction of Hippocratic's technique (B) Stimson's gravity technique (reduction is achieved by assistance of gravity).



Figs. 2.17A to D: Kocher's method of reduction of anterior dislocation of shoulder: (A) Patient comes with abducted shoulder (B) Gently adduct the shoulder and then externally rotate the arm (C) Elevate the externally rotated arm (D) Internally rotate the shoulder.

see Chapter 4 for details). After axillary nerve the other nerve that is injured (frequency wise) is the suprascapular nerve.

RECURRENT DISLOCATION SHOULDER

Acute first time dislocation of shoulder is mostly traumatic in nature. Thereafter in many patients the joint dislocates even with minimal trauma due to failure of important

stabilizing restraints to heal up. Recurrent dislocations are associated with following pathological changes in glenohumeral joint after the acute episode:

Recurrent Anterior Dislocation

Bankart's lesion (Figs. 2.18A and 2.19): This is the commonest lesion being present in almost 90-98% cases. There



Figs. 2.18A and B: (A) Bankart's lesion and (B) X-ray AP view of shoulder joint showing large Hill-Sach's lesion.

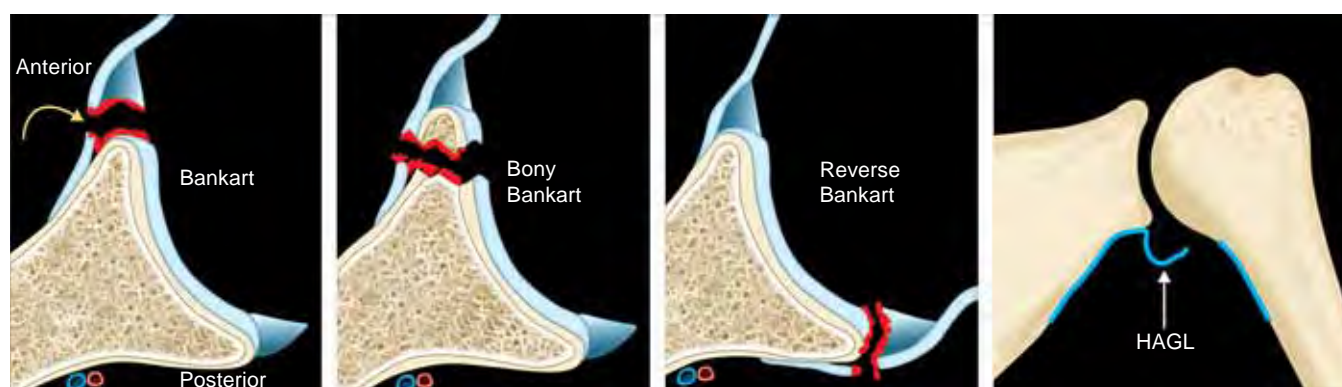


Fig. 2.19: Diagrammatic representation of Bankart's, Bony Bankart's, Reverse Bankart's lesion and HAGL (Humeral avulsion of glenohumeral ligament) lesion.

is detachment of anteroinferior labrum from margin of glenoid that produces recurrent anterior dislocations.

Bony Bankart's lesion (Fig. 2.19): This refers to avulsion fracture of anteroinferior glenoid rim.

HAGL (humeral avulsion of glenohumeral ligaments) lesion (Fig. 2.19): Here the glenohumeral ligaments (a static restraint) are avulsed from the humeral neck with failure of the ligaments to heal up.

Hill-Sachs's lesion (Fig. 2.18B): A defect is excavated on the posterolateral aspect of humeral head due to repeated impact against the anterior glenoid rim in patients who have had several episodes of dislocations. In throwing positions (90 degrees abduction and external rotation) this defect engages the glenoid rim and instability may result.

Glenoid bone defects: These may also result following dislocation and if the loss is more than 20% of glenoid it may give rise to recurrent dislocation.

Recurrent Posterior Dislocation

Reverse Bankart's lesion (Fig. 2.19): It refers to detachment of posteroinferior labrum from the glenoid margin.

Reverse Bony Bankart's lesion: In this there is avulsion fracture of posteroinferior glenoid rim.

Reverse Hill Sachs's lesion: This comprises a defect in antero-medial aspect of the humeral head (Trough sign).

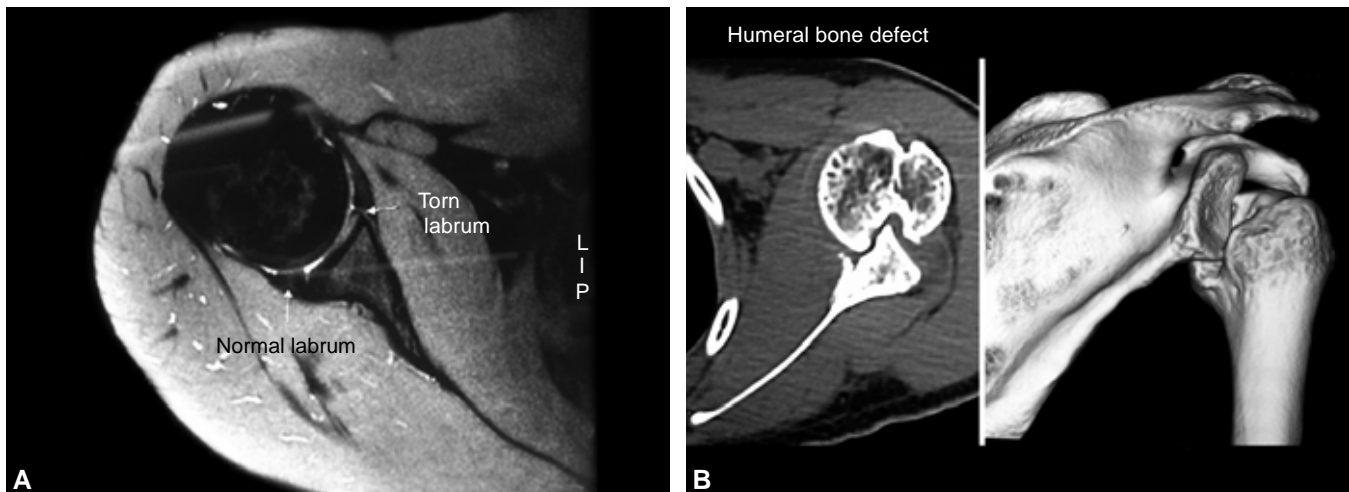
Hyperlaxity of shoulder capsule, usually associated with hyperlaxity of other joints (as may occur in conditions like Marfan syndrome, Ehler-Danlos syndrome etc.) may additionally contribute to recurrent dislocations.

Management of Recurrent Shoulder Dislocation

Management of recurrent dislocation involves first and foremost identifying the lesions with suitable investigations. The investigation of choice for Bankart's lesion is MRI (Fig. 2.20A) but to visualize bone loss in either humerus (Hill-Sachs lesion) or glenoid, a CT scan of the affected shoulder (Fig. 2.20B) is the preferred method.

Once the diagnosis has been made appropriate surgical procedures are to be offered to the patients as per the pathological lesions causing the recurrence.

Following are the surgical procedures commonly employed:



Figs. 2.20A and B: (A) MRI axial section showing Bankart's lesion (Note the torn labrum that has white signal intensity due to fluid seepage) (B) CT axial cut and 3D CT reconstruction demonstrating Hill-Sachs lesion (defect in humeral head) that is engaging against glenoid rim.

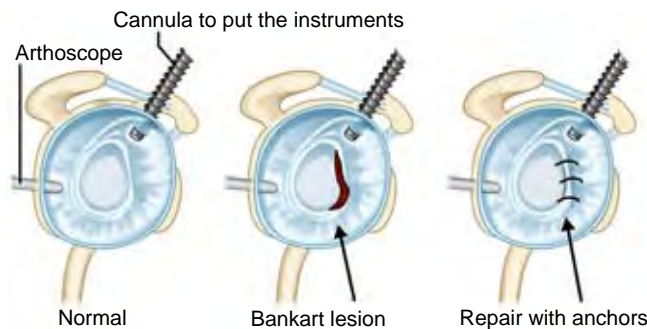


Fig. 2.21: Arthroscopic Bankart's repair is now standard treatment for anterior shoulder instability.

For Bankart's Lesion

Bankart's repair (Fig. 2.21) is currently the mainstay of treatment. Here the torn labrum and the detached capsule are reattached back to the anteroinferior glenoid rim. The procedure now a days is done arthroscopically and arthroscopic Bankart's repair is the treatment of choice (Fig. 2.21).

For Humeral (Hill-Sachs Lesion) or Glenoid Bone Defects

Putti-platt operation (double breasting of subscapularis tendon) is one of the method in managing a Hill-Sachs lesion. Double breasting this tendon shortens it and limits external rotation of humerus thereby preventing the humeral bone defect to engage the glenoid. However, this procedure is only of historical importance and is no longer preferred as it limits significant movement.

The preferred method in patients with large Hill-Sachs lesion or where glenoid bone loss is more than 20% is the Bristow-Latarjet operation (Fig. 2.22). In this surgery the



Fig. 2.22: Bristow-Latarjet operation.

coracoid process along with the attached muscles (conjoint tendon) is osteotomized at its base and transferred down to be fixed to the anteroinferior margin of the glenoid to prevent the head from subluxating anteriorly.

SHOULDER INSTABILITY

It is essential to understand that since shoulder is a joint entirely stabilized by soft tissue, the patients who tend to have lax ligaments from any cause can exhibit abnormal pathological motion in the joint. The reason for the ligament laxity can be multifold appropriately coated as torn loose (ligament laxity after trauma when the native ligaments fail to heal up), born loose (ligament laxity secondary to genetic defects) or microtrauma (players involved in throwing sports who gradually stress their shoulder stabilizers due to repetitive external rotation and abduction). Lax ligaments or capsule from any cause makes these patients more prone to dislocation with minimal trauma and also predisposes them to more chances of recurrent dislocation. However, at times they may not experience a frank dislocation, rather have a minimal extra motion that manifests as a subluxation. Such subluxations withhold them from participating in sporting activities or at times may even interfere in their daily routine. Such patients can be tested for the instability concerned by following clinical tests:

Tests for Anterior Glenohumeral Instability

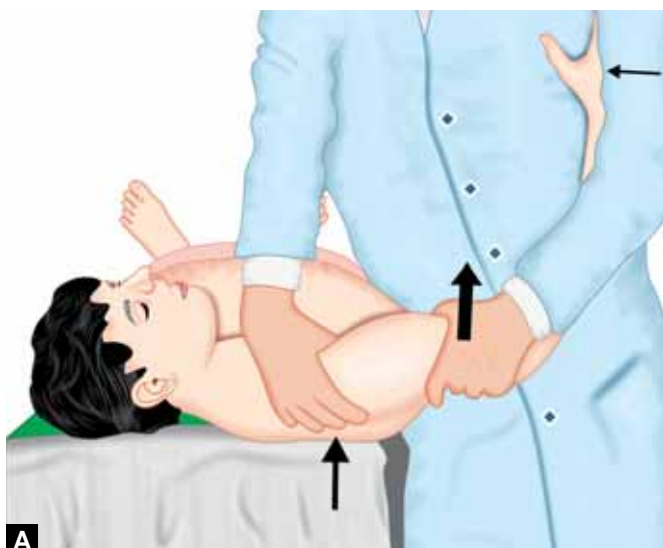
Jobe's Apprehension test (Fig. 2.23): In supine position patient's arm is abducted to 90 degrees and externally rotated to behind the coronal plane (elbow flexed to 90 degrees). Patient become apprehensive and resists the examiner.

Jobe's relocation test: In apprehension test when patient feels apprehension the examiner applies a posterior force against the proximal arm. This relieves the patient's apprehension as the humeral head moves from an anteriorly subluxed position to a centered position in the glenoid.

Anterior drawer test (Fig. 2.24A): The patient is placed supine and the arm is abducted 60 degrees. Axial force is applied to the humeral with the arm in neutral rotation. Now examiner translates the humeral head anteriorly. Translation of the head to the glenoid rim is grade I,



Fig. 2.23: Apprehension test in anterior glenohumeral instability.



A

translation over the rim that spontaneously reduces is grade II, and dislocation without spontaneous reduction is grade III.

Tests for Posterior Glenohumeral Instability

Jerk test/Jahnke test (Fig. 2.24B): This can be performed with the patient standing or sitting. The examiner holds patient's elbow with one hand and stabilizes the scapula with the other hand. The shoulder is flexed to 90°, internally rotated and adducted, and an axial load is applied to elbow. Shoulder may subluxate or dislocate posteriorly with a sudden jerk. Now arm is gradually abducted, humeral head may reduce back onto the glenoid.

Gerber-Ganz posterior drawer Test: Same as anterior drawer except with posterior force.

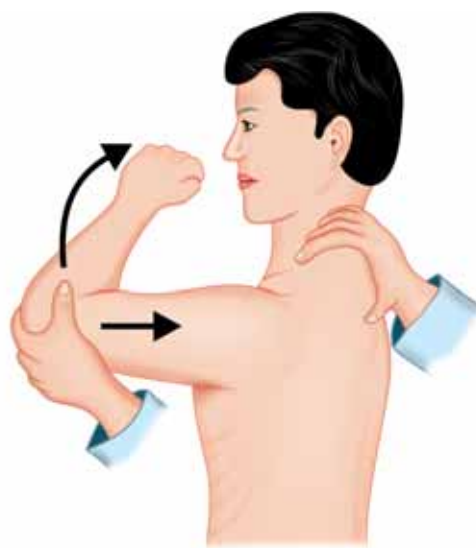
Posterior apprehension test: Examiner pushes the adducted, flexed and internally rotated arm (elbow 90 degrees flexed) posteriorly—apprehension positive.

Tests for Inferior Instability

Sulcus sign (Fig. 2.25): The arm is pulled distally in 0 degree and 45 degrees of abduction. Shoulder is observed for a sulcus or dimple between acromion and humeral head.

Management of Recurrent Instability

The patients who tend to have recurrent instability secondary to generalized ligamentous laxity i.e. born loose patients (as those with Marfan or Ehler Danlos syndrome etc.) mostly present with multidirectional instability (most common being inferior) while the patients who tend to be



B

Figs. 2.24A and B: (A) Schematic representation of anterior drawer test at shoulder (B) Schematic representation of the Jerk test/posterior drawer test at shoulder.



Fig. 2.25: Sulcus sign.

in the other two categories (torn loose or micro trauma) tend to present with unidirectional instability. The management in the latter group is similar to lines of managing a recurrent dislocation. Same surgical procedures are offered after identifying the direction of instability and the cause. The former ones however seldom benefit from surgery and are better managed with stringent physiotherapy to strengthen the shoulder stabilizers. Surgery (inferior capsular shift- a capsular tightening procedure) in such patients is offered only in non-responding cases. Mathysen (Table 2.3) gave a useful physiological classification of recurrent instability that guides the treatment.

TUBS and AMBRI (Mathysen classification): These are two very commonly employed pneumonics to guide treatment in cases of recurrent instability of shoulder (Table 2.3).

HIGH-YIELD POINTS

- Shoulder is the most mobile joint in the body but also the commonest joint to dislocate in the body (followed next in frequency by elbow).
- Shoulder is also the commonest site for recurrent dislocation followed next in frequency by the patella.
- Habitual dislocation (Voluntary dislocater): A small proportion of patients are able to dislocate and relocate their shoulders at will. This is usually associated with generalized ligament laxity. Surgery should be avoided in these patients.
- The most common joint to show habitual dislocation is also shoulder followed next in frequency by patella.
- The weakest part of the shoulder joint capsule is the inferior part but most common dislocation is anterior (subcoracoid sub type).
- Although mostly in orthopedics complications are more in older patients the situation in recurrent dislocation of shoulder is rather reverse. There is greater chance of landing up with recurrent dislocation if the age at first dislocation is less.

Table 2.3: Mathysen classification of recurrent shoulder instability

TUBS	AMBRI
T —Traumatic dislocation leading to recurrent instability	A —Atraumatic dislocation (minimal trauma)
U —Unidirectional instability is usually present	M —Multidirectional instability would be there
B —Bankart's lesion is the most common lesion in such patients	B —Most patients will have bilateral problem
S —Surgery is the mainstay of treatment in such cases	R —Rehabilitation (physiotherapy) is to be tried initially
	I —In non responders Inferior capsular shift procedure is to be done

- The most common pathological lesion to result in recurrent dislocation at shoulder is the Bankart's lesion.
- Some special X-ray views used for shoulder joint are:
 - For Bankart's lesion: West point axillary view
 - For Hill sach's lesion: Internal rotation view and Stryker notch view.

ACROMIOCLAVICULAR JOINT DISRUPTION

Surgical Anatomy

Acromioclavicular joint disruption is common injury among sports person involved in contact sports. It accounts for 3–5% of all shoulder injuries. The AC joint is a diarthrodial joint between the clavicle and acromion. Stability to this joint is given by the AC ligaments and CC ligaments (see Fig. 2.7). Medial CC ligament is conical shaped conoid ligament which runs from the conoid tubercle of the clavicle to the base of the coracoid process. Lateral CC ligament is trapezoid ligament which lies anterior and lateral to the conoid tubercle and inserts more laterally on the base of the coracoid. Rockwood classification (Table 2.4) is most commonly used to classify AC joint injuries.

Diagnosis

Patient presents with pain, swelling and deformity of AC joint following history of injury. Diagnosis can be confirmed by X-ray (Fig. 2.26) of shoulder anteroposterior, axillary lateral view and Zanca view (10° cephalic tilt anteroposterior view).

Management

Rockwood (RW) type I and II are managed conservatively by rest in a sling and analgesics. Treatment of RW type III is controversial and should be individualized (surgical for athletes and high demanding young and conservative for

Table 2.4: Rockwood (RW) classification of acromioclavicular (AC) joint disruption

Type I	Strain to the acromioclavicular ligament, no significant instability is present.
Type II	Complete tear of the acromioclavicular ligaments, but the coracoclavicular ligaments remain intact. There may be slight vertical displacement of acromioclavicular joint.
Type III	Both sets of ligaments (AC and CC) are disrupted. A Type III occurs when the distal clavicle is completely displaced. With up to 100% translation of clavicle relative to the acromion.
Type IV	Both sets of ligaments (AC and CC) are disrupted and posterior displacement of the clavicle through the trapezius muscle.
Type V	Both sets of ligaments (AC and CC) are disrupted with gross displacement (often between 100% and 300% of the CC distance) of clavicle.
Type VI	Both sets of ligaments (AC and CC) are disrupted and the distal clavicle displaces inferiorly into a subacromial or subcoracoid position.

**Fig. 2.26:** Anteroposterior X-ray of shoulder showing AC joint dislocation (encircled).

old, less active). Surgical treatment may be considered if patient does not get relief with conservative trial. RW type IV through VI should be managed by surgical reconstruction.

STERNOCLAVICULAR JOINT DISRUPTION

These are rare injuries. A posterior dislocation of clavicle is a dangerous injury as the vital structures in the chest can get injured. However, an anterior subluxation or dislocation (medial end of clavicle is displaced anteriorly or anterosuperiorly to the anterior margin of sternum) is far more common than posterior (medial end of clavicle is displaced posteriorly or posterosuperiorly to posterior margin of sternum).

Most of sternoclavicular (SC) joint injuries can be managed conservatively (observation/close reduction and rest in figure-of-eight straps). Only irreducible posterior dislocation and chronic posterior dislocation may require surgery.

HIGH-YIELD POINT

Serendipity view and Hobbs views are special views for SC joint injuries.

FRACTURE OF PROXIMAL HUMERUS

These are common in elderly patients and most of them are osteoporotic fractures in postmenopausal women.

Table 2.5: Neer's classification of fracture of proximal humerus

One part fracture	The fragments are undisplaced (Fig. 2.27)
Two part fracture	One segment is displaced from other (Surgical neck fracture, anatomical neck fracture, greater tuberosity fracture, lesser tuberosity fracture).
Three part fracture	Two segments are displaced.
Four part fracture	All the major parts (head, shaft, greater and lesser tuberosity) are displaced.

Note: Displacement is defined as separation between fragments > 1 cm or an angulation more than 45 degree.

**Fig. 2.27:** X-ray showing one part fracture of proximal humerus (marked with arrow).

Most commonly these are caused by low energy domestic fall on an outstretched arm.

Neer's classification (Table 2.5) is most commonly used to classify these fractures, which is based on number of displaced fragments.

Clinical Features

Patient presents with pain, swelling, deformity and bruising of upper arm. Patient should also be evaluated for neurovascular injury including axillary nerve or brachial plexus injury. Diagnosis can be confirmed by anteroposterior (Fig. 2.27) and axillary view X-ray of shoulder joint.

Management

Most of these fractures are undisplaced or minimally displaced fractures (one part fracture). In elderly patient this is usually managed by rest in an arm sling until pain alleviates followed by gentle range of motion exercises. Being a cancellous (metaphyseal bone), the fractures unite rapidly (by 6-8 weeks).

Two Part Fractures

Surgical neck fractures: Close reduction and immobilization in an arm sling for 3 weeks is usually sufficient. If fracture cannot be reduced close satisfactorily then fixation with percutaneous pins, intramedullary nail or with locked compression plate (LCP) is required.

Greater tuberosity fracture: This is usually associated with anterior dislocation of shoulder. Greater tuberosity usually comes to its place when shoulder joint is reduced. If it does not reduce then fixation with intraosseous sutures or cancellous screws is required.

Three and Four Part Fractures

These are difficult to reduce closed and require operative fixation with intramedullary nailing or plating (Fig. 2.28). In highly comminuted fractures chances of avascular necrosis (AVN) of humeral head are high and replacement arthroplasty may be required.

Complications

Shoulder stiffness is the most common complication of proximal humeral fracture. Axillary nerve injury and fracture nonunion are also common. AVN of humeral head is relatively uncommon and usually seen in three and four part fractures.

FRACTURE SHAFT OF HUMERUS

This is fracture of humerus distal to surgical neck and proximal to supracondylar ridge of humerus and accounts

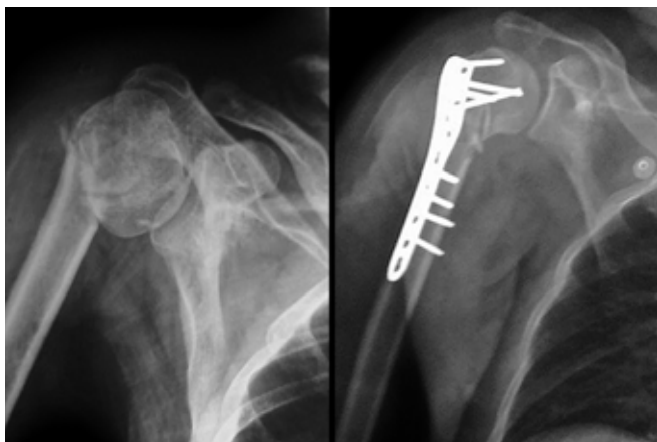


Fig. 2.28: Proximal humeral plating of proximal humerus fracture.

for less than 1% of all fractures. This is usually caused by a fall on the hand in elderly and motor vehicle injury in youngsters.

Humerus is well enveloped by muscles with rich blood supply so chances of healing of shaft fractures are high and some malunion is well accepted. When fracture occurs above the deltoid insertion proximal fragment is adducted by pectoralis major. In distal fracture proximal fragment is abducted by deltoid (Fig. 2.29).

Diagnosis

Patient presents with pain and swelling of arm. Arm is usually bruised and tender. Injury to radial nerve is most common complication and patient should be assessed for radial nerve injury (wrist drop and loss of active extension of metacarpophalangeal joints. Diagnosis can be confirmed on X-ray of arm (Figs. 2.30A to C).

Management

Nonoperative treatment of humeral shaft fracture enjoys high healing and success rate. Anatomical reduction is not necessary and angular and rotational malunion is easily masked by good range of motion at shoulder and elbow joints. Hanging cast (applied from shoulder to wrist with elbow flexed to 90°) and U-slab [Plaster of Paris (POP) slab extending from base of neck, over the shoulder, lateral aspect of arm, under the elbow to the medial side of arm (Fig. 2.31) are useful methods for the conservative treatment of fracture shaft humerus. Gentle physiotherapy and mobilization is started early to prevent joint stiffness.

Functional bracing has replaced all other conservative methods and now it is the most widely accepted method for management of humeral shaft fracture. Hanging cast or a U slab is given for the first 7-10 days and then converted to functional brace (Fig. 2.32).

Operative Indications

- When adequate close reduction cannot be obtained (shortening > 3 cm, angulation > 20°, rotation > 30°).

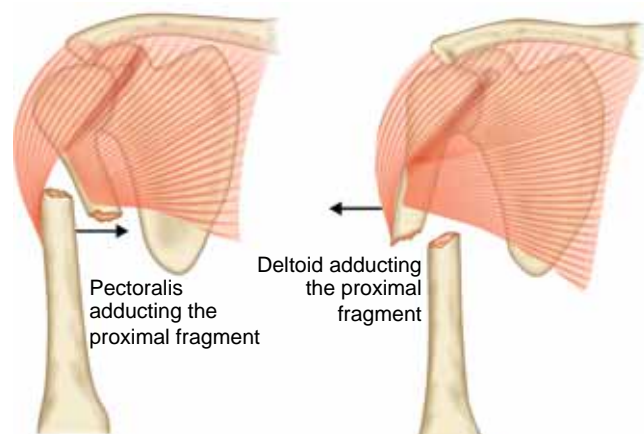
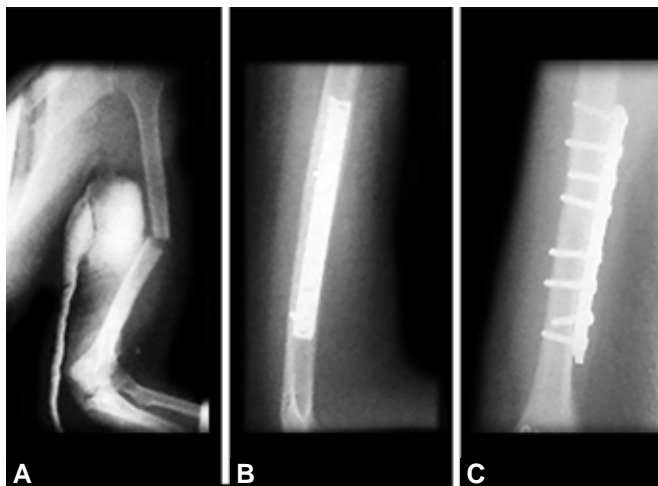


Fig. 2.29: Deforming muscle forces in fracture shaft of humerus.



Figs. 2.30A to C: (A) X-ray arm AP view showing fracture mid shaft of humerus and (B) AP and (C) lateral views of arm after fixation with plate.



Fig. 2.32: Functional brace for fracture shaft of humerus.

- Open wound, associated neurovascular injuries.
- Polytrauma patient, ipsilateral forearm, shoulder or elbow fracture.
- Pathological fractures and segmental fracture.

Operative fixation (Figs. 2.30A to C) can be achieved with close reduction and intramedullary nailing, open reduction and plating and external fixator application in case of open fracture.

Acceptability criteria for humeral shaft fracture reduction: Shortening < 3 cm, rotation < 30 degrees, and angulation < 20 degrees.

Complications

Early Complication

Neurovascular injury: If fracture shaft of humerus is associated with signs of vascular insufficiency (decreased pulse, cold limb, paresthesia) injury to brachial artery must be excluded. This is an emergency and urgent exploration



Fig. 2.31: U-slab applied for a fracture of shaft humerus.

and repair of artery is required. Radial nerve injury presents with wrist drop and loss of metacarpophalangeal joint extension. This is particularly common with open fracture, polytrauma, vascular injury and multiple ipsilateral fractures. Mostly this is a stretching injury to nerve in spiral groove (neurapraxia) and usually recovers. Exploration of radial nerve is usually not required except in cases of open wound and associated ipsilateral injury. Passive range of motion physiotherapy must be instituted and cock-up wrist splint should be given until nerve recovers to prevent joint stiffness. Nerve should be explored if there is no sign of recovery in 3 months.

Late Complications

Delayed union and nonunion: This can occur following closed and operative treatment. Common causes are technical error (inadequate plate size, inadequate reduction before fixation and inadequate screw purchase), mechanical failure due to osteoporotic bone in which screws fail to hold the bone, fracture site distraction (most common cause) due to heavy hanging cast, fracture geometry (transverse fracture) and fracture type (segmental and open fracture). If there are signs of callus formation wait for expected union. Treatment of established non-union in cancellous bone grafting and operative fixation.

Joint stiffness: It is common and can be prevented simply by early range of motion physiotherapy.

HIGH-YIELD POINT

Holstein Lewis fracture is a special variant of humerus fractures that occurs at the junction of upper two third and lower one third. In this region the radial nerve is adherent to the lateral inter-muscular septum as the nerve crosses from posterior to lateral compartment. Hence this fracture gets very commonly complicated by radial nerve palsy, mostly that is transient.

INJURIES AROUND THE ELBOW

ANATOMY OF ELBOW: SALIENT FEATURES

- Elbow joint is a synovial hinge joint having the ulnohumeral and radiohumeral components (Fig. 2.33). The ulnohumeral joint acts as a hinge where spool-shaped trochlea of articular surface of humerus articulates with trochlear notch of ulna. The radiohumeral joint is formed between the spheroidal capitulum of the humerus and the head of the radius. In the upper radioulnar joint circumference of the head of the radius articulates with the radial notch of the ulna. Flexion and extension take place at ulnohumeral joint (mainly) and radiocapitellar joint whereas pronation and supination take place mainly at proximal radioulnar joint.
- Stability of the elbow joint depends on the congruency of articulating surfaces and surrounding capsule, medial collateral ligament (MCL) and lateral collateral ligament (LCL). MCL (particularly anterior band) is primary restraint to valgus force. The lateral ulnar collateral ligament [UCL (part of LCL complex)] is the primary stabilizer against varus and posterolateral instability.
- *Three point bony relationship* (Fig. 2.34): Medial epicondyle, lateral epicondyle and the tip of olecranon form a straight horizontal line when elbow is extended and an isosceles triangle when elbow is flexed to 90°. This three point relationship is maintained in supracondylar fracture of humerus as the fracture line is above the level of interepicondylar line.
- *Anconeus triangle*: On the posterolateral aspect of elbow the radial head, tip of olecranon and lateral epicondyle form a triangle which is occupied by anconeus muscle. Intraarticular injection of elbow can be given in this space. This space becomes prominent with fluid collection in the joint.
- *Carrying angle* (Fig. 2.35): It is an angle between long axis of humerus and long axis of forearm (or long axis of ulna) with elbow fully extended and forearm supinated. In extended position forearm and arm are not perfectly aligned and forearm is slightly deviated outside forming an angle with long axis of arm. This is known as carrying angle. Mean value in male is 11° and in female is 14°. This allows forearms to swing freely without hitting the hips.
- *Ossification around elbow* (Fig. 2.36): Evaluation of elbow fractures may pose difficulty in children due to changing anatomy of growing elbow. There are six ossification centers around elbow which appear in a predictable sequence. CRITOE is a simple way to remember this.
C—Capitulum at 2 years
R—Radial head at 4 years
I—Internal (medial) epicondyle at 6 years
T—Trochlea at 8 years
O—Olecranon at 10 years
E—External (lateral) epicondyle at 12 years.

SUPRACONDYLAR HUMERUS FRACTURE

Supracondylar humerus fracture is a fracture occurring through the olecranon fossa of humerus. It is the commonest fracture seen in children between 3-10 years of age when there is a history of fall on outstretched hand (classically when there is a hyperextension injury to elbow).



Fig. 2.33: Anatomy of elbow joint.

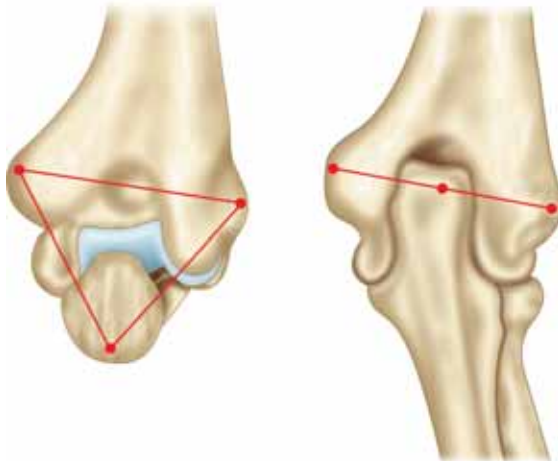


Fig. 2.34: Three point bony relationship of elbow.



Fig. 2.35: Carrying angle.

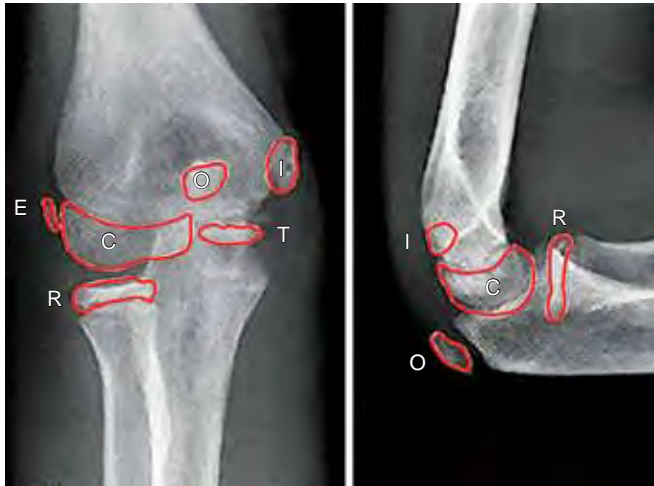


Fig. 2.36: Ossification around elbow.

Types (Based on Mechanism of Injury and Displacement)

Extension type supracondylar fracture: Most common type. Here the distal fragment is pulled posteriorly by the triceps as shown in the Figure 2.37. It is caused by fall on an outstretched hand with elbow in extension.

Flexion type supracondylar fracture: This accounts for less than 5% cases. It is caused by direct blow on posterior aspect of flexed elbow. Distal fragment is displaced anteriorly.

Gartland Classification

- **Type I:** Nondisplaced or minimally displaced fracture.
- **Type II:** At least one cortex (or atleast periosteum) is intact such that there is only angulation but no displacement. Posterior angulation with intact posterior cortex in extension type injury. Anterior angulation with intact anterior cortex in flexion type injury.
- **Type III:** Completely displaced with both cortices fractured.

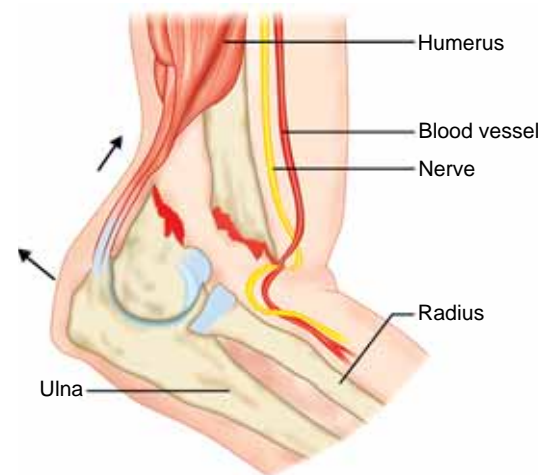


Fig. 2.37: Schematic representation of supracondylar fracture showing the distal fragment being displaced posteriorly by the triceps muscle.

Diagnosis

Patient presents with pain, elbow swelling and tenderness at supracondylar ridges. In completely displaced fracture there may be obvious deformity of elbow. Nondisplaced or minimally displaced fractures may have only subtle clinical features with no swelling of elbow. Radiography (see Fat pad sign) is the mainstay of diagnosis in such cases. A thorough neurovascular examination must be done as this fracture is notorious to end up with dreadful complications.

Radiological Examination

Diagnosis can be confirmed on anteroposterior and lateral views of elbow (Fig. 2.38A). In minimally displaced fracture fat pad sign (radiolucency anterior or posterior to distal humeral diaphysis, Fig. 2.39) may be seen on lateral view. As the fracture hematoma fills up the coronoid and olecranon fossa, the fat in these fossa is displaced, that gives rise to this lucency on radiographs.



Figs. 2.38A and B: (A) Anteroposterior and lateral X-rays of elbow showing supracondylar fracture of humerus and (B) close reduction and percutaneous pinning of supracondylar fracture of humerus.



Fig. 2.39: Fat pad sign in undisplaced supracondylar humerus fracture.



Fig. 2.40: A modified Dunlop traction being used for supracondylar fracture management in a child.

Management

Type I nondisplaced fractures are managed by above elbow cast immobilization for 3 weeks with elbow in 90° flexion, followed by range of motion physiotherapy.

Type II and Type III fractures require reduction. Majority of the fractures are reduced by close manipulation under C-arm image intensifier. Open reduction is required in few cases where adequate close reduction cannot be achieved and in cases with open wound or where injury to brachial artery is suspected. Once reduction is achieved it can be maintained in above elbow cast or with percutaneous pinning (Fig. 2.38B). However, at times one is unable to take up these patients for reduction attempt due to anesthetic problems or other issues. In such situations the fracture can be temporary splinted (Fig. 2.40) by applying a Dunlop (skin traction) or a Smith's traction (skeletal traction).

Method of close reduction: (Extension Type Fracture) (Flowchart 2.1)

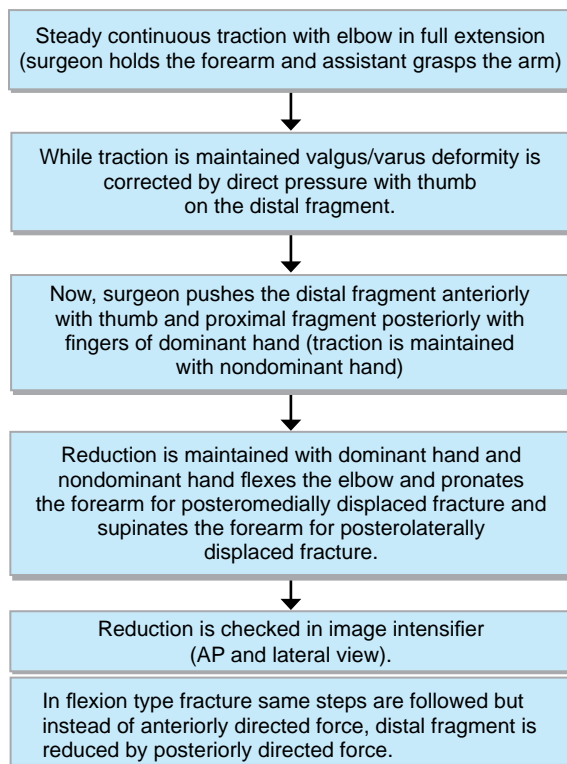
Complications

Early Complications

- **Vascular injury:** Brachial artery may be compressed by fracture fragment or get entrapped between two fracture fragments (see Fig. 2.37). Whenever a patient with supracondylar humerus fracture presents with absent radial pulse, immediately reduction should be attempted as reduction frequently restores circulation. If even after reduction, limb remains ischemic (absent/decreased capillary refill absent radial pulses and absent or decreased pulse oximeter saturation) exploration of brachial artery may be warranted.

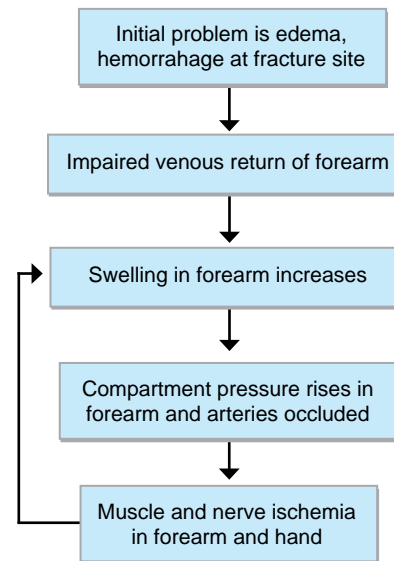
If radial pulse disappears after fracture reduction (elbow is not acutely flexed) it indicates that artery is entrapped between fracture fragments and requires surgical exploration.

- **Compartment syndrome** (Fig. 2.41): Supracondylar fracture humerus is the most common cause of compartment syndrome in children. It results when

Flowchart 2.1: Method of closed reduction.**Fig. 2.41:** Compartment syndrome following supracondylar fracture of humerus—see massive swelling and blebs.

pressure rises within a close compartment causing vascular compromise (Flowchart 2.2). Muscle hypoxia as a result of ischemia causes increased capillary permeability and intramuscular edema which further causes a rise in compartmental pressure. Decreased venous return also contributes to raise compartment pressure. Thus a vicious cycle is set which can only be stopped by immediate surgical release of involved compartment by fasciotomy.

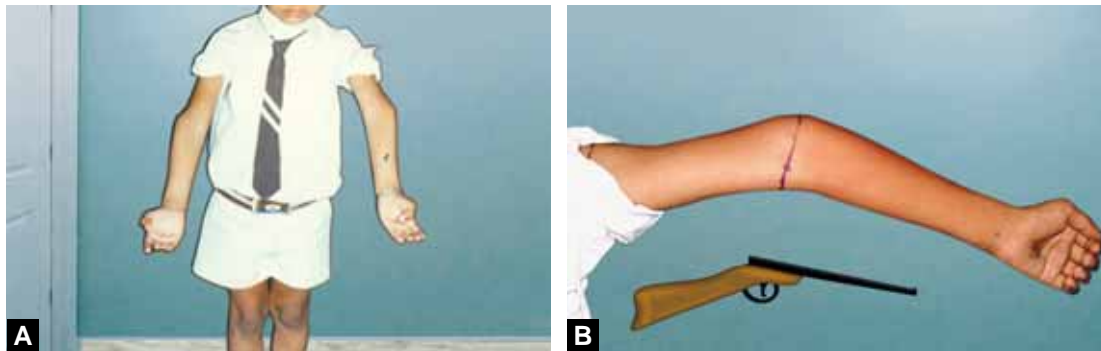
Diagnosis of compartment syndrome should be made on clinical ground by looking for the six “P”s—Puffiness (swelling), pain on passive stretch of fingers

Flowchart 2.2: Events in development of compartment syndrome.

(Passive stretch test), Pallor, Pulselessness, Paraesthesia and Paralysis. The earliest and most reliable sign is the passive stretch test. Pulse is an unreliable sign and distal pulses may be present or absent. Development of paresthesia and paralysis are last features. Wick or slit catheter technique, arterial line pressure monitor can measure the compartment pressure accurately. Pressure more than 30 mm Hg (normal compartment pressure is less than 10 mm Hg) usually indicates need for surgical intervention although threshold pressure is different with different measurement techniques and decision of surgical release of compartment (fasciotomy) should be taken on clinical ground.

Prevention and treatment: Best treatment for compartment syndrome is vigilant avoidance. Injured limb should be kept elevated to decrease soft tissue swelling and edema. However in impending compartment syndrome limb should be kept at heart level because limb elevation also reduces arterial blood flow and thus oxygen delivery to tissues. Tight circumferential dressing should be removed. Treatment of impending or established compartment syndrome is essentially fasciotomy of the involved compartment. Fracture can be stabilized after surgical decompression of compartment.

- *Nerve injury:* Anterior interosseous nerve injury is most common nerve injury followed by median and then radial nerve injury in extension type of supracondylar humerus fracture. In flexion type fractures and in postoperative cases it is the ulnar nerve that is most commonly involved. Adequate neurological examination is although difficult to do in an injured child and so initially diagnosis may be missed. Fortunately almost all nerve injuries are neurapraxia only and improve with time. Watchful expectancy is all that is required. If recovery does not happen in 12 weeks than nerve



Figs. 2.42A and B: (A) Cubitus varus deformity following malunited supracondylar fracture of humerus, (B) see typical appearance of Gunstock deformity.

conduction studies and electromyographic studies should be done. If nerve is found transected then either nerve grafting or tendon transfer should be considered.

Late Complications

- **Malunion:** This is the most common complication of supracondylar fracture. Cubitus varus deformity (Gunstock deformity, Figures 2.42A and B) is more common than cubitus valgus deformity because posteromedially displaced fractures which tend to develop varus angulation, are more common than posterolaterally displaced fractures. These problems which occur months after fracture heals, cause more cosmetic problem and less functional problem. However, lateral condylar fracture, elbow and shoulder instability and distal humeral epiphyseal separation all have been reported as complications following cubitus varus deformity.

Cubitus varus deformity is actually a three-dimensional deformity with rotational malalignment along with coronal plane deformity that occurs due to an uncorrected medial tilt and internal rotation of distal fragment. Rotational component is largely compensated by shoulder movement so only coronal plane deformity correction is all that is necessary.

For mild degree of deformity nothing is required except reassurance. In severe cases corrective osteotomy is required to improve cosmetic appearance or functional deficit. Lateral closing wedge osteotomy (French or modified French) with single plane (coronal) correction and fixation with K wires, screws or plate is the most commonly done procedure.

- Elbow stiffness and myositis ossificans are rare complications. Early range of motion physiotherapy at 3 weeks should be commenced to prevent elbow stiffness.

Myositis ossificans (a/k/a hematoma ossificans): It is the benign pathological bone formation (heterotopic ossification) in muscles and other soft tissues (Fig. 2.43). Trauma is the most commonly inciting event but may occur without trauma in paraplegics, Guillain-Barre (GB) syndrome, acquired immunodeficiency syndrome (AIDS) encephalopathy, closed head injury, following extensive burns and in comatose patient. One-third cases are idiopathic.



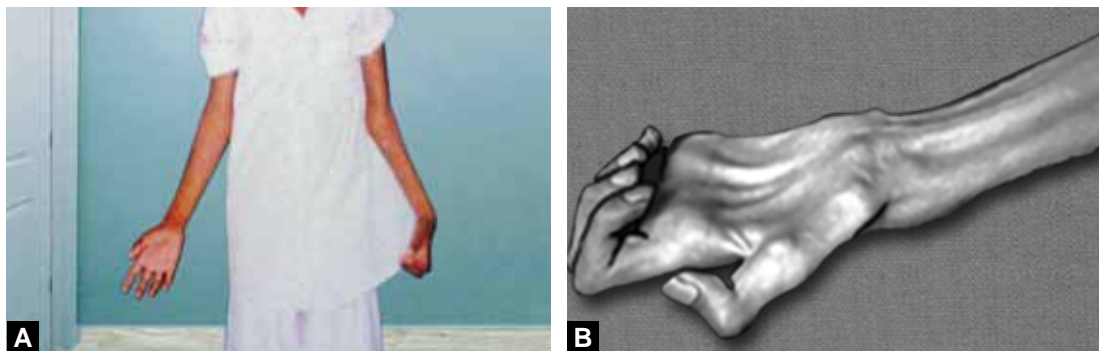
Fig. 2.43: Myositis ossificans of elbow joint.
Courtesy: Dr Sachin Ingole

Most commonly affected muscles are quadriceps, glutei and brachialis. However, elbow joint is most commonly involved joint by myositis ossificans. After injury, massage to the elbow and vigorous passive physiotherapy may provoke development of myositis ossificans.

Pathology: It is calcium hydroxyapatite deposition (ossification) in soft tissues being composed of a benign matrix rich in fibroblasts and osteoclast like giant cells. Ackerman zonal phenomenon is a characteristic feature. In the center actively proliferating fibroblast with numerous mitotic figures, cytological atypia and loose random arrangement are found. In the periphery more organized arrangement of mature fibroblast with transformation into mature osteoid is seen. This is in contrast to neoplastic lesion in which more mature cells are seen in center.

Clinical Features

- **Acute phase:** After few days to few weeks of injury patient develops pain swelling and stiffness of nearby joint.
- **Pseudotumoral phase:** This comes after 2-3 weeks and characterized by painless hard mass.
- **Resolving phase:** This comes after 3-6 months. Gradual resolution of the lesion may occur in this phase.



Figs. 2.44A and B: Volkmann ischemic contracture of forearm muscles.

Radiology

Initial X-rays are normal. Calcification and mineralization is seen 2–3 weeks after the onset of symptoms and matures in next 3–6 months. Periosteal reaction is seen as laminations. There are three variants of myositic mass. In stalked variant a peduncle is attached to underlying bone. In sessile variant, mass has a broad based attachment to underlying periosteum. In a third variant bony mass is only attached to involved muscle.

Diagnosis

It can be made on clinical background and in association with X-ray features. In doubtful cases diagnosis can be confirmed by biopsy. Biopsy also differentiates it from a bone forming tumor like osteosarcoma due to presence of zonal phenomena.

Treatment

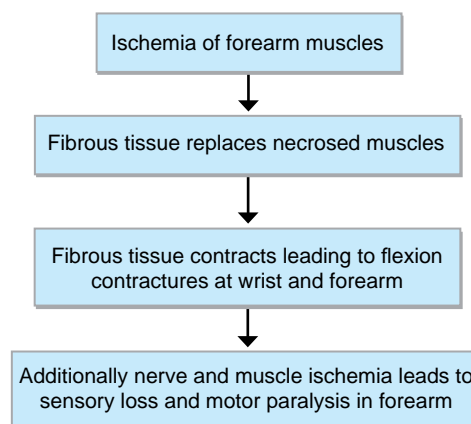
In acute cases treatment consists of nonsteroidal anti-inflammatory drug (NSAIDs), ice, compression dressing, splintage for the involved limb and active range of motion physiotherapy. Passive stretching should be avoided, rather active exercises are to be encouraged. If required, excision of the ossified mass can be done after maturation which usually takes an year or so (Indicated by decreased level of alkaline phosphatase and mature bone deposition on X-ray).

Volkmann's ischemic contracture (Figs. 2.44A and B): It is a consequence of ischemic necrosis of muscles and nerves of forearm which are then replaced by fibrous tissue (Flowchart 2.3). Any obstruction to brachial artery caused by tight plaster, improper use of tourniquet, or compartment syndrome can lead to Volkmann ischemic contracture (VIC).

There are four compartments in the forearm: (1) dorsal, (2) superficial volar, (3) deep volar and (4) compartment containing mobile wad of Henry (Brachioradialis, extensor carpi radialis longus and brevis). Volar compartment is most commonly involved. Clinical picture varies with the severity of the injury.

Mild involvement: Only the deep extrinsic finger flexors are involved and usually involve only two or three fingers.

Flowchart 2.3: Sequence of events in development of Volkmann's ischemic contracture.



The middle and ring fingers are most frequently involved. Flexor digitorum profundus (FDP) muscle is most commonly involved muscle in VIC.

Moderate involvement: After the FDP, flexor pollicis longus muscle is commonly involved. Other muscles, the flexor digitorum superficialis (FDS), flexor carpi radialis (FCR) and flexor carpi ulnaris (FCU) may also be involved later. Typical deformity is the intrinsic-minus hand deformity (claw hand) from extrinsic muscle contracture (hyper-extension at metacarpophalangeal joint and flexion at interphalangeal joints). Concomitant median and ulnar nerve neuropathy further contributes to claw hand deformity in addition to sensory changes.

Severe involvement: Along with forearm flexor compartment extensors are also involved to variable extent. However clinical picture is still that of only flexor involvement because of strong and larger flexors. With severe cases there is elbow flexion, forearm pronation, wrist flexion, thumb flexion and adduction, digital metacarpophalangeal joint extension and interphalangeal joint flexion.

Treatment

Mild cases with intact sensation can be treated with range of motion and strengthening exercises and static and dynamic extension splinting. A turn buckle splint (Fig. 2.45) is most commonly used for mild deformities.

Turning the buckle distracts the contracted tissue gradually and corrects a mild deformity. In moderate cases the surgery of choice is the Maxpage's muscle sliding operation (erasing the common flexor origin and translating it distally on to the interosseous membrane). Severe cases require neurolysis, excision of the infarcted muscle mass and bone shortening procedures.

HIGH-YIELD POINTS

- Ipsilateral radius fracture is most commonly associated fracture with supracondylar humerus fracture.
- *Baumann's angle* (Fig. 2.46): Angle between line drawn perpendicular to long axis of humeral shaft and physeal line of lateral condyle of humerus in anteroposterior view. (Normal 8–28°). It is used to assess the adequacy of fracture reduction. A small angle indicates possibility of varus.
- Iatrogenic ulnar nerve injury is associated with medial pinning in supracondylar fracture. To prevent it, two lateral pins can be inserted to maintain reduction or medial pin should be inserted with elbow in extension.
- Supracondylar humerus fracture is the most common fracture associated with vascular injury (Brachial artery) and is the most common cause of compartment syndrome and Volkmann's ischemia in children.
- Volkmann ischemic contracture most commonly involves FDP and median nerve.
- *Myositis ossificans progressiva*: It is rare, autosomal dominant and fatal condition seen in children usually below 6 years. It is characterized by spontaneous or injury induced ossification of soft tissues including muscle, tendon and ligaments at multiple sites ultimately leading to death. Exact etiology is not known but presence of macrophages, lymphocytes and mast cells in early lesions with perivascular lymphocytic infiltration and response to corticosteroid may indicate towards involvement of immune system.

Apart from progressive involvement of muscles and other soft tissues, microdactyly of the great toe is a characteristic feature. Other common abnormalities are exostoses, dental and ear deformities, hypogonadism and short/broad neck. Sternocleidomastoid muscle is almost always involved to start with and

torticollis is a common initial presenting complaint. Cardiac muscles, smooth muscles and many skeletal muscles like diaphragm, tongue and extraocular muscles are spared from heterotopic ossification. Initial signs of disease are pain and swelling of involved muscle followed by ossification. Neck, spine and shoulder girdle are commonly involved. Death is usually due to respiratory failure and its complications.

- Elbow joint followed by hip joint is most commonly involved joint by myositis ossificans.
- Although a number of causes can lead to compartment syndrome like blunt injury, surgery, infection, snake bite, tight plaster/bandage, tourniquet and I/V fluid administration, the most common cause is a fracture. In children most common fracture that leads to compartment syndrome is supracondylar humerus while in adults it is proximal tibia. Overall, it is tibial fracture that is the commonest cause and most often the syndrome occurs in the leg.
- There is no advantage of fasciotomy after 72 hours.
- A fasciotomy is also indicated in cases where there has been vascular disruption of a major vessel to a limb for more than 4 hours. As there are high chances of developing compartment syndrome after vascular disruption.
- Posteromedial Supracondylar humeral fractures are more common than posterolateral type. Radial nerve injury is more common in posteromedial type and median nerve injury is more common in posterolateral type, but posterolateral type is more commonly associated with nerve injury so median nerve is most commonly injured nerve in supracondylar fractures.
- Jones view is the axillary of the elbow joint.

LATERAL CONDYLE HUMERUS FRACTURE (FIG. 2.47)

Mechanism of Injury

This is a common fracture in children between 5 to 10 years. It is usually caused by fall on an outstretched arm. It causes impaction of the radial head into lateral condyle causing fracture (push off theory). It may also be caused by pull of the common extensor origin (pull off theory).



Fig. 2.45: Turn buckle splint.

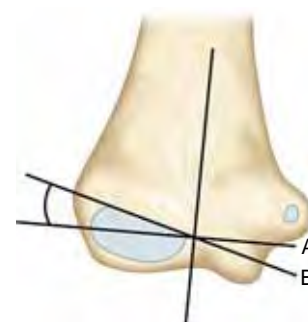


Fig. 2.46: Baumann's angle.



Fig. 2.47: X-ray of elbow AP and lateral views showing lateral condyle fracture (encircled).

Courtesy: Dr Sachin Ingole

Pathoanatomy

Lateral condyle fracture fragment consists of lateral epicondyle and secondary ossification center of capitellum. Secondary ossification center of capitellum appears at around 2 years of age and that of lateral epicondyle at 12–13 years of age. At the time of fracture most of the structures involved are cartilaginous and hence X-ray picture does not give the exact extent of the fracture.

Milch Classification

Milch classification (Fig. 2.48) is used most commonly to classify these injuries. A Milch type I fracture line extends lateral to trochlear groove and through the secondary ossification center of capitellum. In Milch type II, fracture line extends farther medially (medial to trochlear groove) and trochlea remains attached with the fracture fragment. Elbow joint becomes unstable in Milch Type II fracture. X-ray interpretation concerning Milch classification is difficult because fracture line extending through cartilaginous part is not seen in X-ray.

Milch type I fracture is considered as Salter Harris type IV fracture as the fracture line extends through metaphysis, physis and epiphysis. Milch type II fracture is Salter Harris type II fracture as fracture line does not extend through the secondary ossification center of capitellum.

Diagnosis

The child presents with pain and swelling of the elbow. Tenderness is present mainly on lateral aspect of elbow. Diagnosis can be confirmed on X-rays.

Treatment

Treatment is based on the displacement of fracture. A nondisplaced fracture is one in which displacement is less than 2 mm on oblique views. These fractures can be managed by immobilization in above elbow cast in 90° of flexion and internal rotation for 4 weeks followed by range of motion physiotherapy.

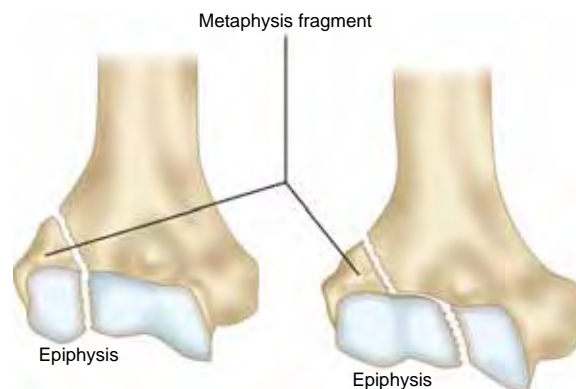
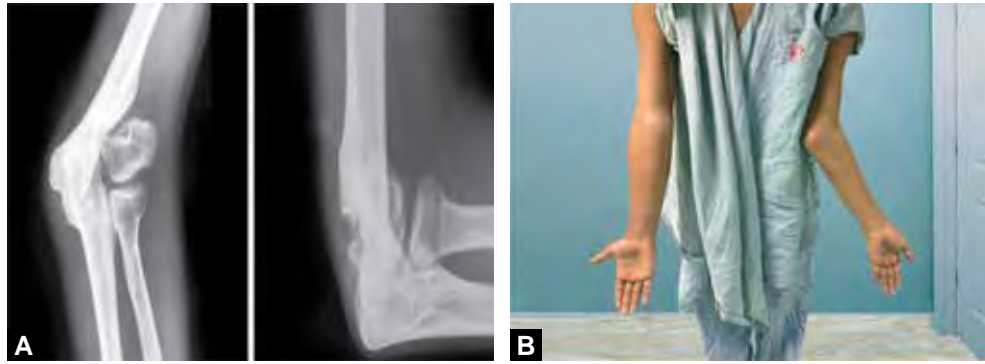


Fig. 2.48: Milch classification of lateral condyle fracture—Type I (Left in figure) and Type II (Right in figure).

However, most of these fractures are displaced owing to pull of the common extensor origin and such fractures require open reduction and internal fixation with K wires.

Complications

- **Lateral spur formation:** Lateral spur formation is the most common complication and usually results from an ossified periosteal flap raised from the distal fragment at the time of injury or surgery leading to cubitus pseudovarum deformity due to lateral bump at elbow. This is a cosmetic problem and functions are usually normal. The most common problematic deformity that occurs is actually cubitus valgus (due to lateral physeal growth arrest and non union of fracture fragment).
- **Nonunion:** This is the most common complication which requires treatment. Fracture is intracapsular so there is continuous synovial fluid irrigation of fracture fragments. Synovial fluid is known to inhibit callus formation. Also there is continuous pull on fracture fragment by extensors of the wrist. These two factors are mainly responsible for nonunion of lateral condylar fracture. Lateral condyle derives most of its blood supply from posterior soft tissues so extensive soft tissue dissection while open reduction can also lead to nonunion. A lateral condyle fracture which does not show signs of healing by 3 months is said to be in nonunion. Early nonunion fracture presents with pain and instability. These patients are treated by open reduction and internal fixation with bone grafting. Late presentation of nonunion is either a painless mass or a cubitus valgus deformity (Figs. 2.49A and B). With increasing valgus tardy ulnar nerve palsy may develop (due to stretching of ulnar nerve with increasing valgus). Severe cases are treated by corrective osteotomy (Milch osteotomy) with or without ulnar nerve transposition.
- **Angular deformities:** Cubitus valgus is more common than cubitus varus deformity due to lateral physeal arrest.
- Growth arrest and AVN are other rare complications.



Figs. 2.49A and B: (A) X-ray elbow AP and lateral view showing nonunion fracture lateral condyle and (B) cubitus valgus deformity following nonunion of lateral condyle fracture.

MEDIAL EPICONDYLE FRACTURE

It is a common fracture in children between 5 years and 15 years of age. Ossification center of medial epicondyle appears about 5 years of age and unites with humeral diaphysis between 16 years and 18 years. It is usually an avulsion injury and caused by fall on an outstretched hand when extended elbow is forced into valgus.

Diagnosis

Patient presents with pain, swelling and tenderness at medial epicondyle. Diagnosis can be confirmed on X-ray (Fig. 2.50) but findings may be difficult to interpret in young patients below 5 years of age as the ossification center is not yet ossified. Approximately 50% of medial epicondyle fractures are associated with elbow dislocation. X-rays may be compared with those of normal side to clinch the diagnosis.

Treatment

Nondisplaced or minimally displaced (<5 mm) fractures are managed by immobilization in a sling for 2–3 weeks followed by range of motion physiotherapy. Intraarticular fragment should be removed urgently. Close extraction of entrapped fragment can be done by valgus stress on extended elbow and then supinating the forearm and extending the wrist. If close attempt fails open extraction should be done.

In displaced fractures good results have been obtained both by closed treatment and open reduction with internal fixation.

Complications

Joint stiffness is the most common complication and can be prevented by early range of motion physiotherapy. Ulnar nerve neuritis is also common especially where fracture fragment is entrapped in the joint. It is usually neurapraxia and improves with time. Nonunion may also occur and requires open reduction and fixation with K wire with bone grafting.



Fig. 2.50: X-ray elbow AP and lateral views showing medial epicondyle fracture (encircled).

DISTAL HUMERAL FRACTURE IN ADULTS

Distal humeral fractures account for 2% of all adult fractures. They are usually caused by direct fall on elbow. High energy road traffic accidents are usually responsible for these fractures in young adults.

They are classified in three types (AO-ASIF classification, Figs. 2.51A to C).

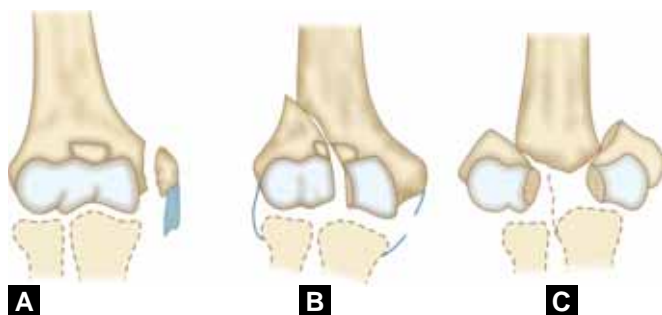
1. *Type A:* Extraarticular supracondylar fracture
2. *Type B:* Partial articular (unicondylar) fracture
3. *Type C:* Complete articular (bicondylar) fracture.

Diagnosis

Patient presents with pain and swelling of elbow. There is severe tenderness and crepitus of the distal humerus. A thorough neurovascular examination should be done. Diagnosis can be confirmed on X-ray.

Treatment

Undisplaced fractures are treated in above elbow cast for 4 weeks followed by range of motion exercises. Displaced supracondylar, unicondylar and bicondylar fractures in adults are treated with open reduction and internal fixation with plates. A severely comminuted distal humerus fracture in an elderly is best treated by elbow arthroplasty.



Figs. 2.51A to C: AO-ASIF classification of distal humeral fractures in adults.

Complications

Early

- *Neurovascular injury:* Injury to brachial artery, median and ulnar nerve may occur with fracture. A thorough neurovascular examination should always be done.

Late

- *Elbow stiffness:* This is the most common complication of distal humerus fracture. Early range of motion should be encouraged to prevent it.
- *Myositis ossificans:* This may occur following any fracture around the elbow and especially seen in fractures associated with severe soft tissue injury. Massage and aggressive movements should be avoided.
- Malunion of fracture leading to cubitus valgus and cubitus varus may occur.

ELBOW DISLOCATION (FIGS. 2.52A AND B)

Elbow dislocation is the second commonest dislocation in orthopedic practice after shoulder dislocation. Although it is the commonest dislocation in children, its incidence is particularly high in the young adults (10-20 years old). It is usually caused by fall on the outstretched hand with elbow in extension and forearm in supination. Posterior or posterolateral dislocation is most common as the ulna is pulled back by the bulky triceps muscle (>90% of cases). It is associated with tear of lateral collateral ligament (LCL) and in more severe cases both LCL and medial capsuloligamentous structures (MCL) are torn. When associated with fractures of radial head and coronoid process (terrible triad of elbow), recurrent dislocation may result.

Classification

Elbow dislocation is classified as per the direction of displacement of ulna. Posterior or posterolateral dislocation is most common. Other types are posteromedial, lateral, medial, anterior and divergent type. Another way to classify is to divide into simple and complex types. A simple dislocation is one without a concomitant fracture while a complex dislocation is associated with a fracture around the elbow. Most commonly associated fracture is a fracture of the medial epicondyle of humerus.



Figs. 2.52A and B: (A) X-ray of elbow lateral and (B) AP views showing posterior elbow dislocation.

Diagnosis

Patient presents with swelling and obvious deformity of elbow. Bony landmarks of elbow (radial head, olecranon, etc.) are palpated at abnormal places. The ulna while translating posteriorly may button hole into the triceps causing bowstringing of triceps. Diagnosis is confirmed on X-rays. A thorough neurovascular examination should be made.

Treatment

Dislocations without fracture are reduced by close maneuver. Patient is made in prone position with forearm is hanging at edge of table. Traction is given on forearm with elbow in flexion. Forward pressure is applied on the olecranon and sideways deformity is corrected by direct pressure. After reduction the elbow should be able to make full range of motion. It is put in cuff and collar sling for 3 weeks. For complex dislocations ORIF of fracture and reconstruction of the torn capsulo-ligamentous structures is usually required.

Complications

Injury to brachial artery, median and ulnar nerve should be looked for in all cases of elbow dislocations. The most common nerve injured in simple elbow dislocation is the median nerve while in complex elbow dislocations it is the ulnar nerve that is generally injured.

Late complications are elbow stiffness, myositis ossificans and recurrent dislocations. Recurrent dislocations usually require reconstruction of lateral capsuloligament structures. These surgeries usually involve reconstruction of lateral ulnar collateral ligament.

HIGH-YIELD POINTS

- Patelofemoral joint is the most common joint to dislocate in children (recurrent dislocation of patella). Elbow is the most common major joint to dislocate in children. Elbow dislocations are common in second decade (13-15 years). In adults it is the second most common major joint to dislocate after shoulder joint.

- Lateral UCL is the main stabilizer against posterolateral rotatory instability of elbow.
- *Hotchkiss terrible triad of elbow injury*: Radial head fracture, fracture of coronoid process of ulna and a posterolateral dislocation of elbow.

PULLED ELBOW (NURSEMAID'S ELBOW)

This is common diagnosis of elbow pain in children between 1 year and 4 years. Sudden subluxation of radial head occurs when traction is given on the hand with extended elbow and pronated forearm (commonly occurs when one tries to lift the child by holding his hand/distal forearm or when child suddenly steps down while one of his parents holds him from hand). Radial head comes out from the anterior portion of annular ligament upon pulling the pronated forearm. When traction is released annular ligament gets interposed between radial head and capitellum thus prevents reduction.

Diagnosis

Typical history and clinical examination clinches the diagnosis. The child starts crying immediately after having pulled or swung in air by holding his hand. A click may be felt by the person while pulling the child. The child keeps his elbow flexed with forearm in pronation. He refuses to use his affected limb. If child allows examination, supination is found restricted. X-rays of the elbow are normal.

Treatment

Radial head is reduced by flexing the elbow and rapidly supinating the pronated forearm. Again a click may be felt in child's elbow while reducing it. The child stops crying and starts using his limb within minutes after reduction.

HIGH-YIELD POINTS

- Panner's disease is AVN of capitellum. It is seen in children younger than 10 years. Child presents with pain and stiffness of elbow. X-ray shows radiolucent and sclerotic areas in capitellum. Treatment is NSAIDs and activity modification.
- Osteochondritis dissecans of the capitellum is similar to Panner's disease except it is seen in older children.

- Pulled elbow is not seen after the age of 4-5 years as after this age the head ossifies and cannot subluxate easily.

FRACTURE OF THE CAPITELLUM

This is a rare injury. Patient presents with swelling and tenderness in front of elbow. Diagnosis is made on anteroposterior and lateral X-rays of elbow. Undisplaced fractures are treated by immobilization in a sling for 2 weeks followed by range of motion physiotherapy. Displaced fractures require open reduction and headless screw fixation. Joint stiffness is common so early movement should be encouraged as soon as pain subsides.

RADIAL HEAD FRACTURE

This is a common elbow injury in adults. A fall on the outstretched hand with the elbow in extension and valgus is the usual event which causes axial loading of radial head against capitellum leading to fracture of radial head.

Diagnosis and Classification (Table 2.6)

Patient presents with swelling and ecchymosis of elbow joint with painful elbow motion. Crepitation of the radial head may be felt with forearm supination and pronation movement. Diagnosis can be confirmed by anteroposterior and lateral views of elbow joint (Fig. 2.53).

Treatment

Undisplaced fracture requires only sling immobilization for 3 weeks. Small nonarticular fragment (Lateral one-third fragment) can be excised. Large articular fragment should be reduced and fixed with headless screw. In comminuted fracture prosthetic replacement may be required.

Complications

Joint stiffness: It is most common complication and early motion should be encouraged to prevent it.

Osteoarthritis: It is a long-term sequel of intraarticular fractures of elbow. It usually does not cause much disability.

Myositis ossificans is an uncommon complication.

Table 2.6: Mason classification of radial head fracture and treatment

Type I	Nondisplaced fracture	Rest in a cuff and color sling for 3 weeks. Early active range of motion is allowed as soon as pain subsides.
Type II	Displaced fracture (fragment involving more than 30% of articular surface that is displaced more than 2 mm)	Open reduction and internal fixation with headless screws.
Type III	Comminuted fracture	Radial head excision with or without prosthetic replacement.
Type IV	Fracture associated with elbow dislocation	Repair of capsule-ligamentous structure and ORIF of associated fractures.



Fig. 2.53: X-ray of elbow AP and lateral views showing displaced radial head fracture.

HIGH-YIELD POINTS

- For fixation of radial head fractures screws are to be inserted in the non-articulating zone (posterolateral part).
- Green span view is the special X-ray view to visualize fractures of radial head and capitellum.
- In children radial head excision should not be done as the radius may migrate proximally causing subluxation of inferior radioulnar joint and cubitus valgus deformity of elbow.
- In Essex Lopresti fracture (*see below*) and in terrible triad (fracture of radial head and coronoid with elbow dislocation) radial head excision is contraindicated and it is reconstructed.

FRACTURE OF THE RADIAL NECK

Fracture of radial neck usually occurs in children. Fall on outstretched hand with elbow in extension and valgus is a common mechanism of injury. Diagnosis is made on X-ray (Fig. 2.54). Undisplaced or minimally displaced ($<30^\circ$ angulation) fracture is managed by rest in a sling or above elbow cast for 2 weeks. More displaced fractures require close reduction and cast immobilization. Percutaneous reduction using K wire or open reduction with or without K wire fixation may be required in severely displaced fracture where close reduction fails.

Complications

Joint stiffness due to malunited fracture, shortening and cubitus valgus deformity due to physeal arrest may occur.

OLECRANON FRACTURE

This is a common fracture in adolescents and young adults. It is also called as Javelin thrower's fracture as it is common in players involved in this sport. At other times it occurs due to direct fall on tip of elbow. Avulsion fracture of olecranon may occur on fall on hand with a partially flexed elbow with triceps muscle avulsing the fracture fragment.



Fig. 2.54: X-ray of elbow AP and lateral views showing radial neck fracture (arrow).

Diagnosis

Pain, swelling and tenderness at tip of elbow are presenting features. Mostly it is a transverse displaced fracture as the proximal fragment is pulled away by triceps. In such cases often a gap can be felt at fracture site. Active extension of elbow joint may not be possible. Diagnosis can be confirmed on X-ray (Figs. 2.55A and B).

Treatment

Olecranon fracture is classified into undisplaced, displaced and comminuted fractures. Undisplaced fractures require above elbow cast immobilization in 90° elbow flexion for 3–4 weeks followed by gentle elbow motion. Simple transverse displaced fractures require open reduction and internal fixation with tension band wiring (Figs. 2.55A and B) using screw and K wire. Comminuted fractures require open reduction and plate fixation. An avulsion fracture of tip involving less than one-third of olecranon can also be excised in low demand patients.

Complications

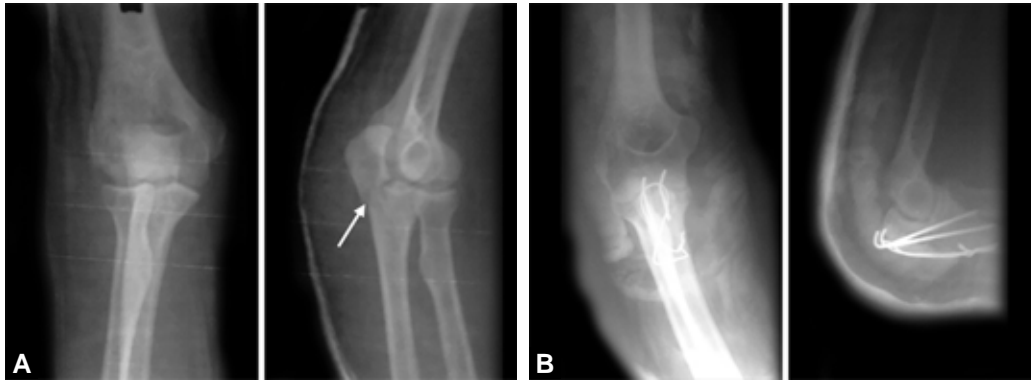
Elbow stiffness: As with other elbow fractures it is common with prolonged immobilization. To prevent it early elbow motion should be started after operative fixation. Treatment is range of motion physiotherapy.

Nonunion can result from inadequate reduction and fixation. Treatment is ORIF and cancellous bone grafting.

Osteoarthritis is a late sequel of imperfect reduction. Usually patient can be managed symptomatically. In severe cases elbow replacement may be required.

HIGH-YIELD POINTS

- **Tension band wiring principle:** Tension band converts tension into compression at opposite cortex. Tension band wiring is usually done in fracture patella, olecranon, medial malleolus and greater tuberosity fracture.



Figs. 2.55A and B: (A) X-ray of elbow AP and lateral views showing fracture of olecranon (arrow); (B) Open reduction and tension band wiring of olecranon fracture.

- Métaizeau's technique is used for intramedullary reduction of radial neck fracture. A wire is introduced through the medullary canal into the fracture fragment and rotated to reduce the fracture.
- The places where excision of bone is the treatment of choice: Comminuted fracture of radial head, fracture tip of olecranon, comminuted fracture of patella.

INJURIES OF THE FOREARM, WRIST AND HAND

FRACTURES OF DISTAL END OF RADIUS

Fracture of distal end radius (DER) is one of the most common fracture diagnosis in orthopedic clinic. It is most common fragility fracture in elderly and is the commonest fracture in adults who give history of fall on outstretched hand. Its highest incidence is seen in postmenopausal women and it rises with age. Low energy fall on the wrist joint with wrist in extension is the most common mechanism of injury in elderly people (Table 2.7). In young adults, this is usually a high energy fracture due to road traffic accidents.

Surgical Anatomy (Figs. 2.56A to C)

- **Radial length (RL):** Radial styloid process is about 1 cm distal to the styloid process of ulna (except in supination when the radial and ulnar processes come at same level). This is measured on the PA radiograph as the distance between two lines perpendicular to the long axis of the radius. One line passes through the distal tip of the radial styloid and one line passes through the most distal point on the articular surface of ulnar head. On an average it is 11 mm.
- Normally distal end of radius has a Palmar or a Volar tilt (On lateral view of wrist, angle between longitudinal axis of radius and a line tangential to the slope of the dorsal-to-volar surface of the radius) of 11° and radial inclination (RI) (On PA view of wrist, angle between a line drawn perpendicular to long axis of radius and a line drawn from the tip of radial styloid process to ulnar corner of distal end of radius) of 22° .

- **Ulnar variance (UV):** It is the shortest distance between two lines both of which are perpendicular to the long axis of radius. One line is drawn tangential to most distal point of articular surface of ulna and one line is drawn tangential to medial corner of articular surface of radius. Normal ulnar variance is negative (ulnar articular surface is proximal to that of radius). A positive ulnar variance means ulna projects more distally than radius.

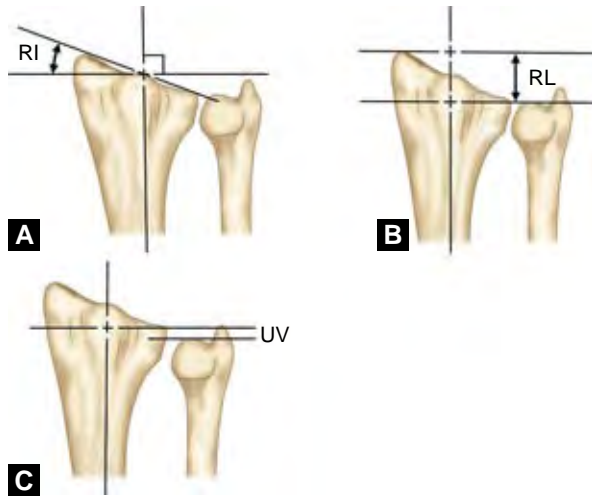
Eponyms for Distal Radius Fractures

Many eponyms have been used to describe different types of distal end of radius fractures:

- **Colles' fracture:** This is the most common subtype. It is a fracture of distal end of radius at the corticocancellous (metaphysis-diaphyseal) junction with dorso-lateral displacement of the distal fragment.
 - **X-ray features:** AP and lateral views of wrist joint shows transverse fracture of radius at corticocancellous junction. Typical displacements of distal fragment in Colles' fracture are supination, impaction into proximal fragment, dorsal tilt and displacement and lateral tilt and displacement producing typical dinner fork deformity (Figs. 2.57A to C).
- **Smith's fracture (Reverse Colles' fracture, Figs. 2.58A and B):** It is caused by fall on the dorsal of hand (flexed hand). It is similar to Colles' fracture except that the distal fragment is displaced anteriorly (volar/ventral displacement and tilt) producing garden spade deformity.
- **Barton fracture (Figs. 2.59A and B):** Fracture dislocation of volar rim (Volar Barton) or Dorsal rim (Dorsal

Table 2.7: Differences in distal end radius fracture in elderly and young adults

	<i>Mechanism of injury</i>	<i>Geometry of fracture</i>	<i>Sex distribution</i>
Elderly people	Simple fall on extended wrist	Usually extraarticular	Much more common in elderly females
Young adults	High energy road traffic accident or sport	High incidence of intraarticular fracture	Equal sex distribution

**Figs. 2.56A to C:** Surgical anatomy of wrist joint.**Figs. 2.57A to C:** (A and B) X-ray of wrist joint AP and lateral views showing—Colles' fracture; (C) Lateral view resemblance the dinner fork, hence the name "dinner fork deformity".**Figs. 2.58A and B:** (A) X-ray lateral views of wrist showing Smith fracture and (B) typical resemblance with garden spade.**Figs. 2.59A and B:** (A) X-rays of wrist joint AP and lateral views showing volar Barton fracture and (B) fixation with buttress plate.

Barton) of radius in which rim of distal radius and carpus are displaced together. Volar Barton is more common than Dorsal Barton fracture.

- *Chauffeur's fracture* (Fig. 2.60): Isolated fracture of radial styloid process.
- *Di punch fracture* (Fig. 2.61): It is a comminuted impacted fracture of distal end of radius resulting in depression fracture of lunate fossa of distal radius.

Clinical Presentation and Diagnosis

Patients usually elderly, present with pain, swelling and obvious deformity of wrist joint. An AP and lateral X-ray

views of the wrist confirms the diagnosis. The most common associated fracture visible in most X-rays is a fracture of the ulnar styloid process.

Treatment

Colles' fracture is mostly managed conservatively by closed reduction and below elbow POP cast application. Reduction is done under hematoma block, axillary block or IV sedation.

One assistant holds the arm and one assistant holds the fingers to give the longitudinal traction across fracture (to disimpact the fracture) with elbow flexed to 90°.



Fig. 2.60: X-ray of the wrist joint AP view showing fracture of radial styloid process (Chauffeur's fracture).

Reduction is achieved by direct pressure on the displaced fragment. Cast is traditionally applied in palmar flexion and ulnar deviation (hand shaking pattern) and pronation to counteract the displacements (Figs. 2.62A to D). Excessive palmar flexion should be avoided. Many studies have shown no benefit of palmar flexion compared to neutral position. Recently there have been increasing trends towards immobilizing the Colles' fracture in neutral position. An unstable fracture where closed reduction is being difficult to maintain with cast can also be fixed percutaneously with multiple K-wires. (Figs. 2.63A and B).

In Smith fracture after disimpaction of distal fragment by longitudinal traction as in Colles' fracture reduction is achieved by full supination and dorsiflexion of wrist. Traditionally cast is given for 6 weeks in distal end radius fracture. Patient is encouraged to move his fingers, elbow and shoulder while in cast.

Operative indications for distal radius fracture: Operative intervention is mainly required for displaced intra articular distal end radius fractures (Barton or Chauffeur) and they can be managed with open reduction and internal fixation with special buttress plates (see Fig. 2.59B). At times the articular surface is impacted (as in Die punch fractures), where one needs to bone graft the distal radius to elevate the depressed fragment. External fixation has a role in management of highly comminuted fractures difficult to manage with plate fixation. External fixator is applied in distraction across radiocarpal joint or fracture (Figs. 2.64A to C). It works on the concept of ligamentotaxis (surrounding capsule and ligaments are stretched and indirectly reduce the fracture fragments).

Complications

Early

- **Tear of Triangular fibrocartilage complex (TFCC):** TFCC is a group of ligamentous structures attached at the styloid process of ulna. These injuries are seen in up to 40–70% intraarticular fractures of distal end radius. In

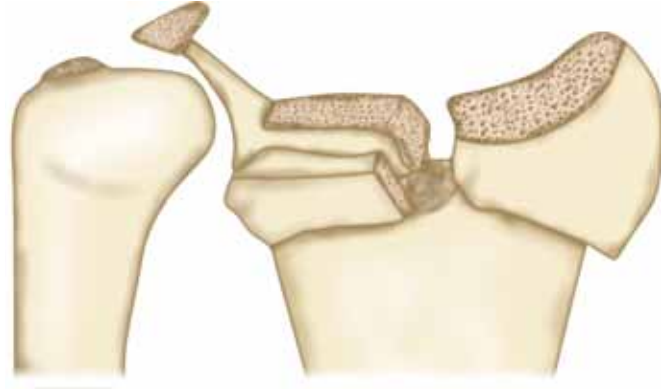


Fig. 2.61: Schematic representation of a die punch fracture of distal end of radius.

most cases there is an evident fracture of ulnar styloid process. Repair may be required when these injuries are associated with distal radioulnar joint instability.

- **Complex regional pain syndrome (CRPS):** Earlier this was known as reflex sympathetic dystrophy or Sudeck's dystrophy or Casalgia. It is a chronic pain syndrome usually involving one of the limbs and may follow a bony or soft tissue injury or a nerve injury. The etiopathogenesis is not completely understood but is thought to be an imbalance between the sympathetic and parasympathetic systems. Mild signs and symptoms of CRPS are seen in approximate 40% of fracture and surgical trauma patients. However incidence of chronic and severe CRPS is less than 2%. Diagnosis is made primarily on clinical ground.

Diagnostic Criteria

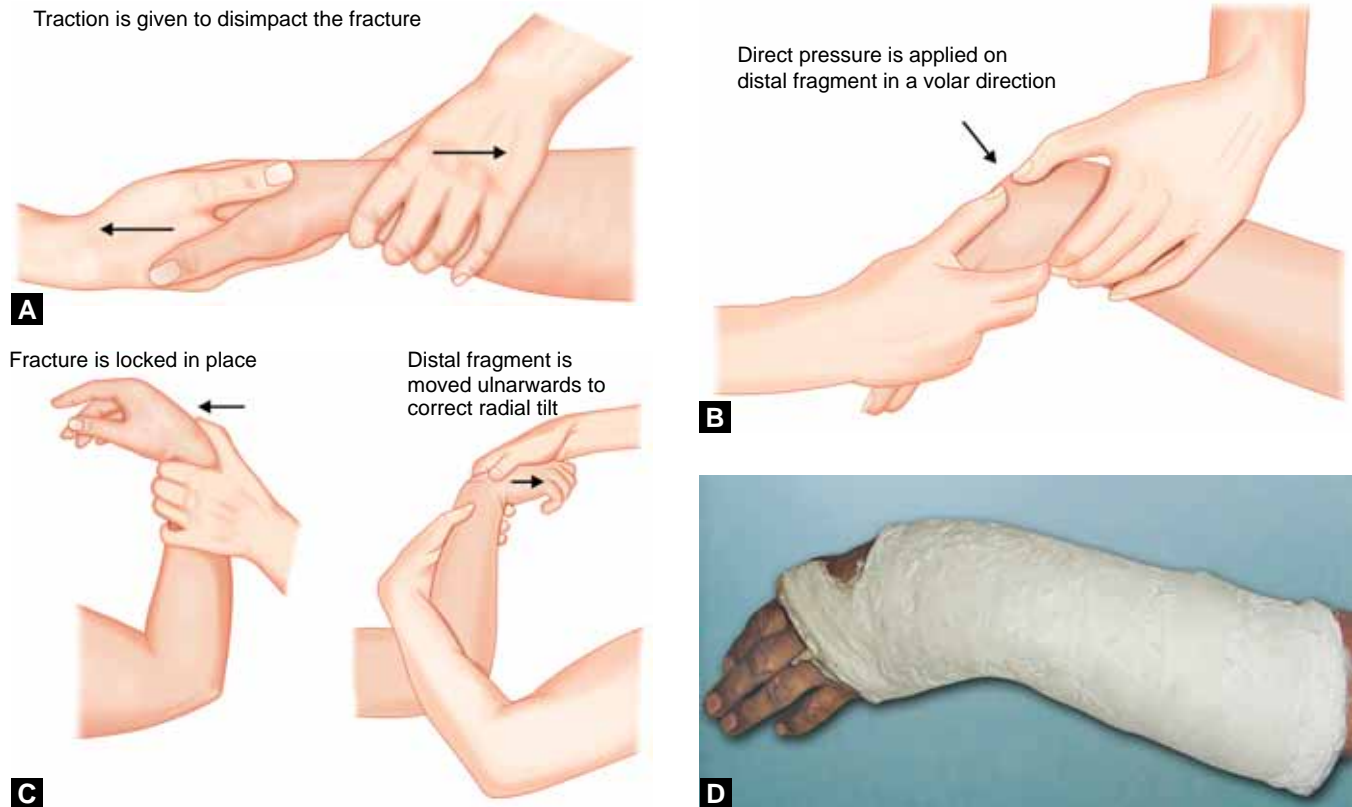
- Presence of an inciting event
- Pain disproportionate to this event
- Presence of signs and symptoms of autonomic imbalance like swelling, edema, vasomotor symptoms trophic changes etc.
- Exclusion of all other possible causes.

Complex regional pain syndrome when associated with nerve damage it is known as CRPS type 2 otherwise it is classified as CRPS type 1.

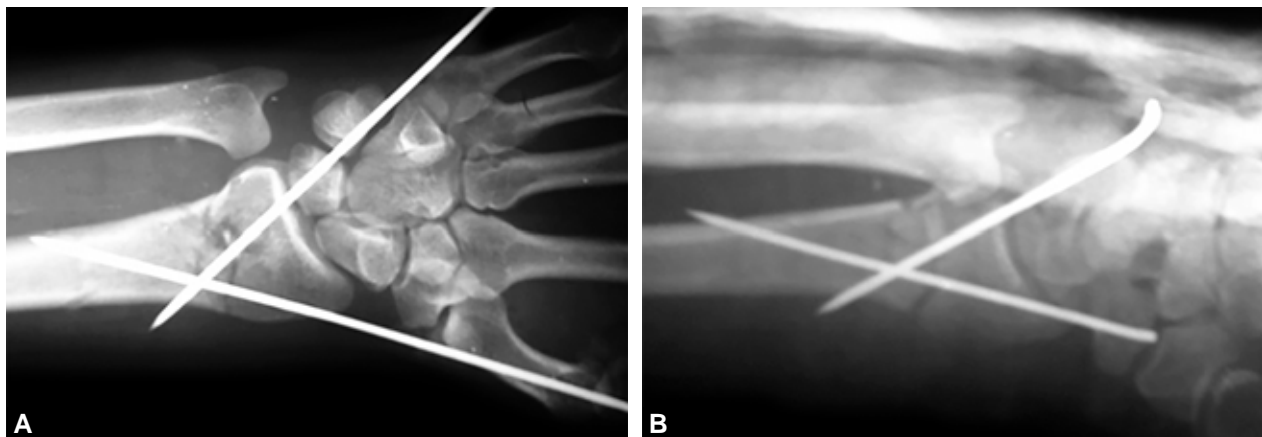
Clinical Features

Early phase: It usually begins weeks after inciting event. Hands and feet are most commonly involved body parts. Patient usually presents with burning pain or with pins and needle sensation of involved limb, edema and vasomotor symptoms. Initially limb is dry, hot and pink and later turns into blue, cold and sweaty. Patient may have temperature and sweating abnormality (altered sensitivity to temperature, excessive sweating, etc.).

Late phase: It is characterized by trophic changes like thinning of skin, fragile hairs, brittle nails and in severe cases muscle contractures causing decreased movement of involved limbs.



Figs. 2.62A to D: Colles' fracture reduction: (A) traction is given to disimpact the fracture (B) direct pressure on the distal fragment to reduce it (C) fracture is locked by palmar flexion and ulnar deviation (D) Colles' cast.



Figs. 2.63A and B: X-ray wrist joint AP and lateral views showing percutaneous K wire fixation of unstable distal end radius fracture.

Radiological features: In the early stage increased uptake is seen in bone scan. After 2–3 months X-rays of involved limb show patchy osteoporosis.

Treatment: Patients with CRPS require functional rehabilitation. Doctor should assure the patient and psychological counseling may be an important part of treatment. Majority of patients get relief by multidisciplinary approach treatment with analgesics, vitamin C, desensitization techniques and guided physiotherapy. A combination of NSAIDs and a centrally acting analgesic like amitriptyline may be given together for excellent analgesia. Desensitization techniques have been used to normalize sensation

of the involved limb. Sympatholytic drugs, nerve blocks, and surgical sympathectomy have also been used with variable success. Immobilization of limb should be avoided.

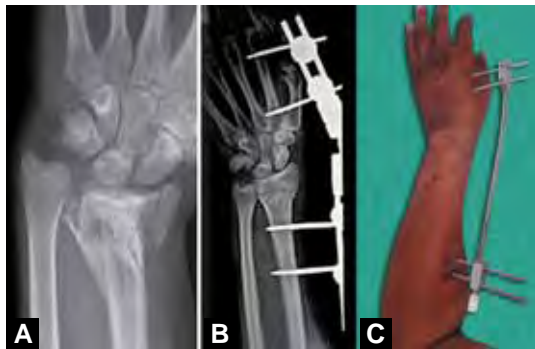
Late Complications

- **Stiffness:** Stiffness of wrist and fingers is most common complication of distal end radius fracture. Shoulder and elbow stiffness may follow if patient does not actively use them after plaster immobilization of wrist joint. Active physiotherapy should be encouraged to prevent stiffness.

- **Malunion:** Malunion is the second commonest complication. It is particularly common following nonoperative treatment of distal radius fracture. Cosmetically it results in the classical Dinner fork deformity (Fig. 2.57C). Loss of palmar tilt and radial inclination may cause loss of grip strength and pain in distal radioulnar joint (DRUJ). Loss of rotational movement may occur with dorsal angulation. Corrective osteotomy may be required for symptomatic malunion with persistent DRUJ or midcarpal pain or weakness of grip.
- **Tendon injury:** Although rare but extensor tendon injury especially of extensor pollicis longus may occur at the time of fracture or later due to friction on callus or malunited fracture. More often it is seen after 2–3 months of fracture. Treatment is by tendon transfer.

HIGH-YIELD POINTS

- Edema or swelling is most consistent sign of CRPS. Localized osteopenia (patchy osteoporosis) is characteristic X-ray finding.



Figs. 2.64A to C: (A) X-ray AP view of wrist joint showing comminuted fracture distal end of radius (B) fixation of same fracture by application of external fixator in distraction mode (ligamentotaxis) and (C) clinical picture of use of external fixator for wrist fracture.

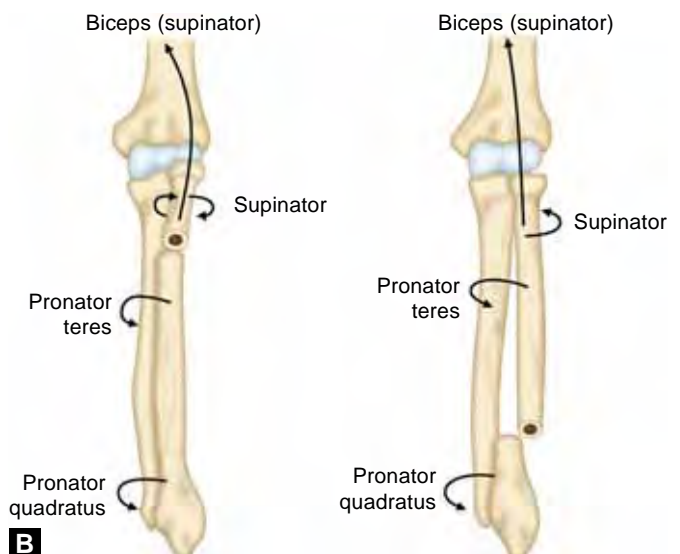
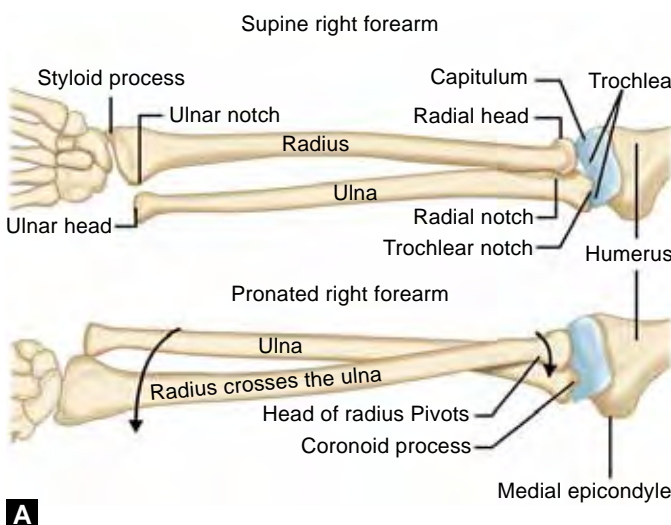
- Although Distal end radius fracture is the most common cause of CRPS in upper limb the most common complication of DER fractures is stiffness followed by malunion.
- Most important deformity to be corrected in Colles fracture is radial length (impaction).

FRACTURE OF FOREARM BONES

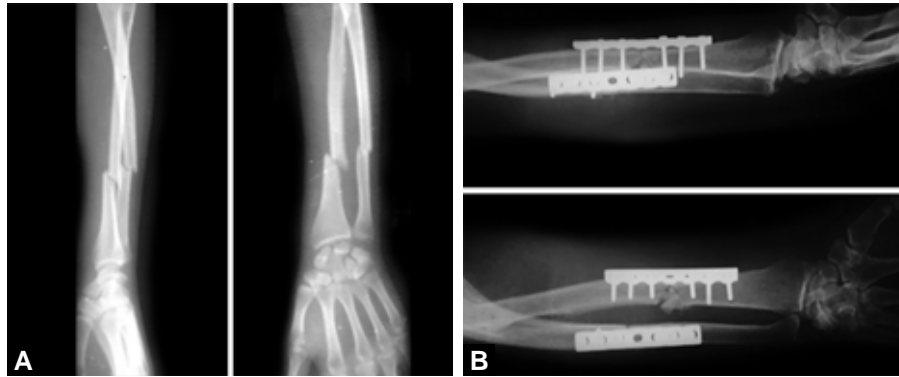
Fracture of radius and ulna is a common diagnosis in orthopedic emergency. These are common in adults and are the commonest fractures found among children. The radius and ulna function as a unit and often fracture together. Most common mechanism of injury is fall on outstretched hand. This usually causes spiral fracture. A direct blow (direct hit by lathi or stick) on forearm causes transverse fracture of forearm bones.

Surgical anatomy (Figs. 2.65A and B): Radius and ulna are attached to each other at proximal and distal radioulnar joints and at mid-portion by interosseous membrane. Supination and pronation take place at radioulnar joints. In supination radius rotates around the ulna. Radius has an apex lateral proximal curve and an apex medial distal curve. Ulna is relatively straight with apex posterior curve. In children deformity of these curves may occur without fracture (plastic deformity) and restoration of these curvatures is essential for optimal functioning of forearm.

Biceps brachii and supinator are supinators of the forearm and tend to supinate (external rotation, towards radius) the proximal fracture fragment of radius. Pronators of forearm (Pronator teres and quadratus) tend to pronate (internal rotation, towards ulna) the distal two-thirds of radius. Likewise in midshaft radius fracture proximal fracture fragment supinate due to strong supinators (Biceps and supinator) and distal fragment pronates due to strong pronator (Pronator quadratus).



Figs. 2.65A and B: (A) Anatomy of forearm bones, see the curvature of radius; (B) Muscle forces displacing forearm fractures.



Figs. 2.66A and B: (A) X-ray forearm AP and lateral views showing fracture both bone forearm and (B) its fixation with compression plating.

Direction of these muscle forces (Fig. 2.65B) is rational behind the position of forearm in cast after close reduction. Fractures of proximal third of radius are immobilized with the forearm in supination, mid-third fracture in mid-prone position and fractures of distal third of radius are immobilized with the forearm in pronation.

Clinical Features

Patients present with pain and swelling of forearm. In displaced fractures, crepitus and obvious deformity may be present. In children plastic deformation (bone bends without fracture) and green stick fractures are common and obvious signs of fractures may not be present. All patients with forearm fractures should be thoroughly assessed for neurovascular injuries. Diagnosis is easily confirmed on X-ray AP and lateral views of forearm (Figs. 2.66A and B).

Treatment

In children forearm fractures are mostly managed with close reduction and above elbow cast immobilization. Operative intervention (compression plating or flexible intramedullary nailing) is required in irreducible fractures and where acceptable reduction cannot be maintained. Other indications of operative intervention are open fractures, vascular injury and compartment syndrome.

Close reduction technique: One assistant pulls the hand and other assistant gives countertraction by grasping the distal arm with elbow flexed to 90°. Angulation and displacements are corrected by traction and any remaining deformity is corrected by direct pressure on the displaced fracture fragment (*see the X-ray and plan your reduction method that where will you need to apply pressure and in which direction?*). Reduction can be confirmed in image intensifier and immobilize in above elbow cast. While applying cast interosseous space must be maintained by proper molding of cast.

In adults an attempt may be given at closed reduction and plaster immobilization but the same is difficult to achieve as reducing two bones simultaneously and maintaining reduction is very difficult. So mostly in adults

these fractures need open reduction. Open reduction and internal fixation with compression plating (Fig. 2.66B) is standard treatment of adult forearm fractures.

Complications

Early

Neurovascular injury: Nerve injury in forearm fractures is almost always iatrogenic (damaged during surgery by surgeon). Posterior interosseous nerve is at risk in proximal radius fractures. Injury to radial artery may occur by displaced fracture fragment or during ORIF of radius fracture. However due to presence of excellent collateral circulation, vascular injury to single forearm artery seldom causes any problem.

Compartment syndrome: Always keep an eye on the circulatory status of forearm. Diagnosis should always be made on clinical ground of tense swelling and pain on passive stretching.

Late

Malunion: Inadequate reduction, loss of reduction or failure to maintain interosseous space in cast may lead to angulation and rotational deformity. Rotational movements (supination and pronation) are worst affected in malunion. In severe functional deformity corrective osteotomy may be required.

Delayed and nonunion: Delayed union of one bone (usually ulna) is not uncommon. Immobilization may need to be extended in delayed union. Nonunion of one or both bone may occur. Inadequate reduction, insufficient immobilization and open fracture are more likely to end up with nonunion. Treatment of established nonunion is bone grafting and internal fixation.

Cross-union: A cross union of the two bones may occur if fracture happens at same level. An open fracture and a concomitant head injury (increased release of growth factors) in the patient further increases the risk of this complication. It limits rotational movements and may require surgery to break the bony bridge between both bones.

MONTEGGIA FRACTURE DISLOCATION

It comprises of fracture of proximal third ulna with radial head dislocation (proximal radioulnar joint dislocation). This is more common in children and relatively rare in adults.

Mechanism of Injury and Classification

Monteggia fractures are classified by Bado classification into four types based on the direction of the displacement of the radial head, type I being the commonest. Although all these are caused by a fall on outstretched hand, the exact mechanism varies with the fracture type (Table 2.8). Monteggia equivalents have also been described by Bado and some other authors for these fractures. Most common equivalents are fractures of the ulnar shaft with fracture of radial proximal epiphysis or radial neck and anterior dislocation of radial head (Figs. 2.67A and B).

Clinical Features

Patient presents with pain and swelling of forearm. There is obvious deformity of elbow. Radial head may be palpated at abnormal location. Elbow flexion, extension and rotational movements are painfully restricted. A thorough neurovascular examination should be done in all patients. Posterior interosseous nerve is most commonly involved nerve by Monteggia fracture. Diagnosis is confirmed by X-rays. In X-ray radial head should be carefully evaluated, if fracture of ulnar shaft is seen. Normally in all degrees of flexion and extension a line passing through longitudinal axis of radial head should pass through center of capitellum (Fig. 2.68).

Treatment

Closed reduction and casting in Monteggia fractures is primarily reserved for pediatric population. Anatomical relationship of head of radius and capitellum should be achieved in all cases by concentric reduction of radial head.

Hence in adults open reduction and internal fixation with plate and screws has become a standard practice. ORIF of ulna usually reduces radial head. If radial head does not come in place after ORIF of ulna than open reduction of radial head should also be done.

Complications

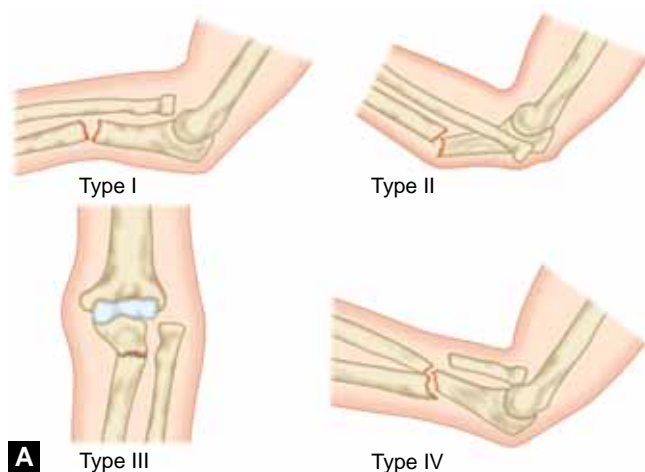
- Stiffness may result from immobilization or myositis ossification. Early and active physiotherapy may restore range of motion after immobilization. Massage and aggressive passive exercises should be discouraged as it may provoke formation of myositis mass.
- Malunion is common in conservatively treated Monteggia fractures. Restoration of ulnar length and concentric reduction of radial head should be done in all cases. In malunited cases elbow flexion and rotational movements are restricted. Osteotomy of ulna with or without radial head excision may be required.
- Posterior interosseous nerve is the most commonly injured nerve, most commonly being involved in Type II and III fractures. Fortunately in most cases it is neurapraxia only and function returns within 3 months. If no recovery is seen by 3 months and electromyography and nerve conduction tests show no signs of innervation nerve should be explored.
- *Compartment syndrome and Volkmann's ischemic contracture*: This may occur following any forearm fracture. Diagnosis should be made on clinical ground. Urgent fasciotomy is the treatment of choice for established compartment syndrome.

GALEAZZI FRACTURE DISLOCATION (PIEDMONT'S FRACTURE)

A Galeazzi fracture refers to a fracture of the radial diaphysis at the junction of the middle and distal thirds with associated disruption of the distal radioulnar joint (Figs. 2.69A and B). This is an unstable fracture and usually caused by fall on outstretched hand. It is almost three times more common than Monteggia fracture dislocation.

Table 2.8: Bado classification of Monteggia fracture

Bado Type	Mechanism of injury	Description
Type I	Forced pronation of the forearm	Anterior dislocation of the radial head with fracture of ulnar diaphysis at any level with anterior angulation
Type II (most common type)	Axial loading of the forearm with a flexed elbow	Posterior dislocation of the radial head with fracture of ulnar diaphysis with posterior angulation
Type III	Forced abduction of the elbow	Lateral dislocation of the radial head with fracture of ulnar metaphysis
Type IV	Type I mechanism in which the radial shaft additionally fails	Anterior dislocation of the radial head with fractures of both radius and ulna within proximal third at the same level
Monteggia equivalents	(i) Isolated radial head dislocation (ii) A proximal ulnar fracture with fracture of radial neck (iii) Fracture of proximal third both bone forearm with radial fracture being more proximal (iv) An ulno-humeral dislocation	



Figs. 2.67A and B: (A) Bado classification of Monteggia fracture (Type I to IV), (B) X-ray forearm AP and lateral views showing Bado Type I of Monteggia fracture.

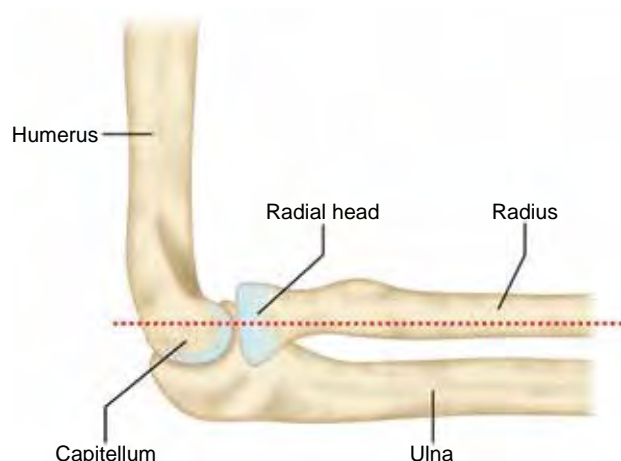


Fig. 2.68: Anatomical relationship of head of radius and capitellum (radiocapitellar line) (see text).

Clinical Features

Patient presents with pain, tenderness, crepitus and deformity of forearm. Instability of DRUJ should be suspected in all patients with fracture of distal one-third of radius. Fracture of ulnar styloid process with large fracture fragment, difficulty in reduction and widening at the distal radioulnar junction in anteroposterior X-ray with or without balloting of distal ulnar end are indicative of unstable DRUJ that is a common association with this fracture. Diagnosis is confirmed on AP and lateral X-rays of forearm.

Treatment

In children these fractures can be treated by close reduction and above elbow cast application. Irreducible fractures in children and Galeazzi fracture in adults must be treated by open reduction and internal fixation with compression plating. Since this fracture always requires

open reduction and internal fixation it is also called as Fracture of Necessity. During fixation it is imperative to ensure adequate reduction of DRUJ and restoration of radial length.

Complications

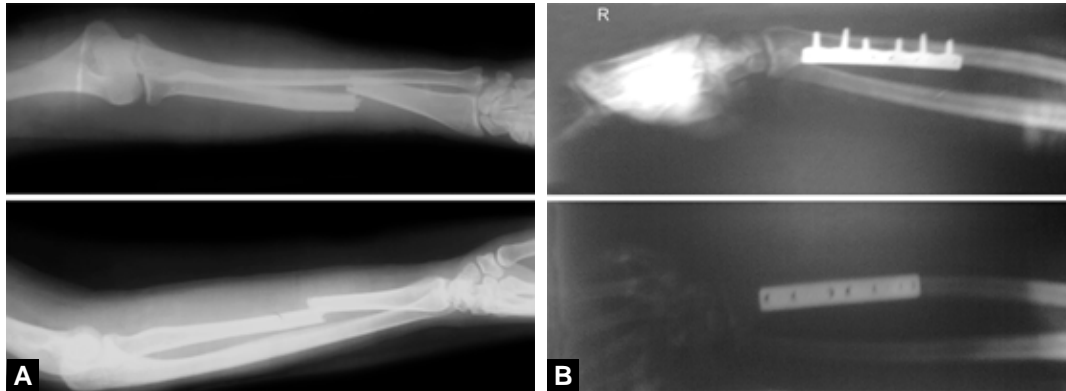
Malunion, nonunion and instability of the DRUJ are the usual complications.

ESSEX-LOPRESTI FRACTURE

It is fracture of radial head with splitting of interosseous membrane and distal radioulnar joint dislocation. This is also an unstable fracture and requires ORIF of radial head with small headless Herbert screw or a radial head replacement to maintain the length of radius. If in this fracture the radial head is excised, the radius will migrate proximally into the elbow restricting movements at that joint.

HIGH-YIELD POINTS

- Monteggia first described the ulnar fracture in 1814 but the term was coined by Bado in 1967.
- *Night stick fracture*: It is isolated fracture of shaft of ulna that occurs in an attempt to resist a lathi blow to the forearm.
- A traumatic dislocation of radial head is mostly anterior but Congenital dislocations of radial head are often bilateral and posterior. In X-ray radial head is seen enlarged and elliptical due to lack of modulation by capitellum. Capitellum may also be seen flattened.
- *Piano key sign*: Ballotting (up and down movement as in pressing a piano key) of distal ulnar end can be demonstrated in instability of DRUJ. It is seen in Galeazzi fracture dislocation, Madelung deformity of distal end radius and TFCC injury.



Figs. 2.69A and B: (A) X-ray of forearm AP and lateral views showing Galeazzi fracture dislocation; (B) ORIF with compression plating of same fracture.



Fig. 2.70: Carpal bones of hand. (S: Scaphoid; L: Lunate; Tq: Triquetrum; P: Pisiform; Tp: Trapezium; Tz: Trapezoid; C: Capitate; H: Hamate).

- In irreducible Galeazzi fractures entrapment of extensor carpi ulnaris tendon is a common cause and may require open reduction by a small separate incision at wrist.
- *Reverse Galeazzi Fracture:* This is a fracture of the distal ulna with associated disruption of the distal radioulnar joint.

CARPAL FRACTURES

There are two rows of eight carpal bones in hand (Fig. 2.70). First row consists of scaphoid, lunate and triquetrum and pisiform. Pisiform is sesamoid bone in the sheath of FCU tendon. Distal row is made up of trapezium, trapezoid, capitate and hamate. These carpal bones are kept in place by many intrinsic ligaments (interconnecting carpal bones) and extrinsic ligaments (connecting carpal bones to radius, ulna and metacarpals).

Scaphoid Fracture (Figs. 2.71A and B)

This is the most common carpal bone fracture. Scaphoid fracture is the most common fracture in young adults and adolescents with history of fall on outstretched hand and is rare in children.



Figs. 2.71A and B: (A) X-ray of hand AP view showing scaphoid fracture (arrow) and (B) scaphoid nonunion (in a different patient) following fracture (encircled).

Surgical Anatomy

Scaphoid bone consists of tubercle, waist and proximal pole (Fig. 2.72). In adults fracture of waist followed by proximal pole is most common and in children distal pole fracture is the commonest. Scaphoid bone receives most of its blood supply from a single important blood vessel (branch of radial artery) that enters the scaphoid from distal pole and travels proximally across the waist to supply the proximal pole (Fig. 2.72). Thus vascularity of scaphoid bone reduces proximally (retrograde blood flow). Due to this precarious blood supply fracture of waist of scaphoid can lead to avascular necrosis (AVN) of the proximal pole of scaphoid.

Mechanism of Injury

It is usually a hyperextension injury caused by forced extreme dorsiflexion of hand following fall on outstretched hand.

Clinical Features

Patient presents with wrist pain and swelling after acute fracture. Usually there is no obvious deformity. Tenderness

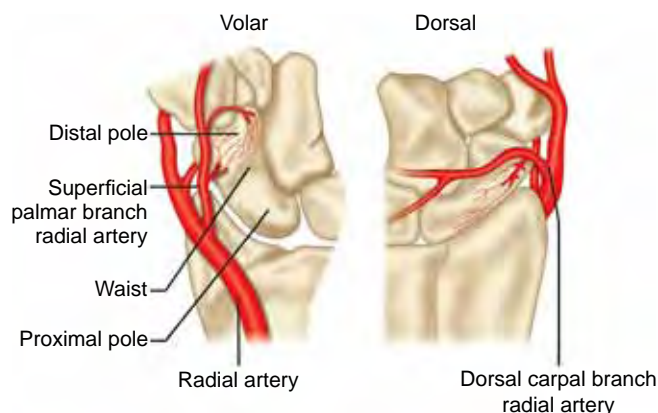


Fig. 2.72: Blood supply of scaphoid bone.

in anatomical snuff box is sensitive test for scaphoid fracture. Pain with axial compression of thumb, tenderness at scaphoid tubercle and painful thumb movement are other signs used for diagnosis of scaphoid fracture. Diagnosis can be confirmed by AP, 45° oblique and ulnar-deviated AP X-rays of hand. Undisplaced scaphoid fractures are often not visible on the initial X-rays. Therefore X-rays should be repeated after 10–14 days if fracture is suspected, by this time resorption occurs around the fracture ends and the fracture may become better defined. Magnetic resonance imaging (MRI) is the most sensitive and specific investigation to detect scaphoid fracture.

Treatment

Undisplaced scaphoid fractures are managed conservatively by cast immobilization. Scaphoid cast is given from below elbow to just short of the metacarpophalangeal joints and also includes the proximal phalanx of thumb. Wrist is held in dorsiflexion and slight radial deviation and thumb forwards in the glass holding position. Cast should be given until fracture unites which usually takes 6–12 weeks. In displaced scaphoid fractures percutaneous/open reduction and fixation with special headless screws (Herbert screw) is required. However, an important thing to remember is that since this fracture is often not visible in fresh X-rays, one has to apply the scaphoid cast if at all there is tenderness in the anatomical snuff box.

Complications

- **Nonunion:** It is seen in approximately 10% of cases and is more common in displaced and unstable fractures. Factors associated with nonunion are fracture displacement greater than 1 mm, AVN and proximal pole fracture. If no radiological evidence of union is seen after 3 months of treatment diagnosis of nonunion can be considered. X-ray features of nonunion of scaphoid fracture are subchondral sclerosis and resorption at fracture site. Treatment of established nonunion is bone grafting (Matte Russe technique) and screw fixation. In unstable nonunion cystic changes, sclerosis and bony erosions lead to collapse of bone fragments

and deformity. In Russe bone graft technique cortico-cancellous bone graft is wedged between fracture fragments and compression screw is inserted.

- **Avascular necrosis:** It is a late and common complication of scaphoid fracture although slightly less common than non-union. It is mostly seen in proximal pole fractures and least in tuberosity fractures due to its precarious and retrograde blood supply. Over 80% of the scaphoid surface is covered with articular cartilage and 70–80% of blood supply comes from the dorsal scaphoid branches entering along the dorsal ridge. This tenuous blood supply makes the scaphoid prone to AVN following fracture. Patient presents with increasing wrist pain and stiffness. X-ray shows sclerosis of fracture fragment, cystic changes, bone collapse and deformity. MRI is the investigation of choice in a suspected case of AVN. This is a difficult condition to treat. Treatment options include vascularized bone grafting or excision of dead bone and carpal fusion.
- **Osteoarthritis:** It is a late complication of scaphoid fracture. Secondary osteoarthritis of wrist joint may occur following nonunion and AVN.

Fractures of Other Carpal Bones

Triquetrum followed by trapezium is most commonly fractured carpal bone after scaphoid (The order in decreasing frequency of incidence is Scaphoid, Triquetrum, Trapezium, Lunate, Capitate, Hamate, Pisiform and Trapezoid). Fracture of other carpal bones like pisiform, trapezium, lunate, trapezoid, capitate and hamate are rare. Mostly these are avulsion injuries and treated by cast immobilization for 2–3 weeks. In displaced fractures ORIF or excision may be required.

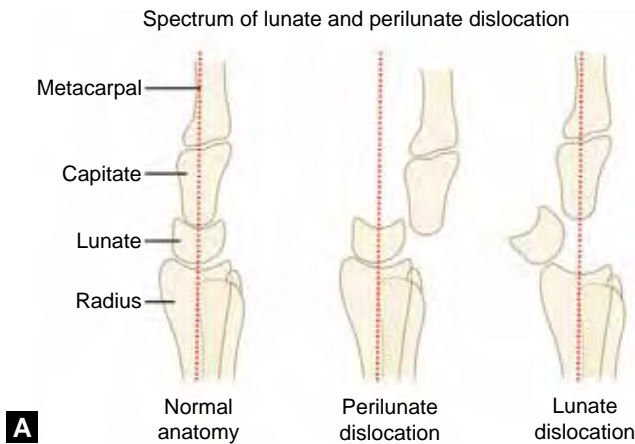
Lunate and Perilunate Dislocations

Common dislocations at wrist joints are lunate and perilunate dislocation. In Lunate dislocation the lunate dislocates out of the carpus while in Perilunate dislocation the lunate stays in its place while all other carpal bones dislocate out of the carpus. In other words, In lunate dislocation long axis of radius passes through the capitate and in perilunate dislocation long axis of radius passes through the lunate (Fig. 2.73A). Perilunate dislocation is the most common of all wrist dislocations (Fig. 2.73B).

X-ray of perilunate dislocation shows discontinuity of Gilula's arc (Fig. 2.74). In lateral view of lunate dislocation, lunate is seen palmarly rotated and no longer articulates with capitate (Spilled teapot sign).

Treatment

In reducible perilunate dislocation close reduction and percutaneous pinning is recommended. Close reduction is achieved by Tavernier maneuver. For irreducible perilunate dislocations open reduction and repair is required.



Figs. 2.73A and B: (A) Diagrammatic presentation of lunate and perilunate dislocation and (B) X wrist lateral view showing perilunate dislocation.



Fig. 2.74: Gilula's arcs.

HIGH-YIELD POINTS

- The most common nerve injured in perilunate dislocation as well as in fracture of lunate is the Median nerve.
- Trans-scaphoid perilunate dislocations is the term used when there is a perilunate dislocation in association with a fracture of scaphoid.
- Terry Thomas sign: This is a radiological sign seen in AP X-ray of wrist when the scapho-lunate ligament is ruptured. In such cases an abnormally wide gap (> 3 mm) can be seen between the scaphoid and lunate (named after British comic character Terry Thomas who had gap in between his central incisor teeth).
- *Space of Poirier*: This is an area of wrist capsule lying between the distal portion of radiocapitate and ulnocapitate ligaments. This is a weak spot in the floor of carpal tunnel and Lunate displaces through this space into carpal tunnel.
- *Gilula's lines*: These are three incomplete semicircles which outline the proximal and distal surfaces

of proximal row carpal bones and proximal surface of distal row carpal bones (Fig. 2.74). These semicircles are broken in carpal fracture dislocations and ligamentous instability.

- 45° semisupinated oblique AP view is best view for proximal pole fracture of scaphoid.
- Bones with retrograde blood flow (blood supply reduces from distal to proximal)—Scaphoid, talus and head of femur. AVN is common in fracture of these bones.
- Magnetic resonance imaging scan is the investigation of choice for occult scaphoid and other carpal fracture.
- Preiser disease is atraumatic AVN of scaphoid. Kienbock disease is idiopathic AVN of lunate bone.
- Just like the shoulder and knee, instability can also occur at wrist. Out of various types Rotatory subluxation of scaphoid is the most common form of carpal instability.
- *Carpal tunnel view*: This X-ray view is used to diagnose hook of hamate fracture.

METACARPAL FRACTURES

There are five metacarpals in the hand consisting of head, neck, shaft and base. Metacarpal bone fractures are common fractures and account for 40–50% of all hand injuries. Neck is the most common site of metacarpal fracture and fifth metacarpal is most commonly involved. Metacarpal fractures are usually caused by direct blow to hand, axial or torsional loading. Direct blow usually causes transverse fracture whereas axial and torsional loading cause oblique or spiral fractures respectively.

Pathoanatomy

Metacarpals are slender bones with slight dorsal convexity. Shaft of metacarpals gives origin to three palmar interosseous and four dorsal interosseous muscles. These muscle forces often pull the fracture fragment and



Figs. 2.75A and B: Safe (intrinsic plus or functional) position of hand for immobilization.

cause apex dorsal deformity and shortening. Hand is immobilized in intrinsic plus position or functional or safe or Jame's position (Figs. 2.75A and B) with MCP joint in 70–90° flexion, IP joint in full extension, thumb in abduction and wrist in slight extension. In this position IP joint volar plate and MCP joint collaterals are taut thus preventing shortening and flexion contracture.

Clinical Features

Patients present with pain, swelling and usually apex dorsal angular deformity of hand. Injury to dorsal aspect of hand is often associated with open wound and damage to extensor tendons.

Treatment

Metacarpal head fractures are intraarticular fractures which often require ORIF with headless screws or K wires. Metacarpal neck and shaft fractures are usually amenable to close reduction and cast immobilization for 3 weeks in functional position of hand. Few degree of angulation (up to 30–40°) is acceptable. Rotational malalignment is least tolerable. Unstable fractures like spiral fractures require close reduction and K wire fixation or open reduction and compression plating. Metacarpal base fractures are usually stable injuries (except for first metacarpal base fracture) and can be managed well with cast immobilization. Displaced intraarticular base fracture may require close reduction and percutaneous pinning.

Fractures of Base of First Metacarpal

Fracture of base of first metacarpal may be extraarticular (transverse or oblique fracture) or intraarticular Bennett's fracture—dislocation or Rolando's fracture-dislocation.

Extraarticular Fractures (Figs. 2.76A)

Extraarticular fractures are usually caused by low energy axial force or a bending or torsion of thumb. Patients

present with pain and swelling at base of thumb and painful thumb movements. These are treated by close reduction and thumb spica immobilization for 3 weeks. Angulation up to 30° is acceptable. In unstable fractures closed reduction and percutaneous K wiring may be required.

Intraarticular Fractures

Bennett's fracture-dislocation: This is an oblique intra-articular fracture of base of first metacarpal, a kind of carpo-metacarpal fracture dislocation (Figs. 2.76A and B) in which distal diaphyseal fragment is displaced laterally, proximally and dorsally by combined pull of abductor pollicis longus (primarily) and adductor pollicis (Fig. 2.77). It is most common of all fractures of base of thumb.

Mechanism of Injury: Carpometacarpal (CMC) fracture dislocations are usually high energy injuries. These are caused by axial force to the partially flexed and adducted thumb as in while punching with clenched fist.

Patient presents with pain and swelling at base of thumb. Thumb movements are painful. Diagnosis is confirmed by anteroposterior and oblique X-rays (Hyperpronated thumb view or Roberts' view best shows this fracture) of hand which show the oblique fracture line with triangular fracture fragment.

Treatment: Small avulsion fractures can be managed by closed reduction and if reduction is stable, thumb spica immobilization for 6 weeks. Mostly these fractures are unstable injuries and require close or open reduction, K wire fixation and cast immobilization in a thumb spica for 4–6 weeks.

Complications: Post-traumatic osteoarthritis of first CMC joint is a long-term complication due to intraarticular nature of fracture.

Rolando fracture dislocation: This is an intraarticular three part fracture (V or Y or T-shaped fracture) of the base of first metacarpal (Figs. 2.76A and B) caused by axial loading of thumb which crushes the base of first metacarpal. Base is split into triangular volar and dorsal fragments. Deforming forces are same as in Bennett's fracture dislocation



Figs. 2.76A and B: Bennett's fracture dislocation, Rolando fracture dislocation and extraarticular fracture of base of thumb; (B) X-ray hand oblique view showing Rolando fracture (arrow).

Courtesy: Dr Rajat Kumar Garg

(Fig. 2.77) but diaphyseal fragment is usually not displaced. Volar or palmar oblique ligament prevents displacement of volar fragment. Close or open reduction and K wire or plate fixation is often required for these fractures.

Finger Carpometacarpal (CMC) Joint Fracture-Dislocations

Fifth metacarpal and hamate is the most commonly injured finger CMC joint as it is the most mobile of these joints (most commonly involved CMC joint is of thumb). Treatment is usually close reduction and cast immobilization.

Boxer's Fracture (Figs. 2.78A and B)

It is transverse or short oblique fracture neck of fifth metacarpal. It is the most common metacarpal fracture and commonly occurs in young people while punching with clenched fist. Anteroposterior and lateral X-rays of hand shows apex dorsal angulation of fracture. It can be treated by close reduction and cast immobilization or K wire fixation.

PHALANGEAL FRACTURES AND DISLOCATIONS

Phalangeal fractures and dislocations are most common hand injuries and fracture of distal phalanx is the most commonly fractured bone in hand. These injuries are usually caused by direct blow or axial loading and often associated with open wound. Phalangeal diaphyseal fractures can be transverse, oblique, spiral or multifragmentary.

Thumb followed by fifth finger MCP joints are most commonly dislocated MCP joints. Proximal interphalangeal joint dislocations are more common than distal IP joint dislocation.

Treatment

Most of the phalangeal fractures are stable undisplaced or minimally displaced fractures and can be managed by

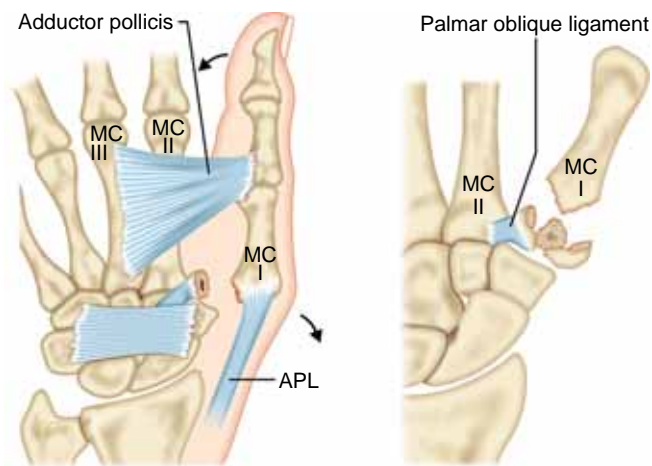


Fig. 2.77: Deforming forces in Bennett and Rolando fracture are caused by abductor pollicis longus and adductor pollicis.

strapping to neighbouring finger (Buddy strapping, Fig. 2.79) for 2–3 weeks. Finger physiotherapy should be started after 2–3 weeks to prevent stiffness. Unstable fractures and intraarticular fractures of base or head require close reduction and K wire or small screw fixation. Close reduction and splinting is usually successful for most metacarpophalangeal joint and interphalangeal joint dislocations. After close reduction finger is buddy strapped and active range of motion physiotherapy is started soon.

Tuft Fracture

Ungual tuberosity of distal phalanx is called tuft. Tuft fracture is usually the crush injury of tip of fingers (shattered by hammer or caught in door). Fracture management is of secondary importance and soft tissues (pulp and matrix) should be taken care of first. Hematoma beneath nail is drained and nail bed repaired. Nail may be removed or reinserted depending on the amount of injury and finger is splinted.

Mallet Finger or Baseball Finger Injury

Mallet finger injury is the disruption of extensor tendon (Extensor digitorum communis) insertion at the base of



Figs. 2.78A and B: X-ray hand (A) AP and (B) oblique view showing Boxer's fracture (arrow).



Fig. 2.79: Buddy strapping for phalangeal fracture.

distal phalanx and consequent inability of active extension of distal phalanx. It is the most common closed tendon injury in athletes. Terminal extensor tendon inserts at the base of distal phalanx so three types of mallet finger injuries are possible.

1. The rupture of the extensor tendon
2. Avulsion of the extensor tendon at its insertion
3. Avulsion fracture of dorsal base of the distal phalanx (Fig. 2.80A).

Mechanism of Injury

Axial loading and sudden violent flexion of distal phalanx is the usual cause of injury. This occurs when fingertip violently strikes to a hard object.

Treatment

Simple avulsion with or without small bony piece are treated by extension splitting (Fig. 2.80B) for 8 weeks. Extension block pinning with K wires may be required if bony avulsion constitutes more than one-third of articular surface.

Jersey Finger

Disruption of FDP tendon from its insertion at palmar aspect of distal phalanx is called jersey finger. It is usually caused by sudden and violent hyperextension of a forcefully flexing finger. This mechanism is common in contact sports and ring finger is most commonly involved finger. Patient presents pain and swelling of palmar aspect of distal finger with inability to actively flex the DIP joint. Treatment is essentially surgical repair of flexor tendon in all cases.

Complications of Hand Injuries

Stiffness is most common complication of hand fractures. It is especially common after intraarticular fractures of head of metacarpals. Hand should be splinted in functional position as described above (see Figs. 2.75A and B) and early range of motion physiotherapy should be started to prevent it. Malunion of metacarpal fractures usually produce apex dorsal deformity. Corrective osteotomy is required if it produces unacceptable cosmetic or functional deformity. Another common complication is hypersensitivity due to injury to small cutaneous nerves either due to injury or due to surgery. Post-traumatic arthritis is a delayed complication of intraarticular fractures of head or base of metacarpals.

HIGH-YIELD POINTS

- Brewerton view is used to see metacarpal head fractures and Roberts view is used for thumb CMC joint.
- *Boxer's knuckle:* It is caused by injury to metacarpophalangeal joints (knuckles) of hand, leading to disruption of sagittal band and dislocation of extensor tendon. Middle finger and radial sagittal band are most commonly involved.
- *Kaplan injury:* It is irreducible dorsal dislocation of finger (most commonly index finger). Volar plate gets interposed between base of proximal phalanx and metacarpal head. It requires surgical reduction. Presence of sesamoid bone in metacarpophalangeal joint is pathognomic of Kaplan injury.

TENDON INJURIES OF HAND

Relevant Anatomy

Tendons attach the muscle to bone and serve to transmit the muscle force to bone thus helping joint movement.

Flexors of Wrist and Hand

Flexor carpi radialis and FCU are wrist flexors. There are two flexor tendons (flexor digitorum superficialis and profundus) to each finger. FDS flexes the PIP joint and FDP primarily flexes the DIP joint and assist FDS in flexing the PIP joint. Flexor pollicis longus flexes the IP joint of thumb and flexor pollicis brevis flexes the MCP joint of thumb.

Zones and Pulleys (Figs. 2.81A and B)

The hand is divided into five zones (Table 2.9) containing flexor tendons and several pulleys. There are five annular (A1 to A5) and three cruciate (C1 to C3) pulleys in each finger. Thumb has two annular (A1 and A2) and one oblique pulley. These are condensed fibrous tissues tunnels through which pass the flexor tendons, thus they help in proper tracking of tendons. A1 pulley is most commonly involved in trigger finger and A2 and A4 pulleys are

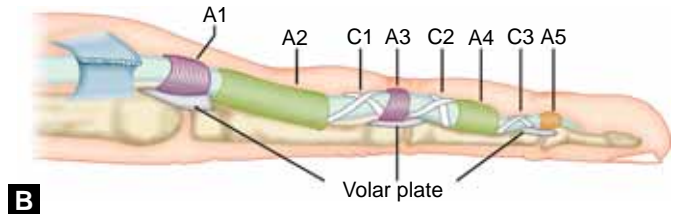
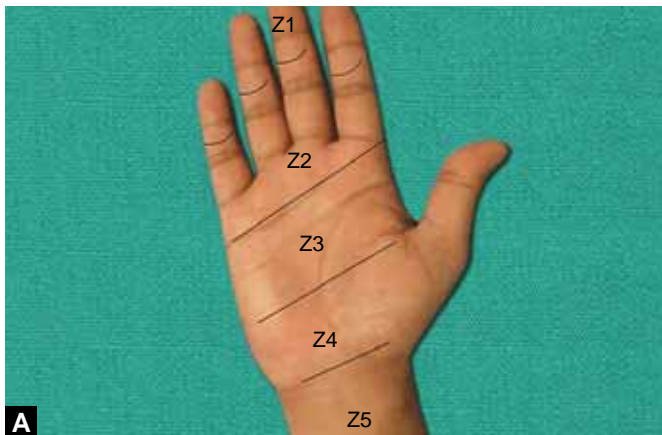
biomechanically most important pulleys, absence of which causes bowstringing of flexor tendons. A1, A3 and A5 pulleys are attached to palmar plate at MP, PIP and DIP joint respectively.

Flexor Tendon Injuries

Flexor tendon injuries of hand are common due to their vulnerable anatomical position (Fig. 2.82). They are usually cut by lacerating injuries or crush injury of hand. If patient presents with these injuries of hand a systemic examination of all flexor tendons should be done. To test the FDS patient is asked to actively flex the PIP joint, but FDP also causes the flexion of PIP joint so to remove the effect of FDP all adjacent fingers are held with all joints in extension (Fig. 2.83). Since all FDPs are interlinked, blocking all fingers blocks all FDPs and the flexion of fingers at PIP joint is now by the action of FDS. FDP is checked by stabilizing the PIP joint and asking the patient to actively flex the DIP joint of finger to be tested. Flexor pollicis longus is checked by ability to actively flex the IP joint of thumb. FCR and FCU are wrist flexors. If FCR is cut then wrist will deviate towards ulna while active flexion is being performed and if FCU is cut then wrist will deviate towards radius while active flexion of wrist is being done.



Figs. 2.80A and B: (A) X-ray of finger showing avulsion fracture of dorsal base of the distal phalanx (encircled) and (B) Extension splitting for mallet finger.



Figs. 2.81A and B: (A) Zones of hand and (B) Pulleys of hand.

Table 2.9: Zones of flexor tendon in hand

Zone 1	Distal to the flexor digitorum superficialis insertion at base of middle phalanx.
Zone 2 (no man's land)	Between insertion of FDS and proximal margin of flexor tendon sheath.
Zone 3	Between proximal margin of flexor tendon sheath and distal edge of carpal tunnel.
Zone 4	Carpal tunnel.
Zone 5	Forearm proximal to carpal tunnel.

**Fig. 2.82:** Tendon injuries of hand are common occupational hazard.**Fig. 2.83:** Clinical examination for flexor digitorum superficialis (FDS).

Extensor Tendon Injuries

Extensor tendons are grouped in six compartments (Figs. 2.84A and B) at wrist. The extensor digitorum communis, extensor indicis proprius and extensor digiti minimi insert at the base of the middle phalanges as central slips and to the base of the distal phalanges as lateral slips. Long extensors of fingers are primarily responsible for MCP joint extension. Lumbricals and interossei are main extensors of IP joints.

Dorsum of hand is divided into eight zones according to extensor tendon injuries. Extensor tendon injuries are more common than flexor tendon injuries. Because of their location on back of hand they are easily injured even by a minor cut. Extensor tendon of middle finger is most commonly injured. Zone IV (Disruption over the metacarpals) is most commonly injured area.

Treatment

Partially torn tendons can be treated by immobilization in extension splitting. Completely torn tendons require operative repair. In acute cases with clean wound primary end to end repair can be done. In contaminated and dirty wound initial thorough debridement is done and tendon repair is delayed until good wound healing (secondary repair) CR and percutaneous pinning or extensor block pinning may be required for bony avulsion. In crush injury of hand often primary repair is not possible and tendon graft from other tendons is used. Palmaris longus is commonly used graft in hand injuries. In chronic rupture cases reconstruction is often not possible and then less

needed tendon can be transferred to more useful positions. Postoperative adhesions and finger stiffness are common complications of tendon repair. In general worst outcome of flexor tendon repair is seen in zone II (dangerous area or no man's land) because both FDS and FDP run together in common sheath.

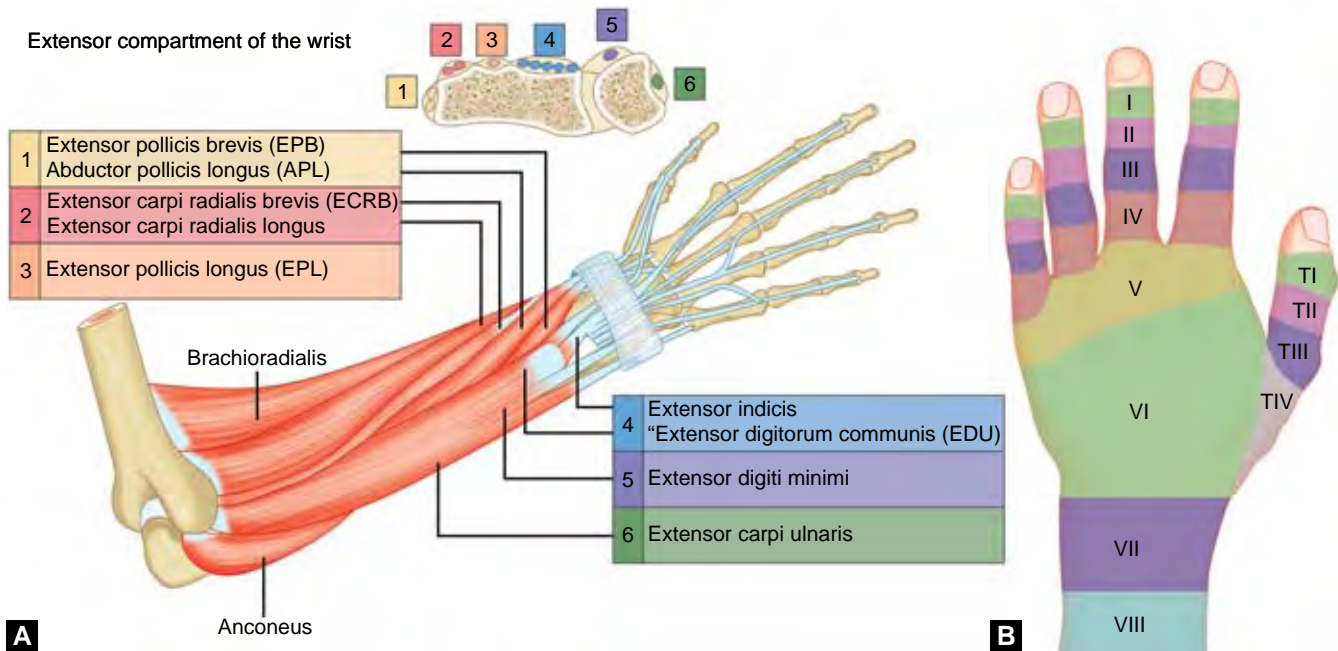
CRUSH INJURY OF HAND

These are common patients in orthopedic emergency and are usually victims of occupational hazards like machines injury, road traffic accidents, animal bites or having the hand caught between two heavy objects. Optimal hand function is necessary for good quality of life especially if dominant hand is affected.

Evaluation of Crush Injury of Hand in Emergency Department

Evaluation of the crushed hand should start from the vascular examination and proceed to assess soft tissue coverage, bone, nerves and tendons. Make sure that radial pulse is intact and check for capillary refill and active bleeding. Any catastrophic bleeding should be immediately stopped by tight compression bandage. Absence of pulses, tense swollen hand and severe pain on passive movement all indicate towards tense compartment and need for an urgent fasciotomy.

Look at the soft tissue coverage of bone and tendons, skin condition and any foreign material and contamination. Hand fractures and dislocations may be quite obvious



Figs. 2.84A and B: (A) Extensor tendons at wrist are divided in 6 groups; (B) Zones of extensor tendons at dorsum of hand.

or may be masked in a swollen hand. Sensation (light touch, pinprick) and motor examination should be done. While doing radial nerve (wrist extension), ulnar nerve (finger IP joint extension, finger abduction/adduction) and median nerve (thumb opposition) examination lacerations of muscles and tendons should be kept in mind. Patient may not be able to move fingers with lacerated muscles and tendons. After splinting the injured limb patient should be sent for X-rays.

Management and Decision Making

Management of crushed limb may require staged surgery. In initial surgery thorough debridement with removal of all contamination and necrotic tissues should be done. In first surgery good debridement, stabilization of fracture and dislocation and an intact vascularity should be goal. Soft tissue coverage may need use of skin graft or flap.

Apart from thumb amputations, the loss of a single digit does not cause significant disability. If adequate soft tissue coverage is possible nerve and tendon repair or grafting can be done. Alternatively, this may be delayed until good wound healing. In badly crushed hands repair or grafting may not be possible, then reconstruction using tendon transfers or arthrodesis may be required later.

HIGH-YIELD POINT

- *Sequence of repair in acute crush injury of hand:* Here the first step is to reduce and fix the fractures. Tendons and nerves should be repaired primarily if conditions permit otherwise delayed repair is done. Adequate soft tissue coverage is the greatest priority. Arterial injury is generally not a problem because

single artery (radial or ulnar) is sufficient to provide adequate blood supply to hand in most cases (Palmar arch receives contribution from both radial and ulnar artery). So, here first to be fixed is the fracture but greatest priority is skin closure.

REIMPLANTATION OF A TRANSACTED DIGIT (OR A LIMB)

A transacted limb means that the limb has separated completely from the rest of the body. With modern anti-sepsis methods and advanced technology it is possible to re-implant some vital body parts provided some criteria are met. Because irreversible necrotic changes begin in muscles after 6 hours of ischemia (warm ischemia time), it is preferable to begin the replantation of parts with good muscular bulk (viz. parts proximal to palms and foot) within this time. With cooling (to 4°C), this time may be extended to 12 hours (cold ischemia time). For parts with less muscle bulk (viz. digits), the allowable warm ischemia time may be 8 hours or more while the cold ischemia time may be as long as 30 hours. If the ischemia time is crossed, re-implantation is not advisable (especially of muscle rich parts) as there is a risk of revascularization injury that can end up in renal damage resulting from myoglobinuria, acidosis and hyperkalemia resulting from metabolites released in significant amounts from necrotic muscles.

Transportation of amputated part: The transacted part is first rinsed gently with sterile saline or ringer lactate to remove excess contamination. Then the part is wrapped with sterile gauze, then soaked in sterile ringer lactate or saline and placed in a plastic bag which is then sealed. The bag is placed on ice in an insulated container so that the

part is not touching the ice to avoid freezing of the part. Cooling of the amputated part to about 4°C is imperative to prolong the viability of the transacted part.

Sequence of repair in re-implantation of digit or limb: Pneumonic “BE FAN of Virender Sehwaag” is an easy way

to remember the order of repair—Bone, Extensor tendons, Flexor tendons, Artery, Nerve, Vein and lastly Skin closure. So, fractures and dislocations should be dealt with first but, meticulous vascular repair is given the greatest priority to save the re-im-planted digit or limb.

FRACTURES OF PELVIS AND ACETABULUM

RELEVANT ANATOMY

Two innominate bones (each formed by fusion of 3 ossification centers- ilium, ischium and pubis) and sacrum constitutes the pelvis. Both hip bones are attached anteriorly by pubic symphysis and posteriorly they articulate with sacrum at the sacroiliac joint (SI joint) to form the Pelvic ring. Both hip bones and sacrum are stabilized by a number of ligaments. Posterior ligaments are stronger than anterior ligaments. These ligaments include sacroiliac ligaments (anterior, posterior and interosseous), sacrospinous ligaments, sacrotuberous ligaments and iliolumbar ligament. Anteriorly pelvic ring is stabilized by relatively weak symphyseal ligaments.

Pelvic Inlet and Outlet (Figs. 2.85 and 2.86)

Pelvic inlet or brim is formed anteriorly by pubic crest and symphysis, posteriorly by sacral promontory and ala of sacrum, and on sides by the iliopectineal lines. Below this is the true or lesser pelvis that contains the pelvic viscera and above this is the false or greater pelvis that represents the inferior aspect of the abdominal cavity. Pelvic outlet is formed by anteriorly by pubic arch, laterally by ischial tuberosities, posterolaterally by sacrotuberous ligaments and posteriorly by coccyx.

Pelvis provides a room and protects pelvic viscera and traversing neurovascular structure. Bladder, urethra and vagina are important structure just behind the pubic symphysis whereas rectum is important structure just anterior and in relation to sacrum. Sciatic nerve, superior gluteal nerve and artery, inferior gluteal nerve and artery and internal pudendal nerve and artery pass through the greater

sciatic foramen to exit pelvis. Obturator nerve and artery traverse through the obturator foramen to exit the pelvis.

PELVIC INJURIES

These range from low energy osteoporotic fractures in elderly to high energy life-threatening pelvic ring injuries in young adults which occur usually in RTA. High energy pelvic injuries are frequently associated with retroperitoneal and intraperitoneal visceral and vascular injuries. Early death in pelvic injuries is due to heavy blood loss (1.5–2 litres or 4–8 units on an average) and concomitant head injuries. Later sepsis and multiorgan failure is the main cause of patient loss.

Vascular and Visceral Injuries

In most of the cases pelvic hemorrhage pools into retroperitoneal space from venous damage (presacral and paravesical venous plexus) and bleeding from fractured bone. Damage to branches of internal iliac arteries may also occur and superior gluteal arteries and internal pudendal artery are most commonly damaged. Polytrauma patients who receive pelvic injuries are also likely to have other associated injuries. Chest injuries, fracture of long bones, head injuries and injury to bladder and urethra are common in multiple injured patients who sustain pelvic trauma.

Classification (Tables 2.10 and 2.11)

Pelvic injuries can be stable or unstable. A stable injury is one which can withstand normal physiological forces

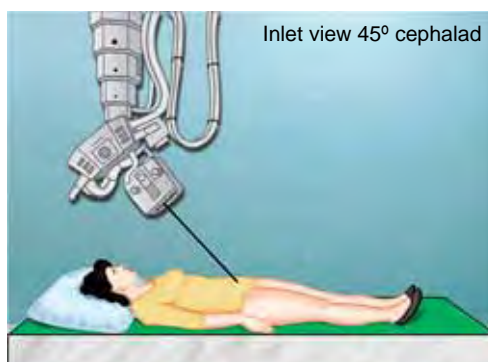


Fig. 2.85: Pelvic inlet view.



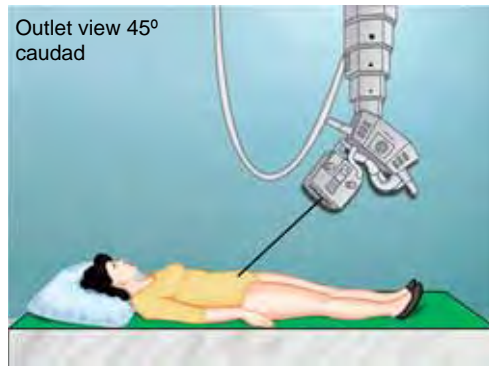


Fig. 2.86: Pelvic outlet view.

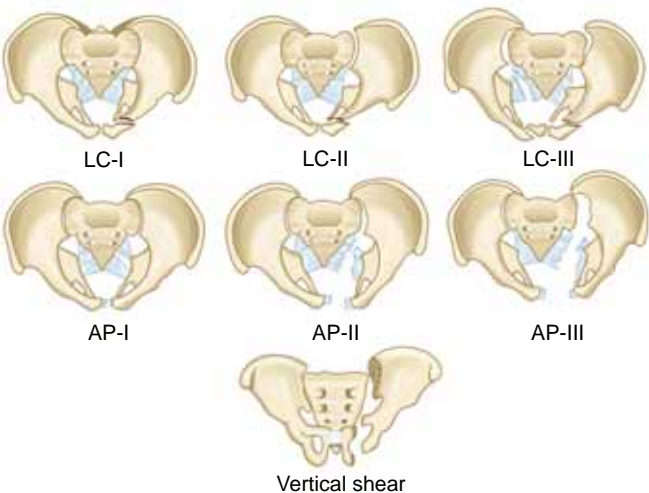


Fig. 2.87: Young and Burgess classification.

without any further deformation while an unstable injury would displace on a rotational or vertical force. Two classification systems are commonly used to classify these pelvic fractures. Young and Burgess classification (Fig. 2.87 and Table 2.10) is based on the mechanism of injury (direction of force) of pelvic fracture. Tile's classification system (Table 2.11 and Fig. 2.88) is based on rotational and vertical stability of the pelvis. Type A are mainly avulsion fractures where either the pelvic ring disruption is not there or is minimal and stable. Type B and C are ring disruption injuries. Type B fractures occur either in antero-posterior compression of pelvis (open book injuries) or side to side compression of pelvis (bucket handle fractures). Both are rotationally unstable injuries but are vertically stable due to largely intact strong posterior ligamentous structures. Type C injuries involve massive displacements and disruption of all ligamentous restraints thereby displaying both rotational and vertical instability.

Initial Assessment and Management (Flowchart 2.4)

Pelvic bone fracture is often a miniscule part of major traumatic burden. Attending orthopedic surgeon should

Table 2.10: Young and Burgess classification of pelvic fractures

Type I	Lateral compression (LC)	<ul style="list-style-type: none"> LC I—Pubic rami fracture plus sacral ala fracture on side of impact LC II—Crescent fracture on side of impact LC III—LC I or LC II on side of impact with contralateral open book injury.
Type II	Anteroposterior compression (APC)	<ul style="list-style-type: none"> APC I—Slight opening of pubic symphysis and SI joint anteriorly APC II—Anterior opening of SI joint with intact posterior SI ligaments APC III—complete disruption of SI joint
Type III	Vertical shear (VS)	<ul style="list-style-type: none"> Symphyseal diastasis with vertical displacement of hemipelvis
Type IV	Combined injury mechanism	Combination of two or more above-mentioned forces leading to complex fracture pattern

Table 2.11: Tile classification of pelvic fractures

Type	Subtypes
A: Stable pelvic ring	A1—Fracture not involving the ring (Avulsion fracture, crest fracture, etc.) A2—Stable fractures of pelvic ring.
B: Pelvic ring vertically stable but rotationally unstable	B1—Open book type B2—Lateral compression, ipsilateral B3—Lateral compression, contralateral or bucket handle type injury
C: Pelvic ring rotationally and vertically unstable	C1—Unilateral C2—Bilateral C3—Associated with acetabular fracture

assess the pelvic trauma patient on the guidelines of ATLS. Proper attention should be paid to ABCs of trauma assessment and rapid management of airway, breathing and unstable hemodynamic status and disability (neurological assessment) is lifesaving (see chapter on management of

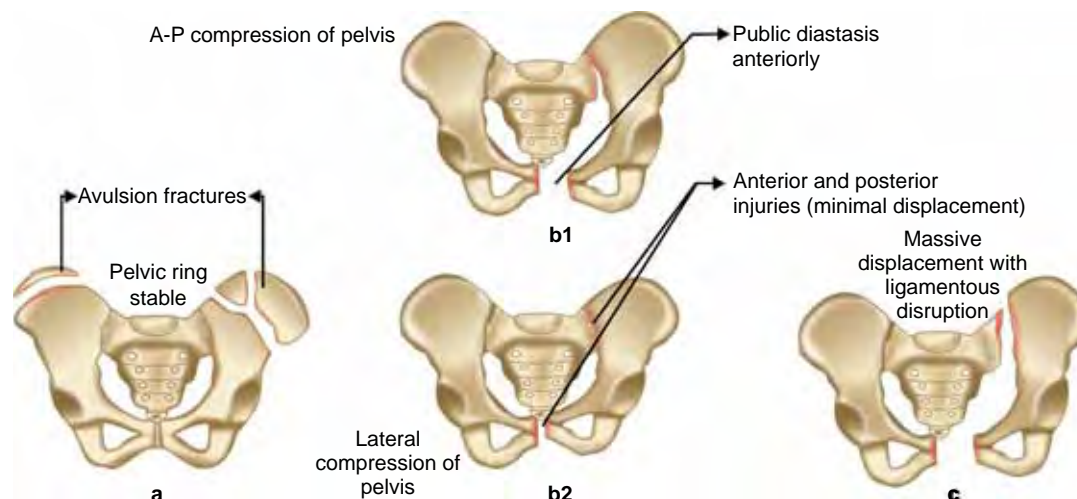
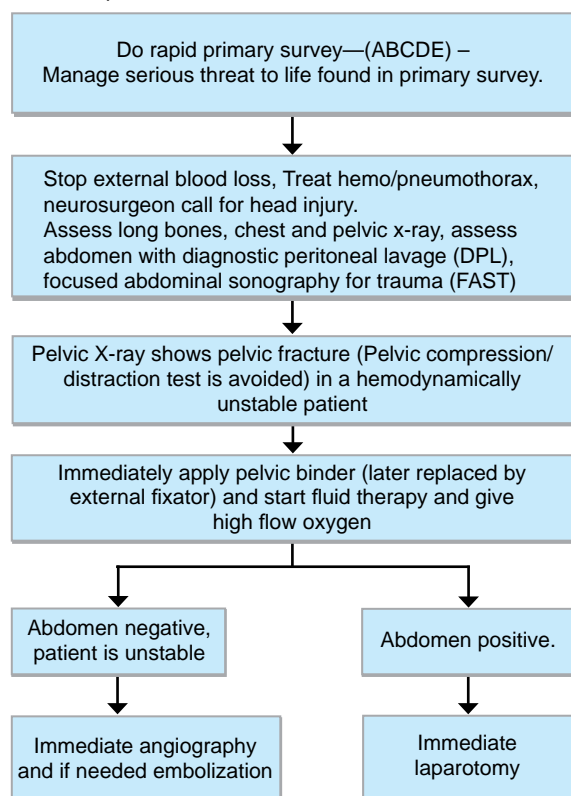


Fig. 2.88: Tile's classification of pelvic injuries.

Flowchart 2.4: Management of the hemodynamically unstable patient with a pelvic fracture.



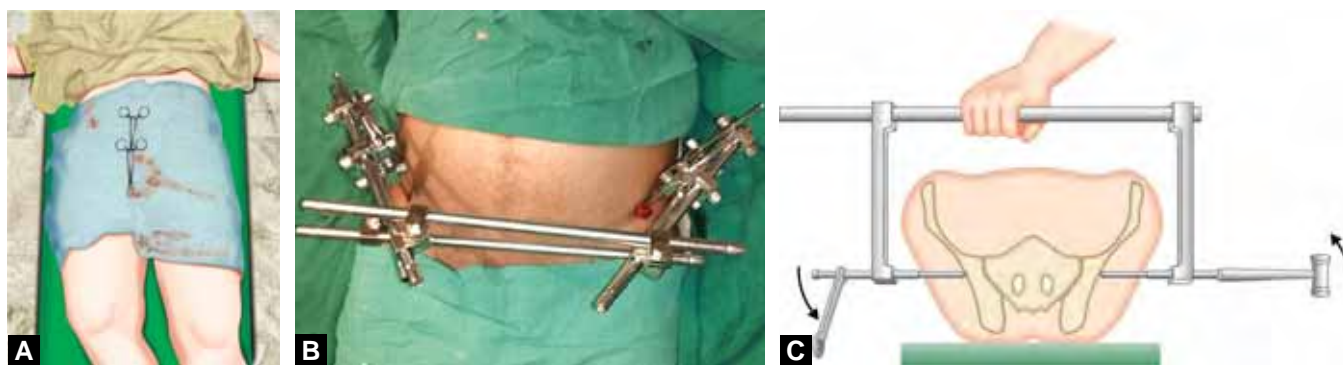
polytrauma). A rapid assessment of presence of an unstable pelvic fracture can clinically be made by compressing the pelvis from side to side (pelvic compression and distraction test). A crepitus or a springy feeling if elicited provides the clue to presence of an underlying unstable pelvic injury. However this test should not be done as it does not give reliable information; rather the maneuver may dislodge the clot and cause a retroperitoneal hemorrhage further worsening the shock. Not uncommon in vertical shear injuries is to find a limb length discrepancy.

In a hemodynamically unstable pelvic trauma patient with high-grade pelvic injury (LC III, APCIII, VS or combined) shock is likely due to pelvic hemorrhage. In these patients pelvic hemorrhage can be controlled with use of noninvasive methods like pelvic binders/sheath wrapped tight around pelvis (Fig. 2.89A) or military antishock trousers—MAST (inflatable trousers for exsanguinating pelvic blood) or invasive methods (Fig. 2.89B) like external fixators (anterior external fixator for anterior pelvic injury/open book fracture and pelvic C clamp for posterior pelvic ring injury, Figure 2.89C), preperitoneal pelvic packing and angiographic embolization. Generally the first step in emergency is to tie a pelvic binder and replace it at earliest with a more effective external fixator applied in compression mode.

Once patient is hemodynamically stable thorough physical and radiological examination should be done. Presence of blood at meatus or inability to void in pelvic injury patient indicates urethral (10% incidence) or bladder injury (20% incidence). On suspicion these injuries should be dealt with in consultation with urologist. Generally intra peritoneal ruptures of the bladder are repaired while the extra peritoneal ruptures can be observed. Urethral injuries can be attempted a delayed repair. In case there is blood at meatus, a single gentle catheterization attempt may be taken but if difficult a supra pubic cystostomy should rather be opted. Abdominal palpation and rectal examination should be done. Rectal examination can identify high lying prostate suggesting urethral injury.

Definitive Treatment of Pelvic Fractures

Pelvic fracture is dealt with after stabilization of patient. Pelvic anteroposterior inlet and outlet views and CT scan are helpful in better identification of pelvic fractures. Inlet view is better to demonstrate anterior-posterior displacement while an outlet view is better to demonstrate a vertical displacement. Goal of treatment should be identification



Figs. 2.89A to C: (A) Pelvic sheath application for unstable pelvic fracture with suspected pelvic hemorrhage; (B) Anterior external fixator application for unstable pelvic fractures; (C) Pelvic C clamp for posterior stabilization of pelvis.

of instability and its management to prevent long-term functional impairment. Intraoperative stress radiographs and CT scan are useful in assessment of instability.

Nonoperative Treatment

The most common type of pelvic fractures are rami fractures (due to lateral compression injuries) and are stable. These Lateral impaction injuries with minimal displacement and pubic rami fractures with no posterior displacement (LC I and APC I) are treated conservatively with protected weight bearing. Walker or crutches are used for early mobilization. Open book fractures (Tile type B1) with pubic symphysis opening less than 2.5 cm respond well to conservative treatment.

Operative Treatment

Unstable injuries mostly need operative fixation. LC II fracture requires open reduction and internal fixation of ilium. APC II or open book type fracture with opening more than 2.5 cm requires open reduction and anterior symphyseal plate fixation or external fixator application. Both fixation methods give good results.

High-grade injuries LC III and APC III are difficult fractures to treat. Posterior ring integrity is important in transferring load to lower limbs. APC III fractures require anterior stabilization with plate or external fixator and posterior stabilization with SI joint screw or plate. LC III injuries are also unstable and require posterior stabilization with SI joint screw or plate.

Complications

Injury to urethra and bladder, sexual dysfunction, thromboembolism (deep vein thrombosis and pulmonary embolism) and sciatic nerve injury are commonly encountered problems. Prophylactic anticoagulation may be warranted in high-risk trauma patients with unstable pelvic injury requiring surgical fixation. Sexual dysfunction is common in men after pelvic injury. Disruption of the pubic symphysis is frequently associated with temporary erectile



Fig. 2.90: X-ray pelvis with both hips AP view showing straddle injury.

dysfunction. Urethral injuries may lead to strictures, incontinence and impotence. Urologist consultation is required for the management of these injuries. Sciatic nerve injury is usually neurapraxia and recovers within few weeks.

HIGH-YIELD POINTS

Learn the terminology of pelvic fractures

- *Straddle injury* (Fig. 2.90): Bilateral fracture of both superior and inferior pubic rami.
- *Duvernoy fracture*: Iliac wing fracture.
- *Malgaigne fracture* (Fig. 2.91): Unstable pelvic fracture which comprises of two vertically-oriented fractures in one hemipelvis.
- *Bucket handle fracture* (Fig. 2.92): This is a lateral compression injury (or type B3 in Tile classification). It is a vertically-orientated fracture through the ipsilateral superior and inferior pubic rami with contralateral SI joint disruption/dislocation (Fig. 2.92).
- *Open book fracture* (Fig. 2.93): This is an anteroposterior compression injury to the pelvis. It causes disruption of pubic symphysis or fracture of pubic rami and the pelvis opens like a book (Fig. 2.93). There may be an associated SI joint disruption.

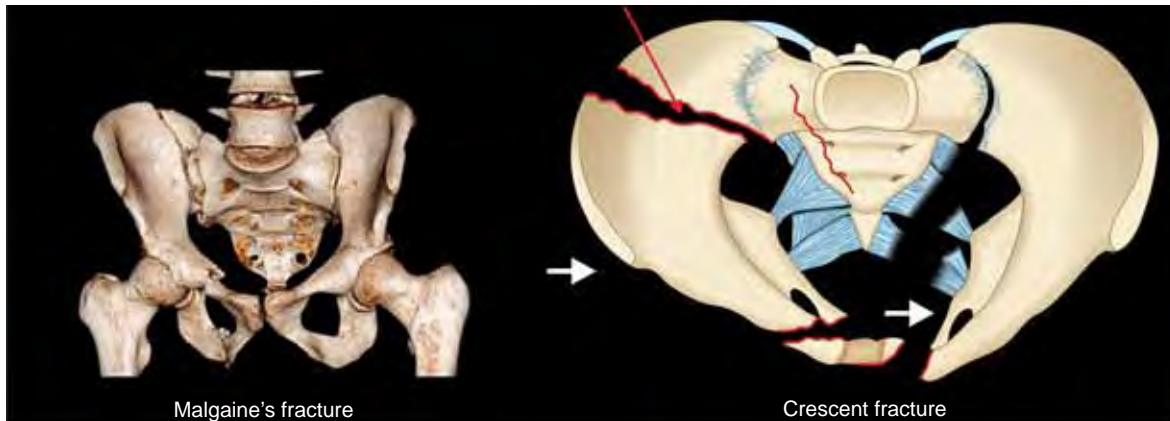


Fig. 2.91: Schematic depiction of Malgaigne's fracture and a crescent fracture of Pelvis.



Fig. 2.92: X-ray pelvis AP view showing unstable bucket handle type pelvic fracture (right pubic rami fracture and left iliac wing fracture).



Fig. 2.93: X-ray pelvis with both hips AP view showing open book fracture.

- *Wind swept pelvis* (Fig. 2.94): It is a lateral compression injury of ipsilateral hemipelvis and open book or external rotation type injury of contralateral hemipelvis.
- *Crescent fracture* (Fig. 2.91): Sacroiliac joint fracture dislocation, iliac wing fracture that enters into SI joint.
- *Suicidal Jumper's fracture*: This is a transverse fracture of sacrum seen in patients who have a fall from height during a suicidal attempt. The fracture is characterized by an H or U shaped fracture line in the upper sacrum (Fig. 2.95), usually involving the S1-S2 region. Typically, the anterior segment of the pelvic ring is not injured.

Morel-Lavallee lesions

- These are post-traumatic closed degloving soft tissue injuries in which the skin and subcutaneous tissues are torn away from the underlying fascia creating a potential space. This disruption may tear the perforating vessel and lymphatics and the potential space may be filled with blood, serosanguinous



Fig. 2.94: X-ray AP view showing a wind swept pelvis (Fractures are indicated by arrows).

Courtesy: Dr Mike Cadogan.

fluid and necrotic fat. These lesions may complicate traumatic pelvic and acetabular injuries. Patients present with enlarging painful mass and antero-lateral thigh (area around greater trochanter) is most

commonly involved area. Treatment options include aspiration, tube drainage and use of sclerosing agent. In one third cases the lesion may be infected in which case an incision and drainage may be required.

ACETABULAR FRACTURES

Acetabulum fractures are rare. These are caused when femoral head strikes the acetabulum. This may happen following a blow on greater trochanter (lateral impact as in fall from height) or in RTA when flexed knee (with flexed hip) strikes against a dashboard nipping off the posterior rim of acetabulum.

Since these Patients are usually victim of high energy injury a rapid primary survey should be done in all these patients to cinch any threat to life. If patient is stable then detailed physical examination should include any associated soft tissue injury (Morel Lavallee lesion), neurological examination (injury to sciatic nerve is most common), limb deformity (concurrent posterior hip dislocation may be there) and other associated fractures.

Surgical Anatomy and Imaging (Figs. 2.96A and B)

Innominate bone is divided into two columns, anterior and posterior. Anterior column includes anterior half of the iliac wing, anterior half of acetabular articular surface

and anterior pubis with symphysis. Posterior column begins at superior aspect of greater sciatic notch and extends below to include greater sciatic notch, posterior part of articular surface of acetabulum, lesser sciatic notch and ischial tuberosity. AP view and special Judet views of the pelvis are often prescribed to identify acetabular fractures. Judet views are oblique views of pelvis and include iliac oblique (45° external) and obturator oblique (45° internal) views and better help to delineate an acetabular fracture.

Classification

The traditional concept of a central fracture dislocation/traumatic protrosio-acetabuli (Fig. 2.97) which occurs in a lateral blow to the trochanter (fall from height with lateral side of hip hitting the ground) that causes the acetabular floor to fracture and the head to migrate inside the pelvis is now a refuted concept. Based on two column principle Letournel and Judet have classified acetabular fractures into more descriptive patterns. These include five elementary and five associated fracture patterns (Fig. 2.98). The resulting pattern is governed by the position of the femoral head at the time of the injury, the magnitude of force and the age of the patient. The central fracture dislocation as per this classification is a both column type of fracture.

Treatment

Acetabular fractures involve articular surface so anatomical reduction and internal fixation is the favored treatment by most of the orthopedic surgeons. However conservative treatment of acetabular fractures also gives good result provided the fracture is minimally displaced and of nonweight bearing zone. All the patients who are chosen for conservative treatment should be put on skeleton traction (above knee supracondylar skeleton traction) for 6–8 weeks. After that patients are allowed to walk with crutches or walker. Passive and active range of

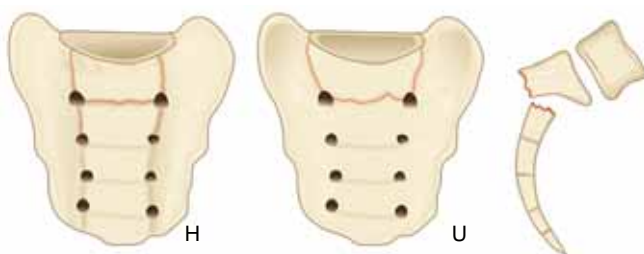
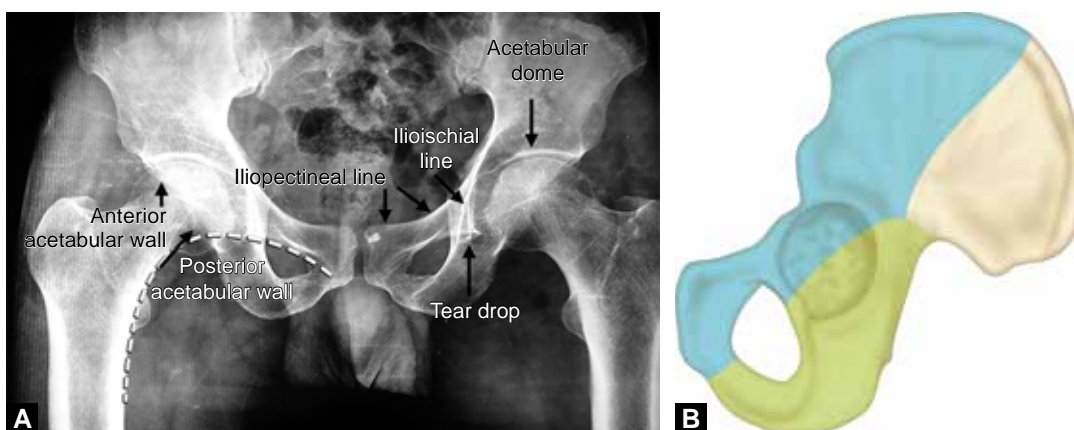


Fig. 2.95: Suicidal Jumper's fracture sacrum make fractures in H and U pattern.



Figs. 2.96A and B: (A) Common landmarks of X-ray pelvis with hip joint AP view (Shenton's line is shown as broken line) and (B) Anterior (blue) and posterior (green) columns of pelvic bone of acetabulum.

motion physiotherapy should be started early. Dislocation of femoral head may be associated with acetabular fracture and requires urgent reduction to prevent AVN. Displaced fractures require congruent open reduction and internal fixation with plate and screws.

Open pelvic fractures are dangerous injuries that apart from routine management described above need special consideration in context of the genitourinary and fecal contamination risk. A meticulous examination of the anus, rectum, vagina and genito-urinary system is imperative in these patients. Colostomy is indicated for all open pelvic injuries where fecal stream is expected to contaminate the open area.



Fig. 2.97: X-ray pelvis with both hips AP view showing a fracture of right acetabular floor (arrow) with a central fracture dislocation (now called as Both column fracture).

Complications

Heterotopic ossification sciatic nerve injury (mostly iatrogenic), AVN of femoral head, venous thromboembolism, are common complications of acetabular fractures.

HIGH-YIELD POINTS

- The most common complication of acetabular fractures is secondary osteoarthritis of the hip joint.
- Posterior wall fractures are most common type of acetabular fractures. Matta's roof arc angle is a special angle that helps in deciding between conservative and non-conservative management in acetabular fractures. It basically predicts whether the fracture is in weight bearing zone or not.
- *Gull wing sign*: Seen in anterior column plus posterior hemitransverse fracture of acetabulum.
- Secondary congruence and spur sign are radiographic signs seen in both column fractures.
- Kocher-Langenbeck approach is most commonly used surgical approach to fix acetabular fracture.
- Obturator view better delineates an anterior column and posterior wall while the oblique iliac view better delineates a posterior column and anterior wall.
- Corona Mortis is a vascular communication between external (inferior epigastric artery) and internal iliac (obturator artery) systems that is present just behind superior pubic rami in 85% of patients. Injury to the corona can lead to a dangerous hemorrhage in patients with pelvi-acetabular injuries.

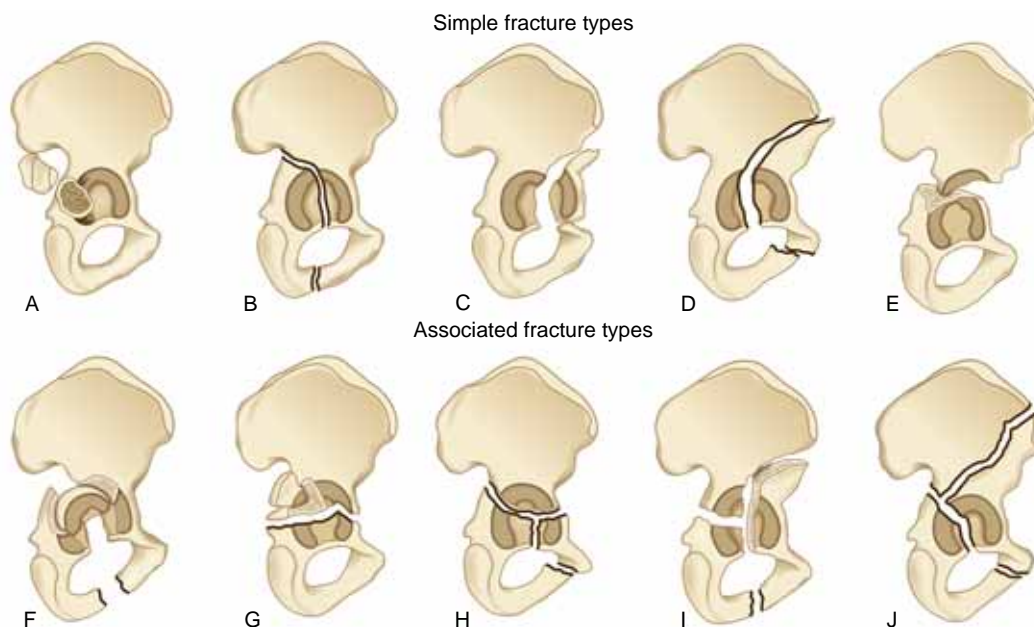


Fig. 2.98: Judet and Letournel classification of acetabular fractures.

(A: Posterior wall; B: Posterior column; C: Anterior wall; D: Anterior column; E: Transverse; F: Posterior column + posterior wall; G: Transverse + posterior wall; H: T type; I: Anterior column + posterior hemitransverse; J: Both column).

BIOMECHANICS, GAIT ANALYSIS AND CLINICAL EXAMINATION OF HIP JOINT

ANATOMY OF HIP JOINT

Hip joint is a synovial ball and socket between acetabulum and head of femur. A fibro-cartilagenous labrum is attached to periphery of acetabular rim to deepen its cavity. Articular cartilage is present at center of acetabulum and covers most of the head of femur. Ball and socket nature of joint, neck-shaft angle of femur and presence of articular cartilage beyond the reach of acetabular rim allows for wide range of motion possible at hip joint. Normal femoral neck is rotated 15° – 20° anterior to coronal plane. This is referred to as femoral anteversion (Fig. 2.99). Femoral anteversion decreases from 140° at birth to 15° – 20° in adults. Acetabulum also has 15° – 20° anteversion and 45° inferior inclination. Neck shaft angle is deduced by measuring the angle between a line in the center of femoral neck and a line in the center of femoral shaft (Fig. 2.100). Normal neck shaft angle decreases from 140° at birth to $125^{\circ} \pm 5^{\circ}$ in

adult. Increase in neck-shaft angle >130 degrees is called coxa valga and reduced neck-shaft angle <120 degrees is known as coxa vara.

Stability of hip joint depends upon the following factors:

- The depth of the acetabular cup and presence of labrum.
- Ligaments on both anterior (illio-femoral, pubofemoral) and posterior side (ischio-femoral). Iliofemoral ligament of Bigelow is the strongest ligament in body. It prevents the pelvis from tilting posteriorly and limits adduction.
- The length and orientation of the neck of the femur.
- *Ligament of head of femur*: This band is called the ligamentum teres. It is implanted into the noncartilage area bearing fovea centralis on the head of the femur. A small artery runs along it to the head of the femur.
- Thick joint capsule and muscle cover.

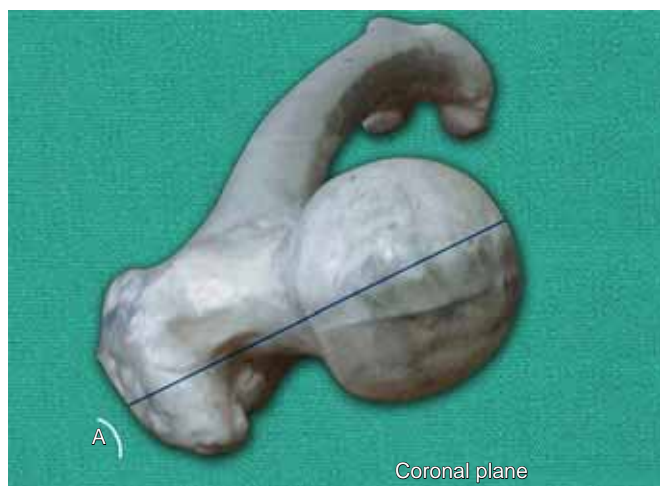


Fig. 2.99: Schematic depiction of femoral neck anteversion (A is the angle of anteversion).

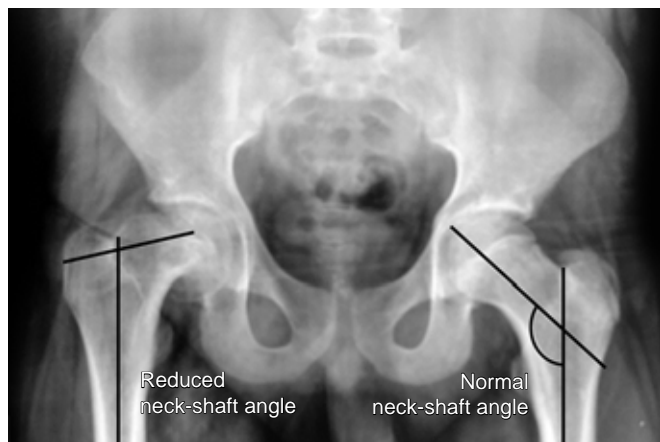


Fig. 2.100: Normal neck shaft angle and coxa vara.

Trabecular System of Femoral Neck

On radiographs, femoral neck can be observed to display two types of trabeculae. There is a horizontal set of tensile trabeculae that form due to abductor muscle forces and there is a vertical set of compressible trabeculae that result from weight bearing forces in femoral head, both crossing each other at right angles. The knowledge of the trabecular anatomy is sometimes useful to decipher an impacted femoral neck fracture on a radiograph. Also, a special index (Singh's index) grades osteoporosis on the basis of this trabecular system (Fig. 2.101).

Vascularity of Femoral Head and Neck (Fig. 2.102)

It can be divided into three main sources.

1. *Capsular vessels*: These arise from the medial circumflex femoral artery (MCFA) and lateral circumflex femoral

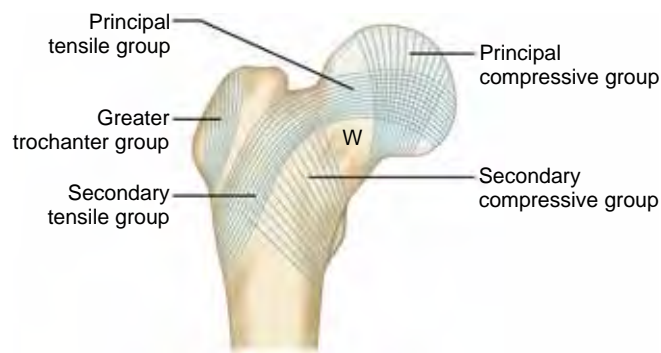


Fig. 2.101: Schematic representation of the trabecular system of femoral neck (W-Ward's triangle, a triangular shadow in trabecular system).

artery (LCFA) which are in turn branches of profunda femoris artery. Branches from MCFA and LCFA form an extracapsular arterial ring at base of femoral neck. Ascending cervical or retinacular vessels arise from extracapsular arterial ring and form a subsynovial intraarticular arterial ring at base of head. Epiphyseal arteries arise from subsynovial arterial ring. Lateral epiphyseal vessels through lateral ascending cervical arteries (branches of MCFA) are the most important source of blood supply to head and neck.

2. *Artery of ligamentum teres (medial epiphyseal artery):* It is a branch of obturator artery. It makes small contribution to blood supply of head.
3. *Intramedullary metaphyseal blood supply:* It makes least contribution to blood supply to head.

HIP BIOMECHANICS AND ABNORMAL GAIT PATTERN

When we stand on two legs the weight of body is equally borne on both legs, the center of gravity is centered

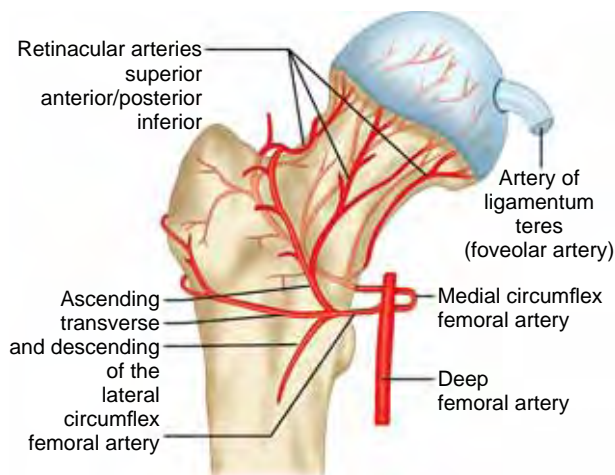


Fig. 2.102: Vascularity of femoral head.

between the two hips and the weight of the body minus the weight of both legs is equally distributed on the femoral heads. In single leg stance the center of gravity is distal and away from the supporting hip (Fig. 2.103A) due to swing leg being considered as part of body.

Three forces act across hip joint:

1. Body weight
2. Abductor muscle force
3. Joint reaction force.

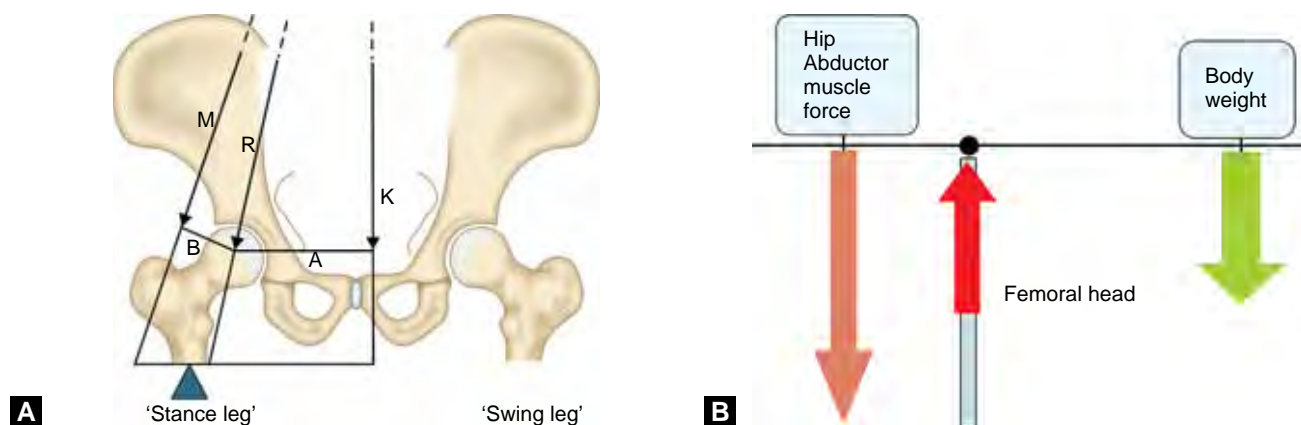
Joint reaction force is the force that generates within a joint in response to forces acting on the joint. In the hip joint these forces are body weight and abductor muscle force. To maintain a stable hip torque produced by body weight should be countered by abductor muscle force (Fig. 2.103B) with supporting femoral head acting as a fulcrum. Thus joint force across a painful hip can be reduced by reducing the body weight (K) or its moment arm (a), or increasing the abductor force (M) or its moment arm (b).

How a Cane or Limp Help to Reduce the Hip Pain?

Cane in opposite hand transmits part of body weight to ground and thus reducing the body weight needs to be countered by abductor muscle force. Hence a cane is always prescribed in opposite hand. Limp towards same side reduces the body lever arm by shifting the center of gravity towards loaded hip. Hence, when the abductors are paralyzed one bends towards the side of paralyzed abductors to shift the center of gravity towards affected hip in an attempt to decrease joint reaction force in hip.

NORMAL GAIT AND ABNORMAL GAIT PATTERNS

Normal gait requires adequate muscle strength, full range of motion of all involved joints, good proprioception and balance (alignment and length of limbs). Gait cycle is divided in stance and swing phases (Fig. 2.104). Stance



Figs. 2.103A and B: Free-body diagram for the calculation of the hip joint force while walking, where K is the body weight (minus the weight bearing leg), M is the abductor muscle force, and R is the joint reaction force, (B) For a stable hip body weight should be countered by abductor muscle force.

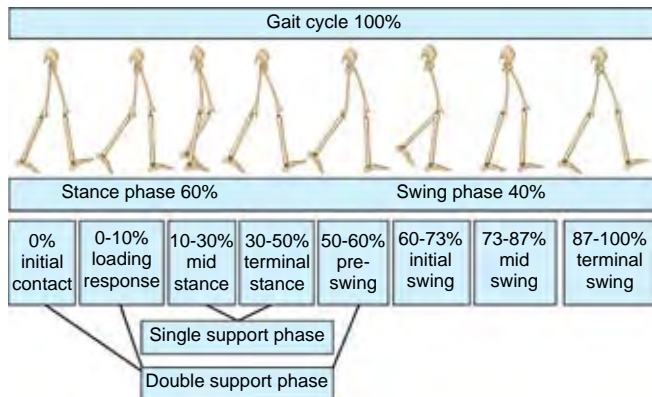


Fig. 2.104: Gait cycle.

phase is the period during which the foot is in contact with ground. In swing phase, foot remains in the air.

The stance phase is subdivided into:

(1) Heel strike or initial contact (2) Loading response (3) Mid stance (4) Terminal stance (5) Preswing.

Swing phase is subdivided into: (1) Initial swing (2) Mid-swing and (3) Terminal swing.

HIGH-YIELD POINTS

- Pre-Swing is the only phase in the gait cycle where all muscle groups are silent.
- Phase with maximum kinetic energy is heel strike/loading response while the phase with maximum potential energy is mid-stance.
- The stance phase usually accounts for 60% of the cycle and the swing phase account for 40% of the cycle.
- *Double support phase*: When both feet are in contact with ground. It lasts for about 10% of cycle. With increasing speed the swing phase becomes proportionately longer and the stance phase and double support phases shorter.
- Cadence is number of steps taken per minute.
- The stride length is the distance between two successive placements of the same foot.

Any deficiency or deviation from normal gait produces abnormal gait pattern which are usually adapted to compensate for that deficiency.

Antalgic Gait

This is the most common pattern seen with painful hip (or presence of pain anywhere in the lower limb). It is characterized by slow walking speed, reduced stance phase on the painful limb, reduced joint excursion and a limp towards the painful hip.

Trendelenburg Test and Gait (Gluteus Medius Gait)

It is seen in weak abductor mechanism. An intact abductor mechanism requires fulcrum (hip joint proper), liver

arm (head and neck) and power (abductors). Common causes are:

Defect in fulcrum: Hip dislocation, advanced cases of TB hip and septic arthritis of hip joint, developmental dysplasia of hip, Perthes disease, advanced cases of AVN hip.

Defect in liver arm: Fracture head or neck of femur, coxa vara and trochanteric fractures.

Defect in power: Abductor paralysis due to poliomyelitis or superior gluteal nerve injury, tensor fascia lata and iliotibial tract palsy and L5 radiculopathy.

During one legged stance of gait cycle, when one stands on one leg (i.e. left leg), the right side pelvis is lifted up to clear the ground. This is done by contraction of abductors on the left side (mainly gluteus medius that is running between ilium and greater trochanter on lateral aspect of hip) with an intact lever arm and fulcrum. If left side abductor mechanism is defective the opposite side of pelvis will dip down by virtue of gravity (positive Trendelenburg sign, Figure 2.105). In this case while walking patient lurches to same side i.e. he shifts all his weight to the left side to prevent the right pelvis from dipping down and keep the pelvis leveled (Trendelenburg gait). When patient lurches on both sides (positive Trendelenburg sign on both hips), it is known as "waddling gait".

Short Limb Gait

Patient walks on toes of shortened limb by keeping foot in equinus or may maintain flexion of hip and knee of the lengthened limb to level the limbs. Often it is confused with Trendelenburg gait. The two can be differentiated by the fact that in short limb gait only the shoulders drop as patient walks but the lurch on to affected side is absent.

Foot drop gait (high-stepping gait): It is seen in common peroneal palsy or sciatic nerve palsy. Patient lifts his leg more to clear the ground and he keeps his forefoot first then heel on the ground.

Stiff knee gait: It is characterized by decreased knee flexion in swing phase. Patient circumducts (excessively abducts) and bring the leg forwards to get clear the ground, i.e. TB knee.

Stiff hip gait: Pelvis is lifted to bring the leg forward, i.e. TB hip, ankylosed hip.

Crouch gait: Patients walk with hip and knee flexion and ankle equinus. It is seen in cerebral palsy and polio (see Chapter 8).

Gluteus maximus lurch gait: It is seen in polio, inferior gluteal nerve palsy, etc. Patients lurch backwards with every step to compensate for lack of hip extension.

Scissors gait: It is seen in cerebral palsy due to adductors spasm of both hip joint.

Hand-to-knee gait: It is seen in polio due to quadriceps weakness with inability to lock the knee while walking. Patient puts his hand on the knee to prevent it from buckling.

HIGH-YIELD POINTS

- Center of gravity in human body lies anterior to S2 vertebra.
- Cane in opposite hand or limp towards same side are effective way to reduce the pain in ipsilateral hip or knee joint.
- Cane is always advised in opposite hand may the problem be in the hip or the leg.

EXAMINATION OF HIP JOINT

Hip examination starts from the point patient enters the clinician's room. Look at the gait pattern and attitude of patient in standing and lying position. This gives an idea about the part of lower limb which is diseased. Inspection should be done from front, back and side to see any wasting, swelling and abnormal skin conditions. Palpate the all relevant bony points (GT, anterior superior iliac spine) and look for tenderness at base of Scarpa's triangle (syn. femoral triangle). Anteriorly femoral head can be located 1 cm below and out to the mid-inguinal point (located at the midpoint of a line between anterior superior iliac spine and pubic symphysis). Palpate the inguinal group of lymph nodes and record range of motion at hip joint.

Tips and Concepts of Hip Examination

- *Fixed deformities of hip joint:* Normally in movement at hip, the pelvis remains stable as movement occurs between femoral head and acetabulum. A fixed deformity of hip is one where the movement at the hip joint is lost in a particular direction either due to joint destruction or due to soft tissue contractures. Rather on attempting that movement the pelvis moves as a whole. So, Pathological fixation of hip joint in a fixed position of joint is one from where limb can be moved further in same plane but cannot be moved in opposite direction as this moves the pelvis. So in a hip fixed in 15° adduction, abduction will not be possible as on

abducting pelvis will tilt but further adduction may be possible.

- Patients with fixed deformities of hip joint usually adopt compensatory postures to hide the deformity, as in fixed flexion deformity patient compensates for by excessive lumbar lordosis (Fig. 2.106). Thomas test is used to assess the fixed flexion deformity of hip joint. *Thomas test* (Fig. 2.107): Patient is positioned supine on a firm bed and then asked to flex the normal hip to bring the knee of normal side to his chest. He is then asked to hold the normal limb in this position with hands. This automatically brings the diseased hip (hip with fixed flexion deformity) into some flexion. The examiner then passively lowers the affected limb to the bed. If the limb remains up off the table, a fixed flexion deformity at hip is suspected. Angle subtended between the thigh and the bed is the angle of flexion deformity.
- In fixed adduction or abduction deformities, to ambulate normally the body compensates by tilting the pelvis such that in fixed abduction deformity anterior

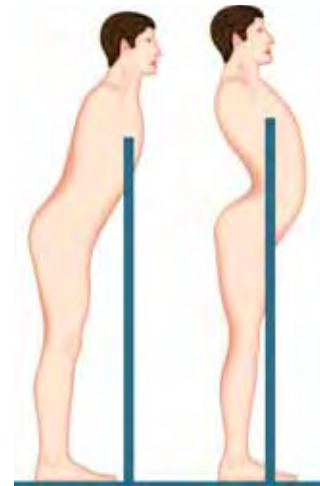


Fig. 2.106: Flexion at hip has been compensated by increasing lordosis at lumbar spine and the trunk has been leveled.

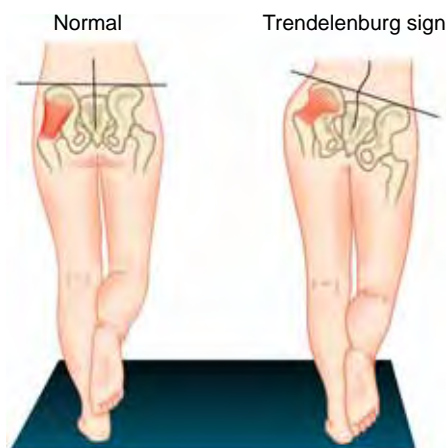


Fig. 2.105: Trendelenburg test.



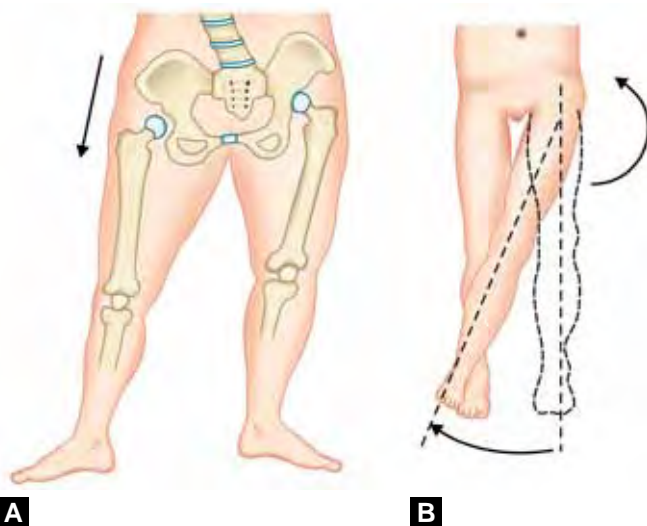
Fig. 2.107: Thomas test.

superior iliac spine (ASIS) will be at a lower level as compared to other side (see Fig. 2.108A). To calculate the amount of deformity the affected limb is further abducted until both the ASIS are at same level (Squaring of pelvis). Angle subtended between the mid line and the affected thigh is the amount of abduction deformity.

- In fixed adduction deformity anterior superior iliac spine will be at higher level as compared to other side (see Fig. 2.108B). To calculate the amount of deformity the affected limb is further adducted until both the ASIS are at same level (Squaring of pelvis). Angle subtended between the mid line and affected thigh is the amount of adduction deformity.
- *Telescopy* (Fig. 2.109): In supine position, flex the hip and knee joint to 90° (or less if this much of flexion is not possible) and adducts the hip joint slightly. To test right hip stands on right side of patient and hold his flexed knee with right hand and put palm on the trochanter and extended fingers on the buttock. Now pulls up and pushes down the knee. An obvious excursion of trochanter can be felt if telescopic test is positive. This test indicates instability of hip joint and is positive in neglected posterior dislocation of hip joint, congenital dislocation of hip, paralytic hip, nonunion fracture neck of femur, advanced cases of AVN and septic arthritis with resorption of head and neck.

True and Apparent Length

Affections of hip can lead to alteration in the limb length. The alteration can occur either due to real bone loss causing true change in length of limb or due to compensatory



Figs. 2.108A and B: (A) Right hip of this patient has fixed abduction. To place it flat on ground, the ipsilateral ASIS has to be dropped down and thus over time it gets fixed at a lower level; (B) Left hip of patient has fixed adduction. To bring this leg into parallel alignment (dotted diagram), the ipsilateral ASIS has to be lifted up and thus it gets fixed at a higher level.

postures adopted by the patient causing apparent changes in length of limb. For example if there is fixed flexion deformity at hip, the malleolus apparently moves proximally as shown in Figure 2.110 (below) although the limbs are actually of same length. Now the patient brings this hip to extension by developing compensatory lumbar lordosis but the malleolus stays proximally located giving a false impression of a short limb. Similarly, in fixed adduction, due to compensation the ASIS gets fixed proximally and the limb is apparently shortened while in fixed abduction, the ASIS goes lower and the limb is apparently lengthened.

The true and apparent lengths can be measured as shown in Table 2.12.

Remember, that finally True length = Apparent length \pm [fixed deformity], where you add for flexion or adduction deformities that shorten limb while you subtract for abduction deformity that lengthens limb.

ASSESSMENT OF SUPRATROCHANTERIC SHORTENING

Any pathology in the lower limb (hip, thigh, leg etc.) can be a cause of limb length discrepancy. The first step in such



Fig. 2.109: Telescopy test of hip joint (To exhibit the test clinician is standing on opposite side).

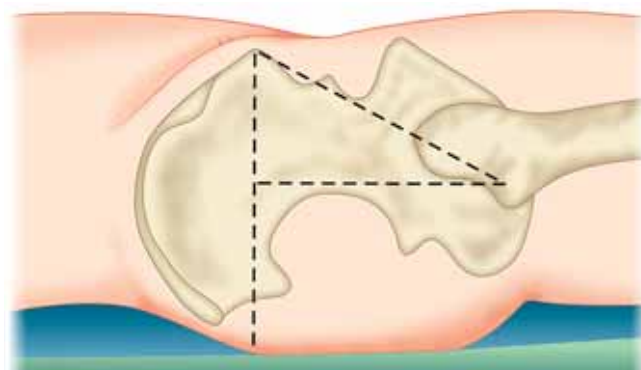


Fig. 2.110: Malleolus moves proximally when the hip is flexed apparently shortening the limb.

Table 2.12: Measurements of true and apparent length

True length	From ASIS* to medial malleolus	Limbs in identical position with respect to pelvis	Pelvis squared	In fixed abduction deformity true shortening will be more than apparent shortening. In fixed adduction deformity true shortening will be less than apparent shortening.
Apparent length (functional length)	From any central point on trunk (umbilicus or xiphisternum) to medial malleolus.	Limbs parallel to each other	Pelvis not squared	It is primarily measurement of pelvic tilt.

*ASIS is identified by first palpating the pubic tubercle and then following the inguinal ligament up and laterally. The first bony landmark encountered is the ASIS.

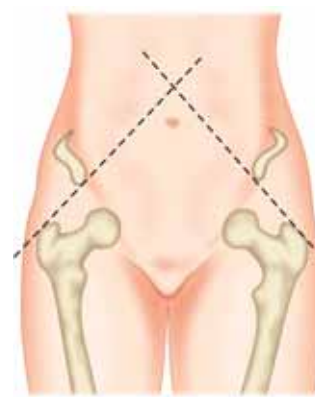
**Fig. 2.111:** Allis/Galleazzi's test.**Fig. 2.112:** Bryant's triangle.

patients is to decipher the level of shortening. This can be deciphered by performing the Galleazzi's test.

Galleazzi/Allis Test (Fig. 2.111): This test demonstrates whether the shortening is in the femur or tibia. The patient lies supine with the hips flexed to 45 degrees and the knees flexed up to 90 degrees and both the lower limbs placed side to side with malleoli touching together. The examiner assesses the position of both knees from the end of the bed and from the side. Normally both knees lie at the same level. When normal knee projects farther forwards than the affected, the affected femur is shorter and when affected knee is lower than the other the tibia is shorter.

In patients with hip pathologies with Galleazzi's Test the shortening can thus be localized to the femur. Next step is to localize whether the shortening is sub trochanteric (measure length from GT to lateral knee joint line and compare two sides) or is supra-trochanteric (pathology located above the greater trochanter as in destruction of femoral head, neck or a dislocation of joint). In hip joint affection one would expect to find supra-trochanteric shortening. This can be deduced and measured in a number of ways as follows.

- **Bryant's triangle (Fig 2.112):** In a squared up pelvis in supine position a line is drawn from the ASIS perpendicular to bed. Another line perpendicular to first line is drawn from tip of GT. A third line from ASIS to tip of GT completes the triangle. This is compared to Bryant's triangle of normal side. Any shortening of base indicates supratrochanteric shortening.

**Fig. 2.113:** Schoemaker's line.

- **Schoemaker's line (Fig. 2.113):** In supine position line joining the ASIS and tip of GT should meet the same line of opposite side at or above the umbilicus in the mid-line. In supratrochanteric shortening this line of affected side meets its counterpart below the umbilicus and the intersection is not centered at mid-line.
- **Chienes line:** With patient lying supine lines are drawn joining the two ASIS and the two greater trochanters. Normally, the two lines would stay parallel. In the case of one trochanter has migrated proximally, the lines will converge on that side.
- **Nelaton's line (Fig. 2.114):** Patient is positioned in lateral position with the diseased side up. Flex the hip joint at 90°.

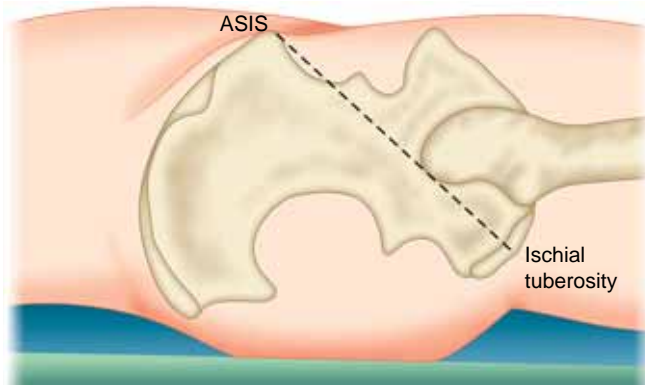


Fig. 2.114: Nelaton's line.

Draw a line joining the ischial tuberosity to ASIS. In supratrochanteric shortening the trochanter will be above this line. Normally this line passes through tip of GT. The advantage of Nelaton's line over the other methods is that it can measure supra-trochanteric shortening in cases of bilateral hip pathologies as comparison with other side is not needed.

HIGH-YIELD POINTS

- Lumbar lordosis can hide upto 30 degree of flexion deformity at hip.
- Thomas test cannot detect bilateral hip flexion deformity. In such cases a prone test is used for detection.

INJURIES AROUND HIP JOINT AND FRACTURE SHAFT OF FEMUR

DISLOCATION OF THE HIP

Hip dislocations are orthopedic emergencies that require immediate diagnosis, evaluation and treatment. Dislocation may be posterior, central and anterior. 90% of hip dislocations are posterior type in both adults and in children owing to the classical mechanism of injury (*see below*). Anterior fracture dislocation is more common than central fracture dislocation which is rarely seen.

Mechanism of Injury (Table 2.13)

Hip is the most stable joint in the body with best articular configuration. The strongest ligament in the body (the Y shaped ilio-femoral ligament or the Ligament of Bigelow) is also present around the hip. So in majority of cases dislocation of hip is a high velocity motor vehicle injury. Posterior traumatic hip dislocations occur when axial force is applied to flexed, adducted and internally rotated hip joint. Dashboard injuries in which person's flexed knee, with flexed hip strikes against the dashboard is a common mechanism of injury for posterior dislocation of hip.

Clinical Features

Patients present with typical attitude of limb (Table 2.13) with inability to use involved lower limb. Since the mechanism is mostly a dashboard injury, many a times these patients can have a concomitant fracture of posterior wall of acetabulum, patellar fractures and posterior cruciate ligament injury in knee. All hip movements are painful. Femoral head may be palpable at the ipsilateral gluteal region in posterior dislocation while it is palpable in groin in an anterior dislocation. In a central fracture dislocation (fracture of acetabular floor where head migrates into pelvis), the head can often be palpated on a per rectal examination. Vascular sign of Narath (i.e. inability to feel femoral pulse against femoral head) is positive in posterior dislocations. However, in anterior

dislocation head may be felt stays in the groin so despite a dislocation femoral pulsation may be palpable.

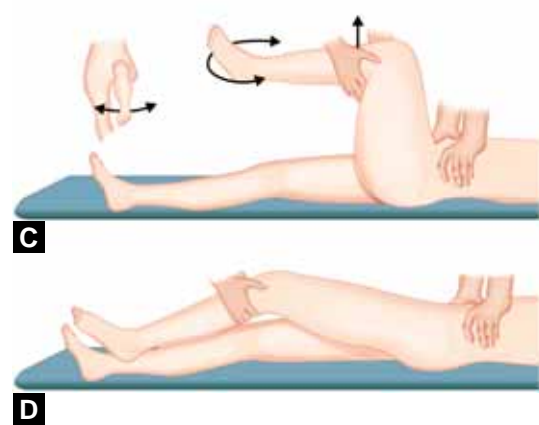
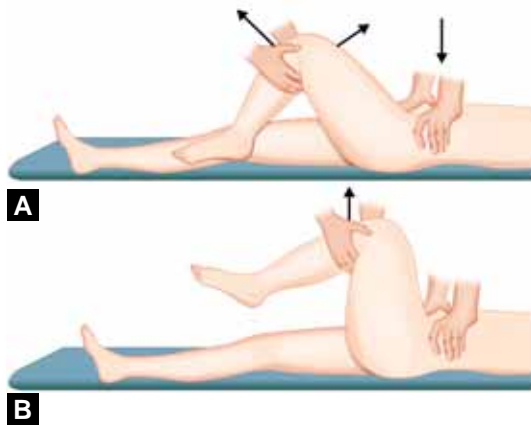
Immediate assessment of vitals, associated injuries and distal neurovascular status is utmost important in patients with hip dislocation. Thorough neurological examination especially of sciatic nerve must be done and recorded before reduction as sciatic nerve injury is the most common acute complication. Clinical examination may also reveal the classical deformity indicating the type of dislocation. Limb length discrepancy may be evident (shortening in posterior while lengthening in anterior dislocation). The diagnosis can be further strengthened on plain AP, iliac and obturator views of the joint. X-ray (Fig. 2.116) shows the empty acetabulum proximally migrated femoral head due to pull by the gluteal muscles (in posterior dislocation) and broken Shenton's line (normally a continuous line formed by the inferior margin of superior pubic ramus and the medial margin of the neck, Fig. 2.96A). For visualization of the acetabular fracture and associated fracture head of femur, CT scan remains the modality of choice.

Management

Hip dislocation with or without acetabular or femoral head fracture is an emergency and must be reduced as early as possible. Most of the times close reduced under general anesthesia is possible. Many methods of close reduction have been described like Allis maneuver (Figs. 2.117 A to D), Biglows maneuver (leverage method, can reduce both anterior and posterior dislocations but not used due to high risk of femoral neck fractures), Stimsons gravity method (Fig. 2.118) and Modified East Baltimore lift (Fig. 2.119). Allis maneuver is the most commonly used method for closed reduction of hip dislocation. Once a stable closed reduction is achieved, a temporary skin traction can be given for soft tissue healing and gradually the patient can be mobilized. However, if a closed reduction fails (interposed labrum etc., or incarcerated bone fragments),

Table 2.13: Mechanism of injury and limb attitude in hip dislocation

Type of dislocation	Mechanism of injury	Attitude of limb
Posterior dislocation of hip	Axial force along the shaft of femur with hip flexed, adducted and internally rotated	Flexion, adduction and internal rotation, true shortening may be present (Fig. 2.115).
Anterior dislocation of hip	Hyperabduction and external rotation of flexed hip joint	Abduction and external rotation with flexion (with limb shortening, obturator type) or extension (with limb lengthening, pubic type) at hip joint.
Central fracture-dislocation of hip joint.	Axial force on internally rotated and abducted hip, direct injury on the trochanter.	Virtually any deformity possible. Mostly flexion, abduction and internal rotation or flexion, adduction and external rotation. True shortening may be present.

**Fig. 2.115:** Classical attitude of flexion, adduction and internal rotation in a patient with posterior dislocation of right hip.**Fig. 2.116:** X-ray pelvis with both hips AP view showing posterior dislocation of hip joint—see adduction and internal rotation (lesser trochanter is not visible) of the femur also the Shenton's line is broken.**Figs. 2.117A to D:** (A) Affected hip is flexed and adducted (B) traction is given in line of femur (C) rotation movements are performed to achieve reduction (D) after reduction hip is abducted and extended.

patient should be urgently posted for an open reduction. Patients with concomitant femoral neck or head fractures also usually require primary open reduction.

Complications

Early Complications

Nerve injury: Sciatic nerve injury is the most common acute complication in posterior dislocation of hip and chances are even more in fracture dislocation. Peroneal

component affection is more common than complete loss as peroneal fibers are the outermost fibers in the nerve. Femoral nerve injury may occur in anterior dislocation. Mostly these cases are neurapraxia which spontaneously recover in 6–12 weeks. If sciatic nerve injury appears after close reduction urgent exploration may be needed to rule out its entrapment by reduction maneuver.

Vascular injury: Superior gluteal artery may be injured. If suspected urgent exploration and vascular repair is required.

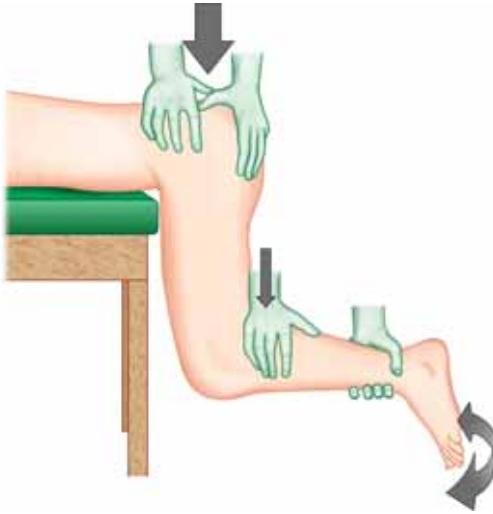


Fig. 2.118: Stimson's gravity method (gravity assisted reduction by making anesthetized patient lie prone with affected hip left hanging).

Delayed Complications

Avascular necrosis of head: Chances of AVN of hip increases with delay in reduction. If hip is reduced within 6 hours of dislocation then AVN of the head occurs in up to 10% cases. The greater the duration of delay in reduction, the greater are chances of development of AVN. Changes of AVN first appear on MRI and it may take even 1–2 years to make diagnosis on X-rays. Patient presents with pain in hip joint after a painless period postreduction. Ultimately patient develops secondary osteoarthritis with collapse of head and may end up needing a total hip replacement.

Heterotopic ossification: This is a common complication of posterior fracture dislocation. It is particularly common after open reduction (more with anterior approach) of posterior dislocation and is associated with severity of trauma. Indomethacin and radiation therapy are used in the prophylaxis.

Osteoarthritis: Secondary osteoarthritis is most common complication of hip dislocation. This happens due to articular cartilage damage at the time of dislocation or reduction, incongruent fracture reduction or due to AVN of head. Most suitable treatment of advanced cases is total hip replacement.

Recurrent dislocation: It is exceedingly rare but known complication. Recurrent posterior dislocation is mostly seen in patients who have a decreased femoral anteversion while anterior one is common in patients with increased femoral anteversion.

Associated fractures: Fractures of femoral head and neck can be associated either due to injury or iatrogenic during reduction. The risk of AVN is greatly increased in such cases.

Thromboembolism: Hip dislocation patients are high risk patients and should preferably be given DVT prophylaxis for at least 2 weeks.



Fig. 2.119: Modified East Baltimore Lift (The examiner flexes the normal hip and passes his forearm under the flexed knee of affected side to convert the system into pulley mechanism with his forearm acting as fulcrum. A downward force on affected leg will pull the dislocated hip anteriorly and reduce it).

HIGH-YIELD POINTS

- Thompson and Epstein classification is used for dislocation of hip joint and Pipkin's classification is used to classify femoral head fractures.
- Anterior hip dislocation is classified by Epstein classification into superior (pubic and subspinous) and inferior types (obturator and perineal).

PROXIMAL FEMORAL FRACTURES

Introduction

Proximal femoral fractures are broadly classified into two main categories: the intracapsular and the extracapsular fractures. Capsule in the neck of femur is attached anteriorly along the inter-trochanteric line and posteriorly just a finger breadth proximal to the inter-trochanteric ridge. So any fracture proximal to this attachment is classified as intracapsular while a fracture distal to the attachment of capsule is classified as an extracapsular fracture (Fig. 2.120). In other words, any fracture that would involve the two trochanters will be extracapsular, hence the other name of extracapsular fracture can be inter-trochanteric fracture.

This division of proximal femoral fractures is primarily based upon the varied behaviour of the two fracture types. Both these fractures involve the cancellous metaphyseal bone with abundant blood supply but behave in entirely divergent manner. Extracapsular fracture displays a good union propensity and almost always unites, but at times if not appropriately treated, it malunites. The intracapsular fracture on the other hand is notorious to end up in non-union, despite involving the cancellous part of bone (Table 2.14). The other important complication seen in the latter type is the AVN of the femoral head. This complication is limited to intracapsular variety as the fracture line in intracapsular fracture cuts off the vascular supply from the extracapsular arterial ring formed at base of



Fig. 2.120: Schematic depiction of intracapsular and extracapsular fracture (E: Extracapsular, I: Intracapsular).

Table 2.14: Reasons for non-union in intracapsular neck femur fracture

Intracapsular nature: Being intracapsular, the fracture is bathed in synovial fluid that has inhibiting factors to callus formation
There is absence of cambium layer of periosteum in this area
Blood supply to the area is precarious
Maintaining reduction is difficult as the head fragment is small and cancellous so it does not offer good purchase to the fixing implant
Often there is posterior comminution that makes fracture highly unstable

femoral neck by the circumflex femoral vessels (Fig. 2.121) while an extracapsular fracture does not. However, both fractures present in almost similar age group and with a similar deformity with only subtle differences (Table 2.15).

FRACTURE OF FEMORAL NECK

These are common fractures in elderly (age group 40–60 years), particularly females. It is a significant burden on health care system due to increasing elderly population. These usually result from household fall and are uncommon in young people where generally they result after high energy impact. These fractures are most common in white females of Europe and America and incidence increases with age.

Risk Factors

These are broadly divided into risk factors associated with decreased bone density and those risk factors which increase the risk of fall. Risk of falling increases with advancing age due to multiple factors like weak eyesight, neurological diseases, weak muscle power and gait abnormalities. Osteoporosis either due to advanced age or due to any disease (i.e. osteomalacia, drug induced, alcohol abuse, rheumatoid arthritis, etc.) increases risk of fracture of neck of femur.

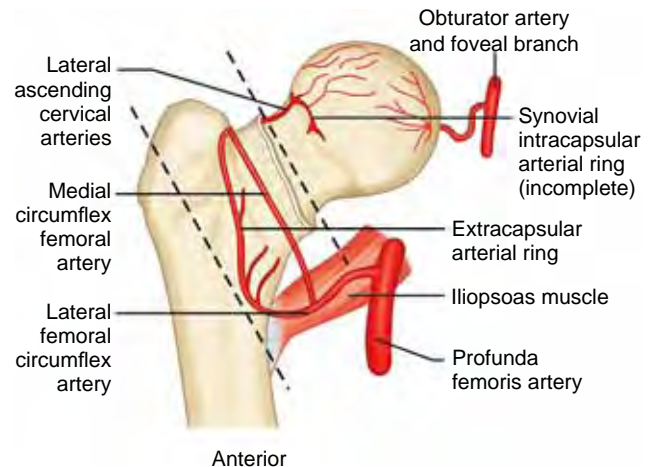


Fig. 2.121: Intracapsular fracture (I) is disrupting the supply from extracapsular ring to head while the Extracapsular fracture (E) is not.

Mechanism of Injury

In elderly people weak bone breaks with simple low energy fall whereas high energy trauma is more common mode of injury in young people. Rarely in runners and military recruits repetitive strain and cyclical loading may cause stress fracture of neck of femur (see Chapter 1).

Clinical Features

Patients present with moderate to severe pain in hip joint with inability to use involved lower limb. On examination limb is externally rotated and shortened (as neck fractures the femur falls into external rotation by virtue of gravity while the limb shortens due to trochanter being pulled proximally by the glutei). The distal fragment is pulled medially by the adductor magnus. On palpation there is tenderness in Scarpa's triangle (femoral triangle) and patient lacks an active SLR. There may not be any obvious deformity in an undisplaced impacted fracture and patient might even be able to perform an active SLR. Such fractures can be traced on X-ray by a change in the trabecular pattern of femoral neck or better by an MRI (investigation of choice for occult fractures). Diagnosis in most cases however, is confirmed on anteroposterior and lateral X-rays of hip joint (Fig. 2.122). X-ray shows the fracture line with break in the trabeculae. Shenton's line is broken greater trochanter is proximally migrated and lesser trochanter appears more prominent due to external rotation of femur.

Classifications

Three commonly used classification systems for neck femur fracture are as follows:

- i. Anatomical classification (Fig. 2.123)

As per the anatomical classification a fracture of neck femur can be subcapital (fracture at femoral head and neck junction), transcervical (through neck) and basicervical (fracture at base of neck).

Table 2.15: Comparisons of extra- and intracapsular fractures of proximal femur

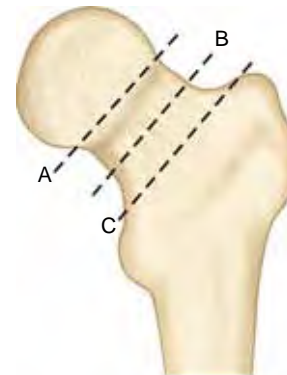
	<i>Fracture neck of femur</i>	<i>Intertrochanteric fracture</i>
Definition	Intracapsular, fracture line is proximal to the insertion of capsule	Extracapsular, fracture line is distal to the insertion of capsule
Age profile	Common in elderly above 60 years.	Mostly seen in relatively older individuals (above 70–80 years)
Mechanism of injury	Low energy fall, high velocity trauma in young patients	Low energy fall, high velocity trauma in young patients
Clinical features	Moderate to severe pain in scarpa's triangle, swelling and echymosis are usually absent	Severe pain, swelling and echymoses are usually present around greater trochanter
External rotation deformity	Less	More, lateral border of foot almost touching the couch
Shortening	Generally less than 2.5 cm	More generally more than 2.5 cm
Trochanteric palpation	Normal	Broadening and tenderness
Straight leg raising and walking	May be possible in impacted fracture	Not possible
Complications	AVN is the most common complication followed by nonunion	Malunion is the most common complication

**Fig. 2.122:** X-ray pelvis with both hips AP view shows fracture neck of femur.

This classification is based upon the prognosis. More proximal is the fracture, smaller is the head fragment to be fixed and hence bad is the outcome. Subcapital fractures are most prone to go into nonunion and land up with AVN of femoral head.

ii. Pauwel's classification

This is a very useful classification that is also a valuable guide to treatment of these fractures. As per the Pauwel's classification, a line is drawn along the fracture line and its angle (Pauwel's angle) is measured with respect to a horizontal line (Fig. 2.124B). Based upon the orientation of the fracture line, the fractures can be classified into three types (Table 2.16), type I being horizontal fractures (angle < 30 degrees from horizontal, less angle) while type III being vertically oriented fractures (angle > than 50 degrees from horizontal, greater angle). In type II fracture angle is between 30 and 50 degrees from horizontal. The fundamental behind this classification is that vertical fractures will displace under load due to shear forces and hence be unstable while the horizontal fractures would compress under load and are thus stable

**Fig. 2.123:** Anatomical classification (A-subcapital, B-transcervical, C-Basicervical).

fractures. So, as per Pauwel's classification, more is the Pauwel's angle, more are shearing forces and thus more unstable is the fracture.

iii. Garden's classification

This is a useful classification to predict the risk of AVN. This classification divides fractures into four types based upon the orientation of the trabecular system in femoral head, neck and acetabulum depending upon how it changes with increasing degrees of displacement (Table 2.17 and Fig. 2.124A). Type IV are most severely displaced fractures having maximum risk of AVN.

Treatment (Flowchart 2.5)

The treatment varies with the age of the patient, the level of the fracture and displacement of fragments. It also depends upon the duration of the fracture and level of activity. Biological rather than chronological age should be taken into consideration.

Nonoperative treatment may be an option in undisplaced fractures with medical contraindications to surgery or in elderly patients with advanced cognitive impairment

and psychiatric problems. These patients are kept immobilized usually in a Thomas splint for 4–6 weeks until fracture heals. In all other patients with undisplaced fracture neck of femur closed reduction and internal fixation with cannulated cancellous screw is advocated.

In displaced fractures in patients with less than 60 years closed reduction and internal fixation with cannulated cancellous screws is recommended (Figs. 2.125A and B). If close reduction fail then open reduction and internal fixation with cannulated cancellous is done. In basicervical type of fracture dynamic hip screw (DHS) can also be used for fracture fixation.

Replacement arthroplasty is the treatment of choice in fracture neck of femur in patients older than 60 years. In less active older patients with no arthritic changes in acetabulum bipolar hemiarthroplasty is a rational option. Total hip replacement is recommended in active, well ambulatory patients with fracture neck femur with concomitant degenerative changes in the acetabulum.

Table 2.16: Pauwel's classification of fracture neck of femur

Pauwel's classification (Fig. 2.124B)—based on orientation of fracture line

Type I	< 30° from horizontal
Type II	30°–50° from horizontal
Type III	> 50° from horizontal

Management of Late Presentation of Fracture Neck of Femur

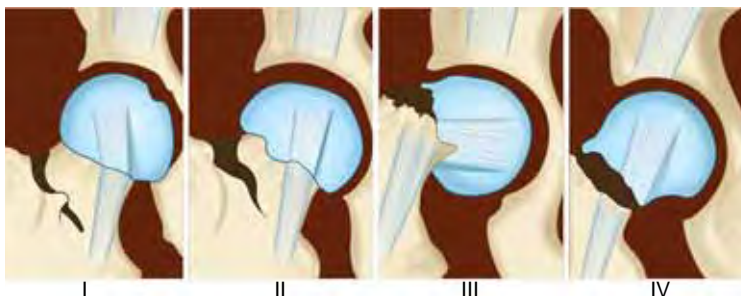
There is lack of consensus on best option for treatment of these cases. Definition of late presentation arbitrarily includes patients presenting 3 weeks or more after fracture neck of femur. A closed reduction is generally not possible in these patients and open reduction involves tissue dissection and is associated with high rates of complications like AVN. In tertiary centers the surgeons mostly order MRI to see the status of the femoral head. If head is vascular, an attempt is made by the methods mentioned below to salvage it. If the head is avascular a replacement arthroplasty is ordered. In other centers where MRI is difficult to get treatment is dictated by age. In patients above 60 years a hemiarthroplasty is the preferred choice. However, in young patients a salvage attempt is made by opting for one of the following methods that can hasten union:

1. Muscle pedicle bone grafting (Meyer's procedure)
2. Open reduction and internal fixation with fibular grafting (free or vascularized)
3. Valgus intertrochanteric osteotomy/Pauwel's osteotomy (Fig. 2.126)
4. McMurray's osteotomy.

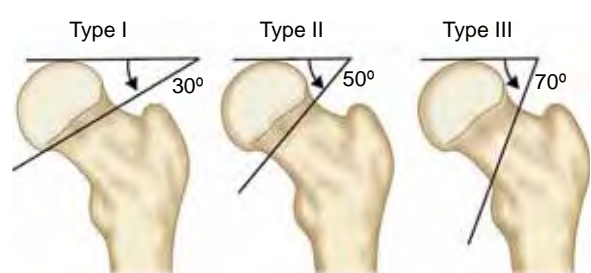
Table 2.17: Garden classification of fracture neck of femur

Garden classification (Fig 2.124A)—based on fracture displacement on AP radiograph

		Description
Type I	Incomplete fracture, valgus impacted	This is a valgus impacted incomplete, subcapital fracture. Fracture line does not break the medial cortex. Trabecular line in head form an angle with those of acetabulum.
Type II	Complete fracture, nondisplaced	This is complete but undisplaced fracture so trabecular lines of head, neck and acetabulum are collinear.
Type III	Complete fracture, partially displaced	This fracture is complete so all set of trabeculae are out of line with each other.
Type IV	Complete fracture, completely displaced	This is completely displaced fractures so there is no contact between head and neck. Head returns to its normal position in acetabulum and trabeculae of head and acetabulum are collinear but head and neck trabeculae are not aligned.

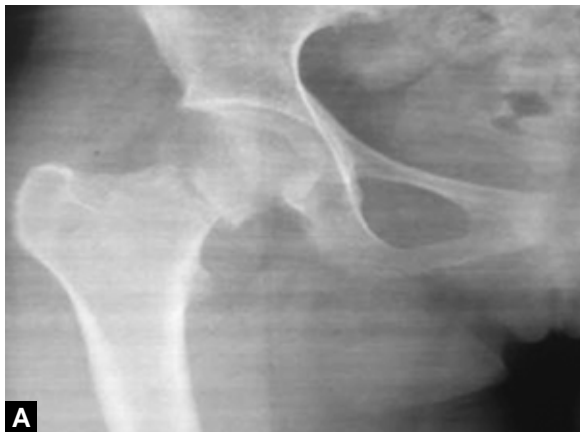
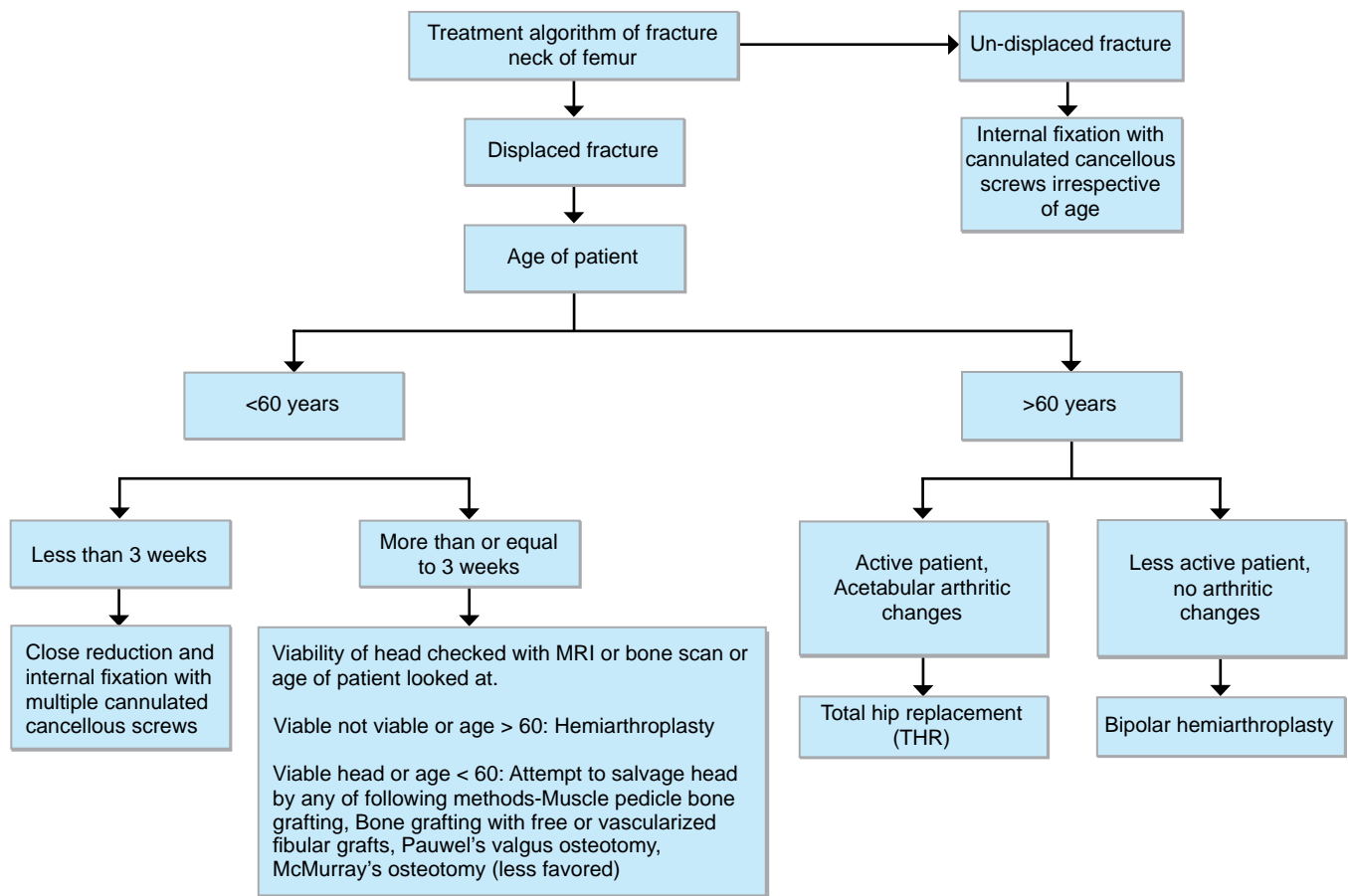


A



B

Figs. 2.124A and B: Garden classification of fracture neck of femur, (B) Pauwel's classification.

Flowchart 2.5: Treatment algorithm for fracture neck of femur.**Figs. 2.125A and B:** X-ray showing fracture neck of femur in 40 years old male fixed with multiple cannulated screws.

Meyer's Procedure

In neglected fracture neck of femur blood supply of femoral head may have been compromised. In Meyer's procedure the fracture is opened from behind and is fixed with cancellous screws. A vascularized (artery intact) Quadratus femoris based muscle pedicle bone graft is re-routed to be attached at the fracture site (Fig. 2.127). These osteo-muscular grafts provide an additional source of blood supply and promote healing.

Bone Grafting with Free or Vascularized Fibular Graft

Open reduction and internal fixation with added fibular bone grafting (Fig. 2.128) is done to hasten union. Cortical fibular bone grafts provide mechanical strength to weak osteoporotic bone in elderly in addition to stimulating the union. Vascularized fibular grafting (with intact blood supply, Fig. 2.129) is technically demanding procedure as it requires microvascular anastomosis but is biologically superior and speeds up union even better.

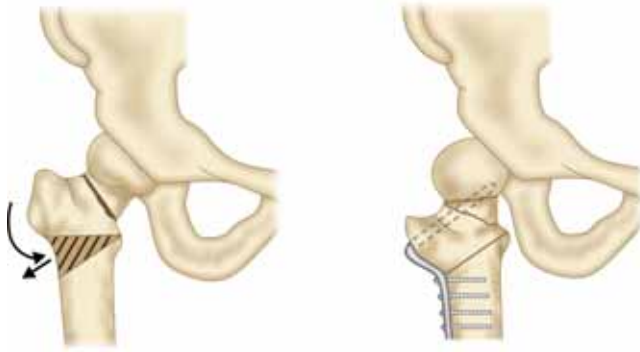


Fig. 2.126: Concept of valgus intertrochanteric osteotomy.

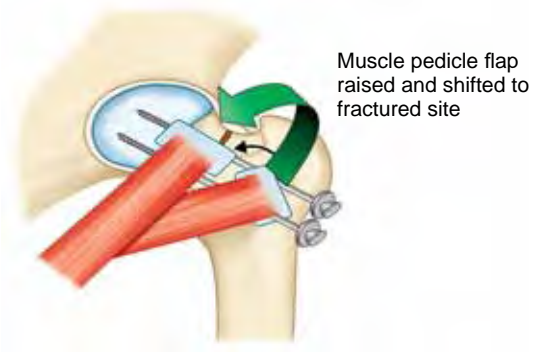


Fig. 2.127: Meyer's procedure.



Fig. 2.128: Neck femur fracture (arrows) reconstructed with fibular grafts (vascularized fibular grafts, arrows).

Pauwel's Osteotomy

Pauwel's osteotomy works on converting a vertical unstable fracture into a horizontal stable fracture so that shear stress turns into impaction force on weight bearing (Fig. 2.126). In this procedure a lateral based wedge of bone is removed from the area of lesser trochanter and the proximal fragment is rotated down to close the wedge shaped gap and fixed with an implant, such that after fixation, a vertically oriented fracture eventually assumes horizontal orientation (Figs. 2.126 and 2.130). Although a bit demanding procedure it is one of the favoured treatment options today.

McMurray's Osteotomy (Displacement Osteotomy or a Pelvic Support Osteotomy) (Fig. 2.131)

This was once a popular procedure in past but is not favoured now-a-days because of difficulty in future hip replacement and some unavoidable complications like shortened limb, limp. The osteotomy works on a "bio-mechanical" principle called as "arm chair effect" that basically describes the fact that the osteotomy bypasses the fracture site and redistributes the forces around it (like putting weight on arms while getting up from a chair bypasses legs and redistributes the forces from knee to elbows)

The osteotomy is done from the base of greater trochanter to the top of lesser trochanter and the distal fragment is displaced medially and abducted. The new line of weight bearing now passes from the acetabulum to the head, directly to distal fragment, bypassing the fracture site. Thus the mechanics have been altered as line of

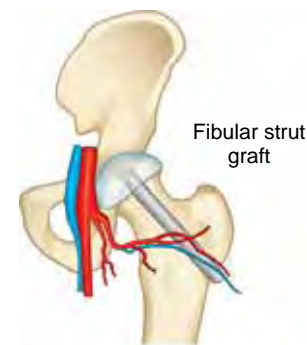


Fig. 2.129: Diagrammatic depiction of vascularized fibular graft.

weight bearing has been medialized. Also, abducting the distal fragment causes fracture line to become more horizontal which redistributes the forces making tensile forces become impaction forces under the stress of weight bearing. This creates a biological environment that hastens union, and hence the principle biomechanical.

Complications

- Avascular necrosis of hip (Fig. 2.132) is the most common complication of fracture neck of femur followed by nonunion (incidence AVN- 25% and Non-union- 20% in displaced fractures). It may take long time (1-2 years) for the signs of AVN (increased density of head, segmental collapse) to appear on plain X-rays. MRI can detect the problem well before the X-rays. In early stage (before collapse of head sets in) it can be prevented by performing a muscle pedicle grafting

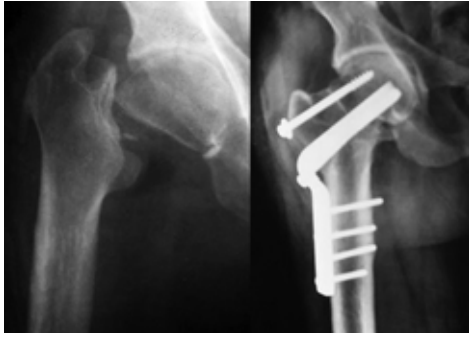


Fig. 2.130: Pauwel's osteotomy for a vertical fracture to convert it into a horizontal pattern.



Fig. 2.132: X-ray showing sclerosed and collapsed femoral head (post-surgery) having undergone AVN.

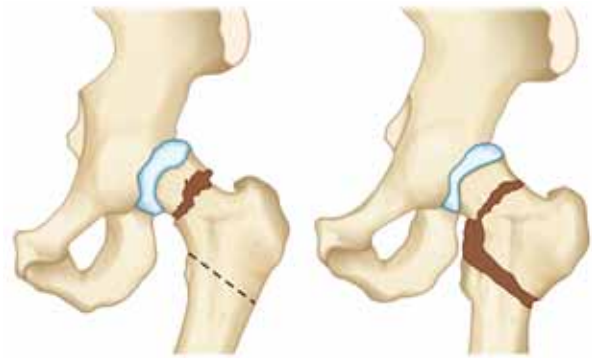


Fig. 2.131: McMurray's osteotomy.



Fig. 2.133: X-ray showing resorbed neck in a case of neglected neck femur with non-union.

(Meyer's procedure) to increase the vascularity. However, once collapse sets in lost head cannot be recovered. In this stage patient is offered three options:

- Arthrodesis/Fusion of joint:* Relieves pain, provides a stable construct but movement at joint is lost.
 - Replacement arthroplasty:* Movement good but in young chances of loosening of prosthesis
 - Excision (Girdelstone) arthroplasty:* Head and proximal neck is excised. The patient can walk as the space fills with tough fibrous tissue and range of motion is excellent but hip is unstable and patient cannot perform heavy work.
- Nonunion:** It is also a common complication. Chances are particularly high in severely displaced fractures. Delay in reducing and fixing the fracture is directly related to non-union and hence urgent treatment is the key in prevention.
 - Management in a patient > 60 years old remains hemiarthroplasty. In a young patient union can be hastened and head can be salvaged by those same procedures discussed above:
 - Meyer's procedure (Vascularized muscle pedicle bone grafting)—Increases blood supply to hasten union
 - Neck reconstruction (bone grafting with fibula)—Neck in prolonged cases is mostly resorbed (Fig. 2.133) and fibular grafts can be effectively used for reconstruction.

iii. Pauwel's osteotomy

iv. McMurray's osteotomy (can be used but is not a preferred option now-a-days)

- Osteoarthritis of hip joint is late sequel of fracture neck of femur. It is usually secondary to AVN and collapse of head. In advanced stages total hip replacement may be needed.

HIGH-YIELD POINTS

- Chances of AVN of head and nonunion of fracture neck of femur are maximum for subcapital fracture > transcervical > basal > intertrochanteric.
- Risk of AVN is directly related to delay in fixation, so urgent treatment is utmost priority.
- Screw fixation in neck femur generally involves putting atleast three cancellous screws in an inverted triangle pattern.
- Bakshi's procedure also involves vascularized muscle pedicle bone grafting but the muscle used is tensor fascia late (unlike Meyer where Quadratus femoris is used).

Fracture Neck Femur in Children (Fig. 2.134)

Fracture of proximal end of femur in children are rare and usually result from high velocity trauma (fall from



Fig. 2.134: X-ray pelvis with both hips AP view showing fracture neck of femur in an 8-year-old child.

Table 2.18: Delbet classification of pediatric hip fractures

Types

I. Transepiphyseal	Least common
II. Transcervical	This is most common
III. Cervicotrochanteric	Second most common
IV. Intertrochanteric	

height, RTA, etc). Delbet classification (Table 2.18) is most commonly used classification to classify these injuries.

Treatment

Conservative treatment (immobilization in hip spica/thomas splint) is associated with high rate of complications and often result in failure of reduction so internal fixation should be done whenever feasible. Undisplaced fracture in children below 3 years can be managed with hip spica in abduction.

Closed reduction internal fixation with percutaneous pinning (smooth Moore's pins or Knowles pins) and postoperative spica application in abduction and internal rotation is done in displaced fractures. Pediatric hip screw/DHS can be used in type IV cervicotrochanteric fractures.

Complications

Avascular necrosis of hip is the most common complication. Coxa vara is the next most common complication. Other complications include chondrolysis, premature physeal closure and limb length discrepancy.

INTERTROCHANTERIC FRACTURE OF FEMUR

This is an extracapsular fracture of proximal femur seen mostly in people above 70 years of age. Like fracture neck of femur these also usually result from low energy simple fall. Young people usually sustain these injuries in RTA.



Fig. 2.135: X-ray pelvis with both hips AP view showing Intertrochanteric fracture of right femur.



Fig. 2.136: X-ray hip joint AP view showing reverse oblique pattern of intertrochanteric fracture.

Clinical Features

Patients present with severe pain in hip joint with inability to bear weight on the involved hip. Swelling and ecchymoses around trochanter are common findings. All hip movements are painful and tenderness can be localized over the greater trochanter. Deformity is same as in the intracapsular fracture (shortening and external rotation) but it is far more apparent due to absence of a restraining capsule. Infact, the leg is often so much externally rotated that the lateral border of foot touches the couch. Diagnosis is confirmed by anteroposterior and lateral X-rays of involved hip.

X-ray (Fig. 2.135) shows the fracture line in trochanteric region which may involve greater or lesser trochanter or both. Based on the fracture pattern the fracture can be classified as stable and unstable (Evans classification). Unstable fracture pattern involves posteromedial comminution, subtrochanteric extension of fracture line and reverse oblique pattern (fracture line extending downwards from medial to lateral cortex, Fig. 2.136).

Treatment

Treatment of intertrochanteric fracture is essential surgery in all patients except those with untreatable medical conditions who are too ill to tolerate surgery and in patients with advanced dementia and psychiatric illness. Conservative

treatment of intertrochanteric fracture requires limb to be kept in below knee skeleton traction in bed until fracture unite and pain subsides (usually 6–8 weeks). Hamilton-Russell traction (Fig. 2.137) is most commonly used for conservative treatment of intertrochanteric fractures.

Operative treatment of intertrochanteric fracture is anatomical reduction of fracture and internal fixation. Fracture is reduced closed under guidance of X-ray image intensifier (Fig. 2.138) and fixed with internal fixation implant. DHS (dynamic hip screw) is most commonly used internal fixation device for intertrochanteric fracture (Fig. 2.139). It consists of a screw that can slide inside a barrel plate. As the patient bears weight, the screw slides inside the barrel and there is compression at fracture site that encourages union (Sliding compression/Controlled cancellous collapse). Intramedullary fixation device like proximal femoral nail (PFN), Gamma nail or Recon nail is recommended in unstable fracture pattern.

Surgery should be done as soon as possible as prolonged recumbency in elderly may cause decubitus ulcers (bed sores, Fig. 2.140) and chest problems like pneumonia and thromboembolic complications.

Complications

- **Malunion:** Since these fractures involve cancellous metaphyseal bone, they rarely fail to unite but if not properly reduced or if reduction fails to keep the fracture fragments aligned, malunion may result. Coxa vara and external rotation deformities are common. Usually these deformities do not cause much functional disability in elderly. Severe coxa vara deformity in young patients may require correction by intertrochanteric osteotomy as it interferes with abductor muscle function leading to Trendelenberg gait (*see above*).
- **Failed internal fixation:** Since most patients are severely osteoporotic, implant (screw) may cut out of the bone superiorly leading to failure. An eccentric placement also leads to this end result (ideally screw should be either in center or in postero-inferior aspect of head). This usually occurs before union (3–4 months) and may necessitate a revision surgery.
- Osteoarthritis rarely may be a late complication of malunited trochanteric fractures due to change in hip biomechanics.



Fig. 2.137: Hamilton-Russell traction for intertrochanteric fracture femur.



Fig. 2.138: Image intensifier is perhaps the most important innovation that has revolutionized the orthopedic surgery.

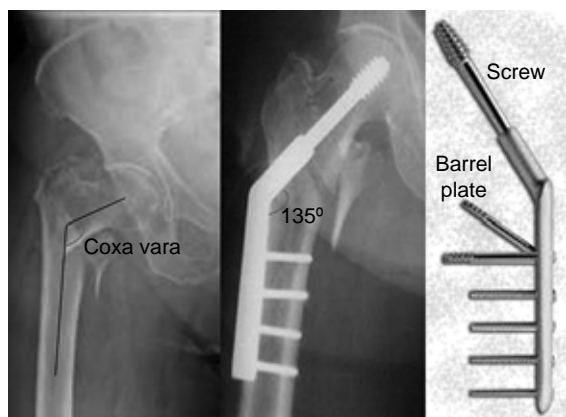
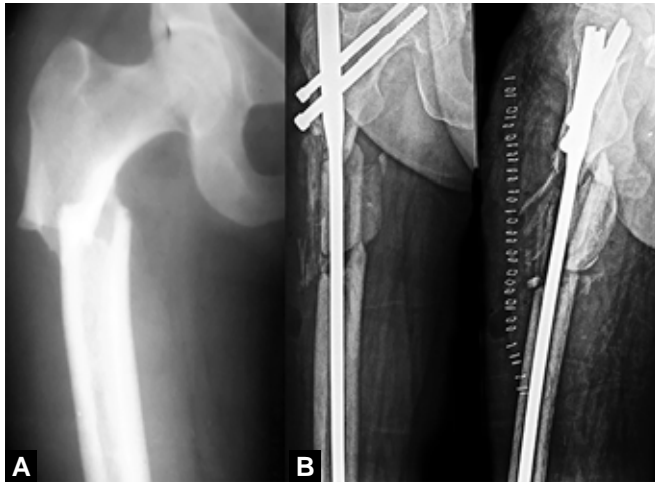


Fig. 2.139: X-ray AP view of hip joint showing intertrochanteric fracture and its fixation with DHS. Note the neck shaft angle has been restored.



Fig. 2.140: Bed sore-complication of prolonged pressure on the skin.



Figs. 2.141A and B: X-ray AP view of hip with thigh showing subtrochanteric fracture of femur and CRIF with proximal femoral nail (different patient).

SUBTROCHANTERIC FRACTURE (FIGS. 2.141A AND B)

These fractures occur below the lesser trochanter and up to 5 cm distal to it. In the elderly these fractures usually result from low energy fall whereas young person sustains these injuries in high velocity injuries. These are less common than fracture neck femur and intertrochanteric fractures. Patients present with severe pain in hip and inability to use involved limb. Limb is externally rotated and shortened. Diagnosis is confirmed by X-rays. A transverse fracture line in this area without history of significant trauma always should arouse the suspicion of the fracture being pathological. Treatment is essentially surgical. Close/Open reduction and internal fixation with intramedullary nail (i.e. PFN, recon nail, Enders nail or Gamma nail) or plate (dynamic condylar screw, condylar blade plate or DHS) is required (Fig. 2.141B).

FRACTURE SHAFT OF FEMUR

The femur is the longest and strongest bone of the body which is surrounded by thick muscle mass all around. Shaft is the area between 5 cm distal to the lesser trochanter and 5 cm proximal to the adductor tubercle. In young adults femoral shaft fractures are usually result of high velocity road traffic accidents. In elderly with severely osteoporotic bones low energy fall may be sufficient to cause femoral shaft fracture.

In children below walking age femur fracture usually results from child abuse. In older children high velocity road traffic accidents accounts for majority of fractures.

Muscle forces causing fracture displacement in femoral shaft fracture are depicted in Figure 2.142 and Table 2.19.

Fracture geometry largely depends upon the type of applied force. Geometry of fracture according to type of force is tabulated in Table 2.20 (common to fractures of all long bones).

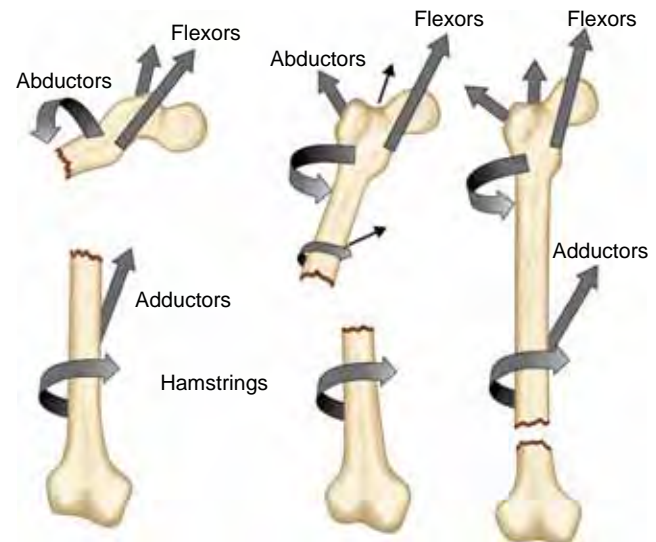


Fig. 2.142: Deforming forces in fracture shaft of femur.

Table 2.19: Deforming forces in fracture shaft femur

Fracture site	Proximal fragment	Distal fragment
Proximal third	Abducted and flexed by abductors and flexors of hip joint (iliopsoas)	Displaced upward and medially by the adductor and hamstring group of muscles
Middle third	Abducted but less as compared to proximal third fractures and flexed due to the iliopsoas muscle	Externally rotated by the weight of the foot and displaced upward and postero-medially due to the adductors and hamstring muscles
Distal third or supracondylar	Pulled in flexion and adduction by the iliopsoas and adductor muscles	Flexed posteriorly by pull of the gastrocnemius muscle.

Table 2.20: Common mechanisms of fractures

Type of force	Geometry of fracture
Bending	Transverse/oblique
Twisting/torque	Spiral
Moderate axial compression combined with bending and torsion	Oblique
High energy force and direct impact	comminuted

Classification

Winquist classification (Table 2.21, Fig. 2.143) is based on amount of comminution.

Clinical Features

All patients of femoral shaft fractures should be assessed on the basis of ATLS guidelines as most of them are high velocity road traffic accidents victims so have multiple

Table 2.21: Winquist classification of femoral shaft fracture

Type 0	No comminution
Type I	Minimal comminution at fracture site
Type II	More comminution than that in type I but more than 50% of the circumference of the cortices of two major fracture fragments remains intact
Type III	Comminution involves more than 50% of the circumference of the cortices of fracture fragments. Only a small area of contact is left between fracture fragments
Type IV	Comminution of entire bony circumference over a segment of bone, no contact between cortices

injuries. Diagnosis of femoral shaft fracture is usually straightforward. Patients present with pain, swelling, deformity and shortening of thigh. A careful examination of the involved limb should be done as concomitant ipsilateral hip dislocation, knee injuries and tibia fractures are not uncommon. It is imperative to secure an i/v access and closely monitor the vitals as the fracture is associated with a significant blood loss that can make the patient collapse due to shock. A rare but dangerous complication is fat embolism syndrome and splinting early (with Thomas splint) guards against both apart from avoiding additional soft tissue trauma during transportation. Diagnosis is confirmed by anteroposterior (AP) and lateral X-rays of the injured thigh. AP view of the pelvis and AP and lateral views of the ipsilateral knee should also be done.

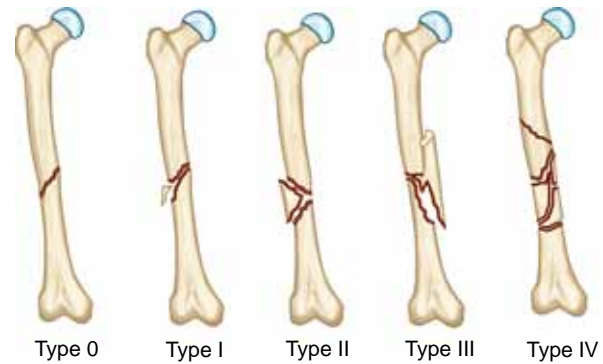
Treatment of Femoral Shaft Fracture

Treatment in fractures of shaft of femur is dictated by the age of the patient.

Age > 10 Years

Treatment of fracture shaft of femur in adults is essentially surgical. Nonoperative treatment (cast bracing and skeleton traction) is indicated only in patients with medical contraindication to anesthesia or surgery. Many types of skeleton tractions have been devised for fracture shaft of femur including Russel's traction (for distal femoral fracture), 90–90 traction for proximal shaft femur fracture. Skeleton traction (by placement of Steinman pin in distal femur or proximal tibia) is also applied for the temporary stabilization of femur until patient can be shifted to operation theatre for definitive fixation.

Operative treatment of choice for femoral diaphyseal shaft fracture in this age group is closed intramedullary interlocking nailing (Fig. 2.144). Küntscher revolutionized the management of diaphyseal fracture of shaft of femur by developing V-shaped intramedullary nail in early 40s and later cloverleaf model of intramedullary nail in late 40s. Present form of modern interlocking intramedullary nail has passed through several stages. In the 1950–60 surgeons used to do open nailing of femoral shaft fractures. In 1960 development of image intensifier allowed surgeons for close intramedullary nailing.

**Fig. 2.143:** Winquist classification of femoral shaft fracture.**Fig. 2.144:** X-ray hip with thigh AP and lateral views showing CRIF of femoral shaft fracture with femoral interlocking nail.

Close intramedullary interlocking nailing is minimally invasive technique in which close reduction of fracture is done under guidance of image intensifier. Medullary cavity is reamed with reamers and nail is placed into the medullary cavity. Modern interlocking nails have holes for proximal and distal interlocking screws which provide rotational stability to the fracture.

External fixator is indicated in open femoral shaft fractures and as temporary stabilization in severely injured patients who cannot tolerate intramedullary nailing (DCO). ORIF with plate is indicated in fractures extending into metaphyseal region.

In age 5 to 10 years: In children below 10 years of age interlocking nails cannot be used for fixation. These nails use greater trochanter as the entry portal and in children this may damage the growth plate in the region that is open till 10–12 years of age. Shaft fractures in these patients are preferably fixed by smooth nails (Rush nails) or elastic nails (Ender's nail and TENS-Titanium elastic nailing system) (Fig. 2.145). The elastic nails are bendable nails and need not be inserted via the trochanteric portal. They are inserted from the sides of metaphysis above the growth plate and 2 or 3 nails can be stacked inside the medullary cavity to provide stability.

6 months to 5 years: In stable fractures with shortening less than 3 cm, after acceptable closed reduction a hip spica cast is applied with hip in flexion (60°–90°) and abduction

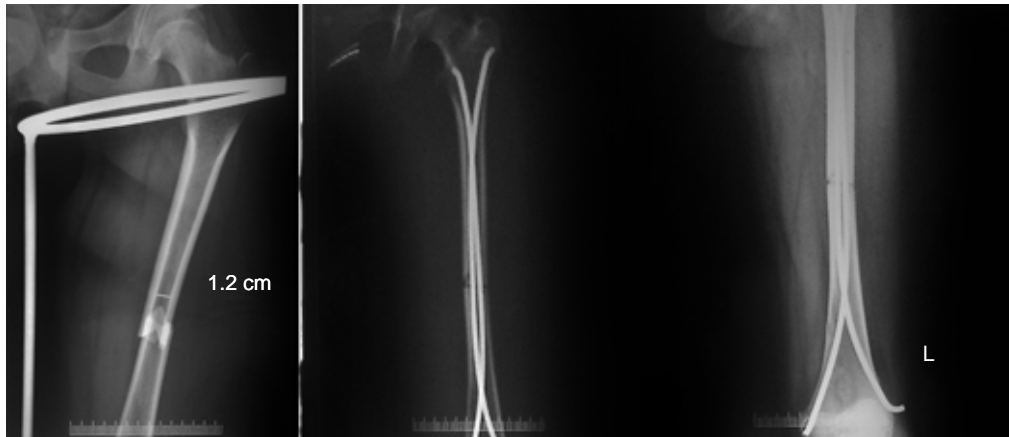


Fig. 2.145: Fracture shaft of femur in 9-year-old girl and its fixation with elastic nails.



Fig. 2.146: Hip spica for fracture shaft of femur in children less than 5 years.

(30°–45°) and knees in 90° flexion (Fig. 2.146) after well padding of the child. In case shortening is more than 3 cm skeletal traction may be given for a short period to distract and align and then a spica is applied. In children under the age of 2 years applying a spica directly is often difficult as the child is not cooperative. These children are initially managed with Gallow's (Figs. 2.147A and B) or Bryant's traction (Fig. 2.148) for 2–3 weeks till fracture becomes sticky or some callus is seen on X-rays and then a hip spica can be safely applied.

Up to 6 months: Pavlik harness is applied in 80°–90° hip flexion and around 45° hip abduction (Fig. 2.149). It does not require any anesthesia and allows for easy nursing and toilet care.

Complications

Early Complications

- **Fracture femur and blood loss:** The femur is the largest bone in the body and significant blood loss (1–1.5 liter or 2–4 units) may occur even in close fracture shaft of femur. Almost 40% of these patients eventually require preoperative blood transfusion. However in patients of fracture shaft femur with hypotensive shock other causes of blood loss (intraabdomen hemorrhage,

intrathoracic hemorrhage, head injury, etc.) should also be ruled out as very often these patients have multiple injuries.

- **Fat embolism syndrome (FES):** First described by Von Bergman in 1873, FES is a rare (less than 4% incidence) but a dangerous complication. It can be seen after fractures of femur, pelvis, and tibia, and, postoperatively, after hip and knee arthroplasty. This is more common in closed fractures (can occur in open fractures with severe soft tissue damage) and in patients with multiple fractures. Fat emboli occur in all patients with long bone fractures but only small numbers of patients develop FES.

Pathophysiology: It is not clear but two main theories have been put forward. According to the “mechanical theory”, fat emboli are released from the injured site into the blood. These emboli get lodged into the pulmonary vasculature and from there they travel to brain or cutaneous sites. Their lodging into microvessels causes ischemia and inflammation. According to the “biochemical theory”, hydrolysis of embolized fat by pneumocytes into free fatty acids cause toxic injury and inflammation in the lungs leading to acute lung injury and acute respiratory distress syndrome (ARDS). Trauma induced hormonal changes may cause systemic release of chylomicrons into the circulation which coalesce and get deposited into blood vessels.

Clinical features: Symptoms of FES usually develop 24–72 hours of injury and the risky period spans for over a week. The syndrome characterized by triad of pulmonary dysfunction, cerebral dysfunction and axillary and sub-conjunctival petechiae. The latter are non thrombocytopenic and result from occlusion of dermal capillaries by fat globules and subsequent extravasation of RBCs. Respiratory signs and symptoms appear earliest and include dyspnea, tachypnea, cyanosis and hypoxemia. Cerebral dysfunction manifests as confusion, drowsiness and may progress to convulsions or coma. Nonpalpable petechial rashes may appear in the chest, axilla and conjunctiva.



Figs. 2.147A and B: Gallow's traction for shaft femur in less than 2 years old. Note traction is applied on both legs. Weight should be just enough to lift the buttock off the bed.



Fig. 2.148: Bryant's traction (a modified form of Gallows traction where mattress is raised for counter traction).



Fig. 2.149: Pavlik harness is used for fracture shaft of femur in children below 6 months.

Investigations: Blood gas analysis (most important investigation) shows hypoxia and hypocapnia. Serial chest X-ray may show diffuse bilateral pulmonary infiltrates (Snow storm appearance). Fat globules may be detected in urine, blood and sputum on cytological examination. A formal way of establishing the diagnosis is by applying the Gurd's criteria (Table 2.22).

Treatment: The first step in treatment is prevention. Early splinting of fracture (by Thomas splint or external fixator) reduces the chances. In case the syndrome is established then treatment of FES is only supportive. Treatment aims at maintaining adequate oxygenation, ventilation and normal hemodynamics. I/V alcohol to dissolve fat, heparin (activates lipase and blocks thromboxane), aspirin and corticosteroids all have been tried with doubtful success but are better avoided as of today. Mechanical ventilation to maintain oxygenation is the best form of therapy today. With time the fat dissolves and the emboli are washed off. Corticosteroids may be useful in the setting of ARDS but most studies do not support much role. Early fracture fixation should be considered to prevent further embolism. Caution is to be exercised in nailing these patients. Unreamed nailing is preferred to prevent the fat emboli from dislodging from bone marrow.

Table 2.22: GURD'S CRITERIA for diagnosis of Fat Embolism syndrome

Major criteria	Signs of CNS depression PaO ₂ < 60 mm Hg Axillary and subconjunctival petechiae
Minor criteria	Pyrexia > 38.5 Pulse > 110/min Retinal embolism Reduced platelet count Fat globules in urine Fat globules in sputum Increased ESR

FES is diagnosed when atleast one major plus four minor criteria are present.

Neurovascular injury: Excessive traction during nailing may cause pudendal nerve palsy and presents with numbness of penis, scrotum or labia. Mostly it is neurapraxia only and recovery occurs within 3 months. Sciatic and peroneal injuries may also occur. Usually these are traction injuries (excessive stretching) and recover fully. Vascular injury is rare but femoral artery may be damaged by fracture fragment particularly at junction of middle and distal third of femur.

Infection: Infection may occur following surgery of close fracture shaft of femur. Incidence is low as intramedullary nailing is a minimally invasive surgery. Open contaminated fractures are at increased risk of infection and risk increases with increase in Gustilo grading of open fractures.

Late Complications

- **Knee stiffness:** Some degree of loss of flexion and extension lag is common after nailing of fracture shaft of femur. Scarring of quadriceps due to injury by fractured fragment or missed knee ligament injury is the most common cause. Treatment is dedicated post-operative physiotherapy. If knee stiffness persists even after 6 months of treatment, knee manipulation under anesthesia or arthroscopic arthrolysis of intraarticular adhesions of knee joint or quadricepsplasty may be required.
- **Malunion:** Angular deformities are more common in fractures of proximal third of femur. Valgus or varus angulation less than 10° are usually clinically insignificant. Arthritis can rarely develop in a malunited weight bearing long bone due to change of anatomical axis of limb and unequal load distribution of the joint. Rotational malunion may also occur following intramedullary nailing. External rotation deformity is more common although internal rotation deformity is more problematic. Significant malunion (> 15° of rotational deformity and > 10° of angular deformity) may require osteotomy. In adults after femoral shaft fracture reduction, angulation and rotation should be less than 10 degrees. In children below 12 years up to 25 degrees of angulation and rotation are acceptable.
- **Delayed and nonunion:** With appropriate treatment a shaft femur fracture generally unites in about 100 days (3–4 months), however, there is no uniformly acceptable definition of delayed and nonunion in fracture shaft of femur. Most surgeons agree for 6 months beyond which a fracture shaft femur can be labeled as having gone into delayed union. Incidence of delayed and nonunion is low with modern interlocking intramedullary nailing. Treatment of delayed union is bone grafting. Nonunion after intramedullary nailing requires removal of nail and overreaming of medullary

canal and placement of larger nail (exchange nailing) with bone grafting.

- **Heterotopic ossification:** Heterotopic bone formation is not uncommon after intramedullary nailing and most common sites are at entry point of nail and around GT. Head injury is the most common associated risk factor. Surgical excision is rarely required.

HIGH-YIELD POINT

- The most common fracture associated with fat embolism syndrome is femur fracture. Bilateral fractures and multiple fractures are associated with greater incidence.
- Fracture of middle third and transverse fracture (caused by bending load) is the most common location and type of femoral shaft fracture respectively.
- However, in children the fractures most commonly involve the upper third while pathological fractures especially in elderly involve the relatively weak metaphysis-diaphyseal junction.
- Nails used for femur can be inserted antegrade (from greater trochanter) or retrograde (from intercondylar area of distal femur). Mostly antegrade nailing technique is used to avoid opening the knee joint. However, retrograde nails are easier to insert owing to easy identification of entry point and are used in obese patients, floating knees (simultaneous lower femur and upper tibia fractures as both bones can be nailed from one incision) and periprosthetic fractures in a TKR patient.
- The diameter of the nail that can be inserted in femur is decided by measuring the diameter of isthmus, the narrowest part of the medullary cavity of femur.
- Knee ligament injuries are most common associated injury and fracture neck femur is the most commonly missed concomitant fracture with fracture shaft of femur.
- **Waddell's triad:** Femoral fracture plus head injury plus intrathoracic/intraabdomen injury. It is seen in pediatric pedestrian who are struck by motor vehicles.
- Lower limb fractures with maximum shortening are posterior dislocation of hip > femoral shaft fracture > subtrochanteric femur fracture > Inter-trochanteric fracture > Intracapsular neck femur fracture.

LIGAMENT, CARTILAGE AND MENISCAL INJURIES OF KNEE JOINT—CLINICAL EXAMINATION AND MANAGEMENT

Knee is the largest joint of body consisting of tibiofemoral and patellofemoral articulations. Tibiofemoral joint is a modified synovial hinge joint between femoral condyles and tibial plateau allowing flexion and extension and some medial and lateral rotation in flexion. Patellofemoral

joint is a synovial joint in which patella glides over femoral trochlea with knee movements. Patella has least contact with femur in extension where only lowest patellar facet contacts with femur. With increasing flexion this contact area increases (maximum contact at 90 degree of flexion).

HIGH-YIELD POINTS

- Patella is the largest sesamoid bone in the body within the quadriceps tendon. It has the thickest articular cartilage (8 mm thick) and still is the most frequent site of articular cartilage degeneration.
- Patella moves upwards on extension of knee and rides down within the trochlear groove in knee flexion. It is centered in the trochlear groove at about 30 degree of knee flexion.
- Fabella is a sesamoid bone present in the tendon of lateral head of gastrocnemius muscle. The ligament that extends from the fabella to fibular head (fabello-fibular ligament) is called the Ligament of Valloise.

RELEVANT ANATOMY

The tibial condyles are flat as opposed to the femoral condyles that are rounded. Hence, like the shoulder knee joint is inherently unstable and stability is largely dependent on surrounding capsulo-ligamentous complex.

Ligaments and menisci primarily stabilizing the knee joint are (Fig. 2.150):

- Collateral ligaments (Medial and Lateral)
- Cruciate ligaments (Anterior and Posterior)
- Menisci (Medial and Lateral)

COLLATERAL LIGAMENTS (FIG. 2.151)

This group includes the medial and the lateral collateral ligaments that are extraarticular and extra synovial. Their attachments are as follows:

Lateral collateral ligament (LCL)/Fibular collateral ligament: It extends from the lateral femoral epicondyle to apex of the head of fibula.

Medial collateral ligament (MCL)/Tibial collateral ligament: It begins from the medial epicondyle (exactly little proximal and posterior to the epicondyle) of femur and runs down to attach on the medial condyle of tibia

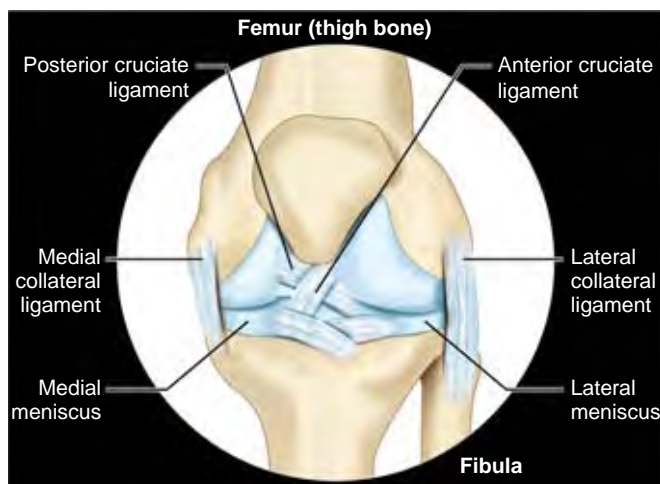


Fig. 2.150: Anatomy of knee joint

approximately 6–7 cms distal to the joint line. It is further divided into superficial and deep fibers. The main functional role is played by the superficial part. The deep MCL is basically a thickening of medial aspect of the joint capsule only lying deep to the superficial MCL. It has the meniscofemoral (part between femoral attachment and outer surface of meniscus) and meniscotibial (part between tibial attachment and outer surface of meniscus) components. The meniscotibial component is also called as the medial coronary ligament of knee (Fig. 2.151). Lateral coronary ligament is a capsular thickening which connects the lateral meniscus to lateral condyle of tibia. Popliteus tendon passes through a hiatus in the lateral coronary ligaments (popliteus hiatus) to attach to the lateral condyle of femur.

Function of collateral ligaments: The collateral ligaments are present on either sides of the knee joint. Their prime role is to provide stability against a varus or a valgus force. For example as shown in Figure 2.152, if a valgus stress (distal to joint, limb moves outwards) is given to the knee, the MCL is stretched and torn and vice versa. So, collateral ligaments basically stabilize the knee joint in the coronal plane (varus stability—LCL and valgus stability—MCL).

Cruciate Ligaments

These include the anterior and the posterior cruciate ligaments that classically cross centrally in the joint in the shape of an “X” when viewed from the front. Both these are intra articular ligaments but are considered to be extra synovial in nature (as they have their own synovial sheath that contains their neurovascular supply and hence do not derive their nutrition from synovial fluid). Their anatomy and course is as follows:

Anterior cruciate ligament (ACL): It takes origin from medial wall of lateral femoral condyle (posteriorly in the area of the inter-condylar notch) and courses anteriorly and medially to insert on the inter-condylar area of the

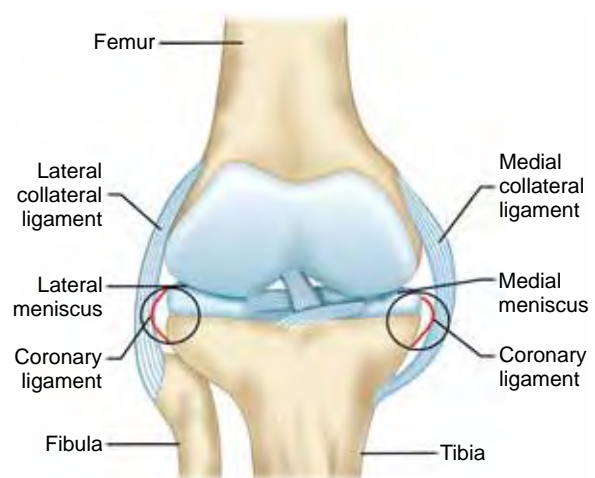


Fig. 2.151: Diagram depicting the coronary ligaments of the knee.

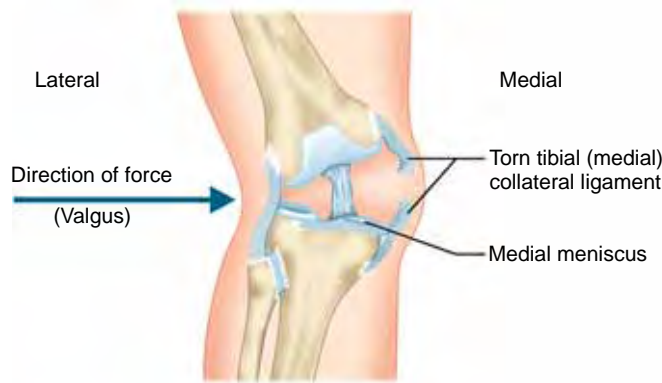


Fig. 2.152: MCL getting stretched and torn in valgus stress to the knee.

tibia. In other words, it starts anteriorly from the intercondylar area of tibia and goes back to insert on the lateral condyle of femur (Fig. 2.153). In a more detailed description, ACL is portrayed to consist of two bundles anteromedial bundle (bulkier), which is tight in flexion, and a posterolateral bundle, which is tight in extension.

Posterior cruciate ligament (PCL): This ligament has a course entirely opposite to that of ACL. It takes origin from lateral wall of medial femoral condyle (anteriorly in intercondylar notch) and courses posteriorly and laterally to insert on an area that is around 1.5 cms posterior and inferior to the posterior articular margin of the tibia. In other words, it starts posteriorly on the tibia and courses in front to attach on the medial condyle of femur, running exactly opposite to the course of ACL (Fig. 2.153). It also consists of two bundles anterolateral which is tight in flexion and a posteromedial bundle (bulkier) which is tight in extension.

Function of cruciate ligaments: Since the ACL runs from front on tibia coursing back to attach on femur, it will be stretched when the tibia moves forwards on femur while the PCL would stretch when the tibia is forced back on the femur. Hence, these ligaments function to provide the knee stability in the antero-posterior direction. ACL prevents the tibia from displacing forwards on femur while the PCL prevents the tibia from displacing backwards on femur (Fig. 2.153). Thus, their prime role is to stabilize the knee in the sagittal plane of the body. However, these ligaments also have a minor accessory function. The ACL is a secondary restraint to internal rotation of tibia and resist varus displacement at full extension while the PCL is a secondary restraint to external rotation of tibia and resists valgus displacement at full extension.

Menisci

Menisci are the wedge shaped semi-lunar fibro-cartilagenous disks (made primarily of Type I collagen) that are sandwiched between the opposing femoral and tibial condyles. These are intraarticular and intrasynovial structures that

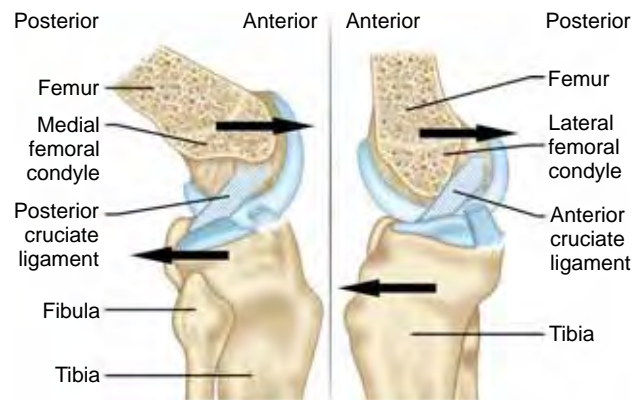


Fig. 2.153: Schematic representation of ACL and PCL on a sagittal section of knee.

derive their nutrition primarily from synovial fluid. Each meniscus has a posterior horn, a body and an anterior horn. Anterior horn is attached in front on the intercondylar tibia and the body courses back along the outer margins of the tibial condyles to insert as the posterior horn on the back of the intercondylar tibia (Fig. 2.154). Also they are attached to the tibia via the coronary ligaments (see Fig. 2.151 above). The medial meniscus is larger than the lateral, the latter being more circular while the former is more elliptical.

Function of menisci: Their prime role is to convert the flat tibial condyles into sockets so that the femoral condyles fit nicely into them. They also have a few accessory functions. They are elastic structures and hence act as the shock absorbers in the knee on axial loading and protect the articular cartilage by dissipating the forces (hence absence of menisci leads to arthritis). They also play some role in the nutrition in the joint as they are involved in distribution of the synovial fluid.

Comparison of medial and lateral meniscus is depicted in Table 2.23.

Miscellaneous Knee Ligaments

Menisco-femoral ligaments (Fig. 2.155): Two menisco-femoral ligaments attach the posterior horn of lateral meniscus to intercondylar wall of medial femoral condyle. The ligament of Humphry passes anterior to the PCL, whereas the ligament of Wrisberg passes posterior to the PCL.

Posterior oblique ligament (POL) and oblique popliteal ligament (OPL): POL is a condensation of the postero-medial capsule that strengthens the knee on the postero-medial aspect. The knee is also strengthened on the medial side by a slip from the semi-membranosus as it inserts on the postero-medial tibia. This is called the Oblique popliteal ligament.

Postero-lateral corner ligaments (PLC): Postero-lateral corner of knee (Figs. 2.156A and B) refers to structures that stabilize the postero lateral aspect of the knee. They consist

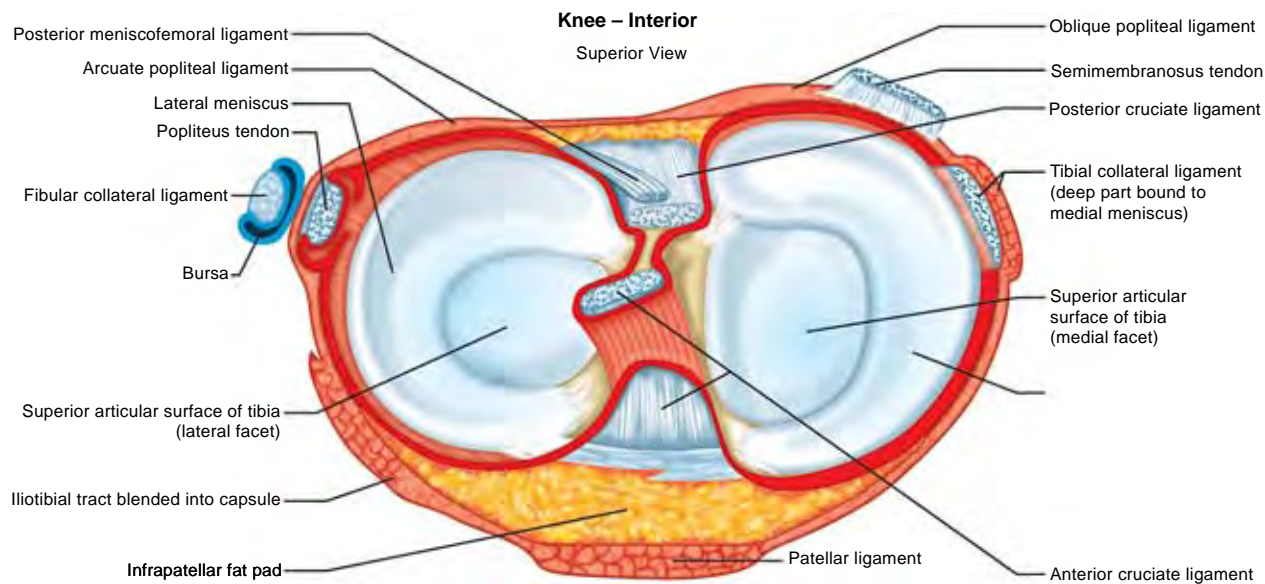


Fig. 2.154: View of the tibial plateau from above showing the two menisci.

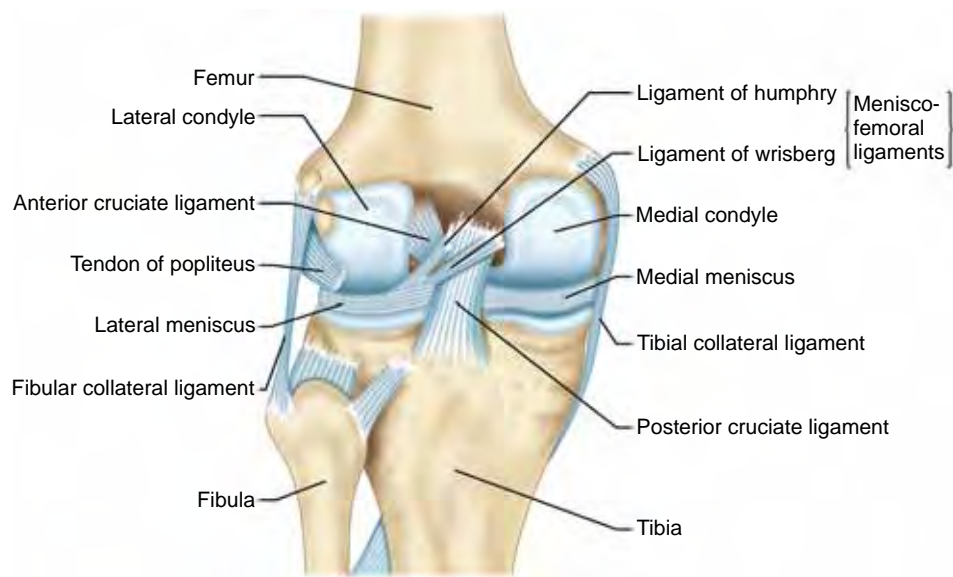
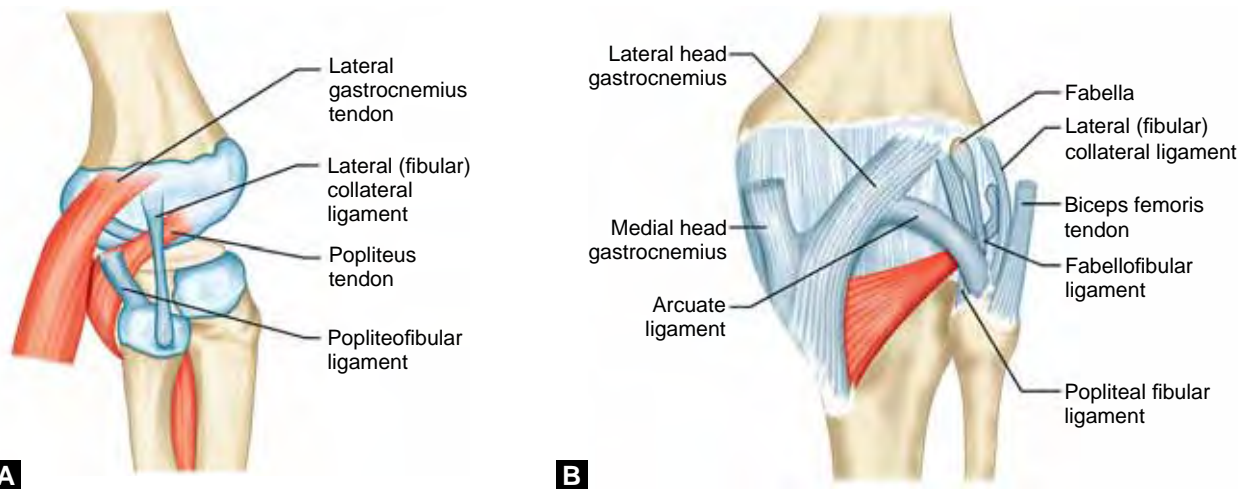


Fig. 2.155: Posterior view of knee joint showing meniscofemoral ligaments.

Table 2.23: Comparison of medial and lateral menisci		
Features	Medial meniscus	Lateral meniscus
1. Shape and attachment	C shaped but more elliptical. Wider of the two. Anterior horn is attached anterior to ACL insertion in Intercondylar fossa. Posterior horn is attached anterior to PCL in posterior part of Intercondylar fossa.	Semi-circular in shape. Anterior horn is attached adjacent to the ACL and anterior to lateral tibial tubercle. Posterior horn is attached posterior to lateral tubercle in the Intercondylar fossa.
2. Fixity	Peripherally attached to medial capsule and MCL, so it is less mobile.	Its attachment to the capsule is interrupted by the passage of the popliteal tendon (popliteus hiatus in coronary ligament), hence it is more mobile.

of the LCL, popliteus tendon, popliteal fibular ligament, arcuate ligament (Y shaped thickening of the capsule on postero lateral side between popliteus muscle and lateral gastrocnemius muscle) and the fabello fibular ligament.

The PLC works in coordination with PCL to strengthen the knee from the postero lateral aspect and prevents excessive hyperextension of knee, varus angulation and tibial external rotation.



Figs. 2.156A and B: Structures making up the postero-lateral corner of the knee as viewed from lateral (A) and posterior (B) aspect.

MECHANISMS OF INJURY

Knee ligament tears are very common injuries amongst sports persons. The following forces can act to disrupt these ligaments during sports injuries:

- Valgus or varus force
- Hyperextension or hyperflexion force
- Rotation force
- Combined forces

Valgus or Varus Injury to the Knee

Valgus injury to the knee occurs when there is a blow to the outside of the knee (Fig. 2.157A). The tibia is forced outwards with respect to the femur stretching and tearing the MCL, mostly from its femoral attachment (Fig. 2.157B). An exactly opposite situation can be expected in a varus injury that would injure the LCL. As the likelihood of varus force is less, LCL is torn less often, especially in isolation.

Hyperextension and Hyperflexion Injury

A hyperextension injury is a very common injury that occurs when a grounded leg gets stuck and knee hyperextends (Fig. 2.158A). Since the leg is grounded, for the knee to extend the femur has to move back on tibia. In other words the tibia has moved forwards with respect to the femur and this tears the ACL (Fig. 2.158B).

A hyperflexion injury would thus conversely tear the PCL. However, PCL injury is more commonly seen when there is a posterior blow to a semi flexed knee (Fig. 2.159). This can also occur during a dashboard injury.

Rotational Injury to the Knee

When a rotation force is applied to the knee, the menisci are churned in between the rotating condyles tearing them. Hence, in a twisting injury to a semi flexed (rotation is not possible in an extended knee as it is physiologically locked) weight bearing knee, the meniscus is sucked in and

nipped off between femur and tibial condylar surfaces, the medial meniscus tearing much more often than the lateral.

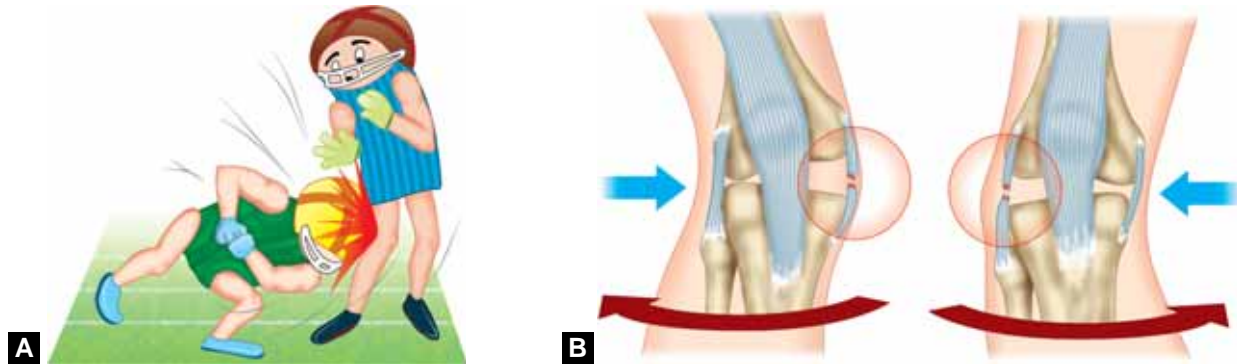
Combined Forces

More commonly in practice the forces that disrupt the knee ligaments tend to act in combination and thus isolated ligament tears are rarely seen. Infact, it is argued that isolated tears reported are cases where the other ligaments have healed up. Thus on most occasions the orthopedic surgeon is confronted with different patterns of knee injuries where different forces tend to tear a different set of ligaments. The most common pattern that presents to the orthopedic clinic is the well known, "O'Donoghue's unhappy triad of knee injury" where the ACL, MCL and the medial meniscus all three are torn simultaneously. It usually occurs when a combination of forces cause valgus and flexion at knee with internal rotation of femur on tibia as when a running athlete abruptly changes his direction leading to a non-contact pivoting of the knee. Both MCL and medial meniscus are adherent structures and hence tear out very easily forming a part of this complex.

Another characteristic pattern of knee injury that is important for the clinician is the Segond fracture (Fig. 2.160). Here there is a chip of bone visible on the lateral side of tibial plateau (because of avulsion of capsule from lateral tibia) that occurs almost always in combination with an ACL tear. The surprising fact is the mechanism. This fracture occurs after varus and internal rotation force while the ACL tear in O'Donoghue's triad involves valgus stress.

CLINICAL PRESENTATION

Most patients present with complaints of knee pain and swelling following a knee injury. Swelling is abrupt in case of cruciate ligament tears as there is hemarthrosis from tearing of vessels that stretches the capsule, the most pain sensitive structure in the joint. However, in meniscal



Figs. 2.157A and B: (A) Schematic depicting of valgus injury to the right knee (note distal to knee leg going laterally); (B) Diagram depicting torn MCL in valgus injury and torn LCL in varus injury.



Figs. 2.158A and B: (A) Schematic depiction of knee hyperextension occurring during sports injury; (B) Schematic depiction of ACL tear in a hyperextended knee.

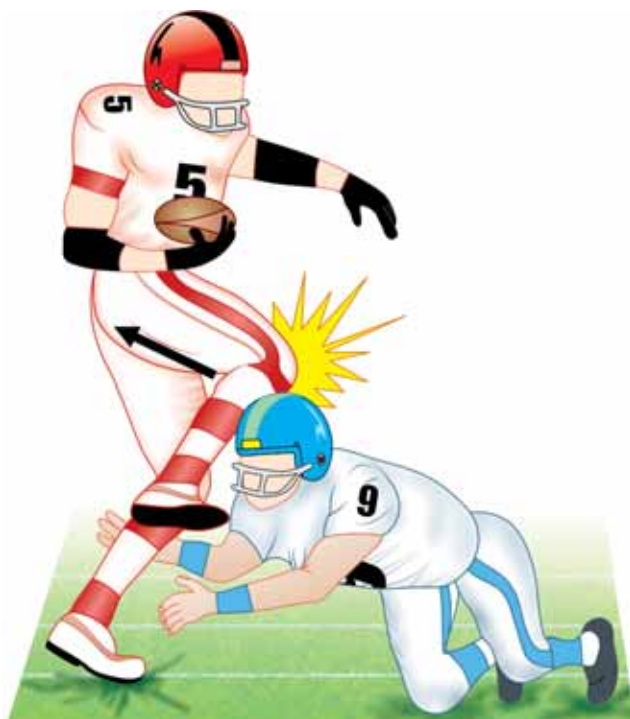


Fig. 2.159: Schematic depiction of PCL injury mechanism.



Fig. 2.160: X-ray showing Second fracture where ACL is torn in the intercondylar area and a chip of bone (capsular avulsion from tibia) has avulsed from lateral tibial plateau (arrow).

tears the swelling appears after a night as it is mainly a synovial reaction to the injury, the menisci primarily being avascular.

When these patients present a few days after the injury, one can enquire about a history of a pop or a click. Often a torn piece of meniscus entrapped in the joint gives

a clicking sound on flexion extension of knee as would occur in climbing up or down the stairs. At times, the torn part is large. It can get trapped in between the condyles restricting the knee from full extension, a condition called as Locking of the knee. The locking usually gets resolved with subsidence of swelling, but it may occur from time to time, either resolving by itself or requiring manipulation by the patient or the doctor.

The patients with cruciate ligament tears tend to have an extra sagittal motion in their knee that can present with a sensation of giving way of the knee. They express a feeling of buckling or instability in the knee (as the knee would dislocate) if they try to run or stress their knees. An indirect way is to enquire the comfort while climbing uphill or downhill. In going downhill one has to put a hyperextended knee of the ground and hence patients with ACL injury are troubled while the reverse occurs in PCL injury patients.

In patients with any clinical signs suggestive of ligament disruption, a good clinical examination is mandatory.

CLINICAL EXAMINATION

Following clinical tests are done to test the integrity of the knee ligaments.

Testing for Collateral Ligaments

Collateral ligaments are best tested by stress tests. Examiner keeps one hand on knee of patient and with other hand holds the leg to give a varus or valgus stress

to the knee. Varus and valgus tests are shown in Figures 2.161 and 2.162 and the interpretation of these tests is given in Table 2.24. Performing the tests at 30 degree knee flexion relaxes other structures in the knee and one can specifically isolate the testing to the collateral ligaments.

Testing for Cruciate Ligaments

The conventional test for anterior cruciate ligament injury is the Anterior Drawer test (Fig. 2.163) while a more sensitive and a better test is the Lachman test (Fig. 2.164). PCL on the other hand can be tested by the Posterior drawer test, by Godfrey's posterior sag or by the Quadriceps active test. A complete description of all the tests is given in Table 2.25.

Testing for the Menisci

Although a number of tests are described for meniscal injuries as shown in Table 2.26 below, the best test for meniscal injury today is considered to be the Joint line tenderness.

IMAGING

Plain X-rays may show avulsion fracture of the tibial spine by ACL or back of upper tibia by PCL. A Second fracture (see Fig. 2.160) can be recognized on plain radiographs wherein the ACL is ruptured. In chronic cases of MCL tear one may spot calcification at the femoral insertion of MCL, called as Pellegrini Steida lesion (Fig. 2.169, see below). The imaging modality of choice (IOC) is the Magnetic



Fig. 2.161: Varus stress test.



Fig. 2.162: Valgus Stress test.

Table 2.24: Varus and Valgus stress tests for collateral ligament injury*

	<i>In 30 degree knee flexion</i>	<i>In full knee extension</i>
Varus stress test (Fig. 2.161)	If lateral joint opening occurs it indicates LCL injury	If lateral joint opening occurs it indicates LCL plus PLC injury
Valgus stress test (Fig. 2.162)	If medial joint opening occurs it indicates MCL injury.	If medial joint opening occurs it indicates concomitant posteromedial capsule and posterior oblique ligament (POL) injury in addition to MCL injury.

*More than 10 mm opening indicates complete tear of ligament



Fig. 2.163: Anterior drawer test for ACL injury.



Fig. 2.164: Lachman's test for ACL injury.

Table 2.25: Testing for the cruciate ligaments

Test for ligament injury

Anterior Drawer Test (Fig. 2.163)	With knee flexed to 90° and feet resting on the couch (it is useful to sit on the foot of the patient to prevent the feet sliding forward), the examiner grasps the upper tibia with both hands, and making sure the hamstrings are relaxed, pushes the upper tibia anteriorly. Up to 3 mm of forward movement of the tibia is considered normal. The Grading for the test is: Grade 1 = 5 mm, Grade 2 = 5 to 10 mm, Grade 3 > 10 mm. Anterior Drawer test has low sensitivity, especially after an acute injury due to the protective spasm of the hamstring muscles. Also, any large swelling in the knee, and any effects of the posterior horn of the medial meniscus can cause a decrease in the sensitivity.
Lachman test (Fig. 2.164)	This test was originally described by JS Torg. The knee is flexed to 20°, with one hand grasping the lower thigh and the other the upper part of the leg; the joint surfaces are moved back and forth. If the ACL is torn there would be gliding. Lachman test is more sensitive than anterior drawer test in diagnosing ACL tears.
Posterior Drawer test (Fig. 2.165)	With knee flexed to 90° and feet resting on the couch (it is useful to sit on the foot of the patient to prevent the feet sliding forward), the examiner grasps the upper tibia with both hands, and making sure the hamstrings are relaxed, pushes the upper tibia posteriorly. If the tibia glides posteriorly against the femur Posterior drawer test is positive.
Godfrey's posterior sag (Fig. 2.166)	The hips and knees of both limbs are flexed to 90° and both the limbs are suspended by holding them by the toes. If PCL of any side is torn, the leg on that side sags posteriorly.
Quadriceps active test	In PCL tears, at 90° of knee flexion, when viewed from side, backwards displacement of the upper tibia is visible (Posterior Sag). In this position, the examiner's hand supports the thigh and resists knee extension by keeping a hand at the ankle. The patient is then told to actively contract the quadriceps. A posterior sag caused by torn PCL is corrected when the quadriceps contracts.

Table 2.26: Tests for meniscal injuries

McMurray's test (Fig. 2.167)	With the patient supine, and the knee is acutely flexed, grasp the heel in one hand. Place the other hand over the knee, with the thumb and fingers on the joint line. Gently externally rotate the tibia and passively extend the leg from flexion. A palpable painful clicking at medial joint line is considered a positive test for medial meniscus tear. For lateral meniscus tear internally rotate the leg while extending the knee. Painful clicking along the lateral joint line is considered to be a positive test.
Apley's test (Fig. 2.168A)	With the patient prone the knee is flexed to 90° and rotated while applying a compression force, if symptoms are reproduced meniscal tear is present. (Apleys grinding test) The same maneuver is now repeated but with leg pulled up (thigh pressed down with other hand), if symptoms are reproduced ligament tear is present (Apley's distraction test).
Thessaly test (Fig. 2.168B)	In this test patient is asked to stand on test leg with knee 5° flexion (other leg is in air with flexed knee). The patient may hold the hands of examiner for balance during the test. Now patient rotates the knee and the body medially and laterally three times. Same test is now repeated in 20° knee flexion. A positive test is indicated by joint line discomfort or locking/catching sensation. This test is claimed to have high diagnostic accuracy (in 20° flexion) and is being used as a first line screening test. This test reproduces the active dynamic loading of the knee joint.



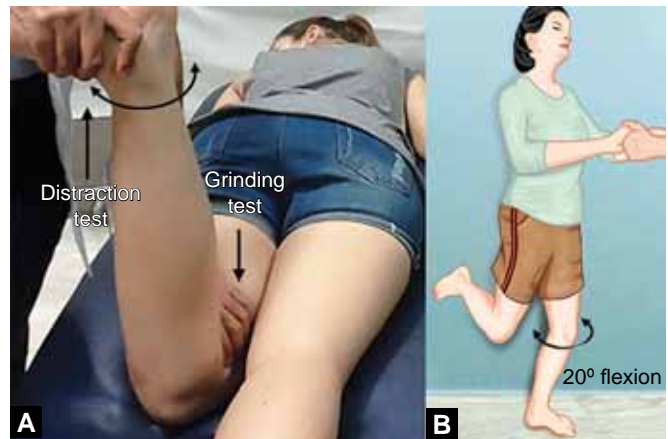
Fig. 2.165: Posterior drawer test for PCL tear.



Fig. 2.166: Godfrey's posterior sag.



Fig. 2.167: McMurray test.



Figs. 2.168A and B: (A) Apley's test and (B) Thessaly's test.



Fig. 2.169: X-ray knee showing calcification at the femoral attachment of MCL (Pelligrini Steida lesion) (arrow).

resonance imaging (Figs. 2.170A and B). However, arthroscopic evaluation of the knee is considered the gold standard for diagnosing intra articular knee ligament tears (but it's not IOC as it is invasive) and final treatment decision is based on that. However diagnosis of PCL tear is mainly based on the clinical examination (Positive posterior drawer test).

MANAGEMENT

The patients who present with acute knee injuries tend to be in pain and an examination is often difficult. In such a situation a wise option is to institute the RICE therapy (rest to the limb, ice fomentation, compression and elevation of the affected part to reduce swelling). The patient is advised physiotherapy for a period of 3–4 weeks and returns for the examination once the desired range of motion (> 90 degree) is attained. Once the patient presents again a thorough history, clinical examination and necessary investigations are done to reach the final diagnosis and then further management depends on the structures that are torn.

Collateral Ligament Tears

Most collateral ligament injuries heal excellently with conservative treatment only. Knee is braced and patient is instructed for protected weight bearing with crutches. Once pain improves, range of motion (ROM) exercises is started. When patient gains full ROM crutches are discarded (usually in 4–6 weeks). A surgical repair (end to end suture) is mostly indicated in complete tears.



Figs. 2.170A and B: (A) MRI showing intact (A1) and torn (A2) ACL; (B): MRI showing normal (B1) and torn (B2) Meniscus.

Cruciate Ligament Tears

Partial ACL tears are managed conservatively. Knee is kept in a long brace and partial weight bearing is allowed with an ambulatory aid gradually progressing to full weight bearing. With dedicated physiotherapy the patient usually return to sports by 6–8 weeks. Isolated complete tears of the ACL in athletes should be managed by early arthroscopic reconstruction (reconstruction refers to replacement of the torn ligament with a tendon graft), however, in middle aged population and non-sports persons a trial of neuromuscular rehabilitation (knee brace, quadriceps and hamstring exercises) may be given. Those who complain of residual instability after conservative management are then managed by arthroscopic ACL reconstruction.

Isolated PCL tears are given a conservative trial. Patients complaining of instability after conservative management need arthroscopic PCL reconstruction.

Arthroscopic cruciate ligament reconstruction: In arthroscopic cruciate ligament reconstruction tendons are harvested from the patient (most commonly hamstrings-semitendinosus and gracilis) and fixed in tibial and femoral tunnels with screws/endobuttons (Fig. 2.171).

Meniscal Tears

Although meniscal tears are mostly seen in young patients who sustain a twisting injury to knee, meniscal tears

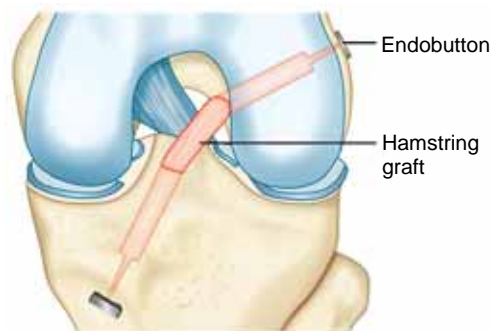


Fig. 2.171: Anterior cruciate ligament (ACL) reconstruction—Hamstring tendon fixed in femoral and tibial tunnel fixed with endobuttons.

become more prevalent with age due to degenerative changes in the ageing meniscus. Underlying pathology in a meniscus such as a discoid meniscus (*see below*) or a meniscal cyst (*see high-yield points*) also makes it more prone to injury.

Medial meniscus is less mobile due to its peripheral capsular attachment and attachment to MCL. Also popliteus sends few fibers into the posterior margin of the lateral meniscus, thus withdrawing it posterolaterally during flexion of the knee thereby preventing it from getting caught between condyles of femur and tibia. Hence medial meniscal tears (particularly of posterior horn) are much more common than lateral meniscal tears.

Classification of Meniscal Tears

Meniscal tears are classified based on tear pattern or by their proximity to blood supply. Various tear patterns have been described (Table 2.27).

These tears can then be further classified by their proximity to the meniscus blood supply, namely whether they are located in the “red-red,” “red-white,” or “white-white” zones (Fig. 2.172).

Only the peripheral 10–30% of the meniscus is vascularized (red-red zone) and has pain fibers. Peripheral meniscal tear in red-red zone have the maximum healing chances whereas central meniscal tears in white-white zone do not heal.

Treatment

Peripheral tears in red-red zone may heal by conservative therapy. Other tears rarely heal due to poor vascularity and need to be treated surgically.

Following surgical options are available:

- Meniscus repair:** Acute and simple meniscal tears, in peripheral zone (red-red and red-white) can be repaired by suturing (stitching) the torn pieces together.
- Arthroscopic meniscectomy:** A degenerative tear, complex tear or a tear in the inner margin of meniscus (white-white zone) is not amenable to repair and is trimmed away. Depending on the size of tear meniscectomy may be partial or subtotal.

ROTATORY INSTABILITIES OF KNEE

Just as in shoulder, instability can also exist at knee. In patients with chronic ligament tears, over time the capsule and the strengthening ligaments get stretched and knee develops abnormal motion in various planes which if untreated leads to abrasion of cartilage and development of early arthritis.

Important rotatory instabilities that can exist at knee are the Antero-lateral (most common) and the Postero-lateral instability. The former is tested by the Pivot shift test while the latter can be detected by the Dial test or a reverse Pivot shift test (see Table 2.28 below for details of the test).

DISCOID MENISCUS

Discoid shaped (see Fig. 2.175) meniscus is most common meniscal variant. It is almost exclusively seen on lateral side. In this condition the meniscus is disk like (rather than being wedge shaped). Due to its abnormal shape discoid meniscus is more prone to tear.

ARTICULAR CARTILAGE INJURIES

Articular cartilage (which is a hyaline cartilage) is smooth and glistening tissue that covers the articulating ends of bones and allows them to glide over each other with very little friction. It can be damaged by injury or normal wear and tear.

Classification of Articular Cartilage Injury (Table 2.29).

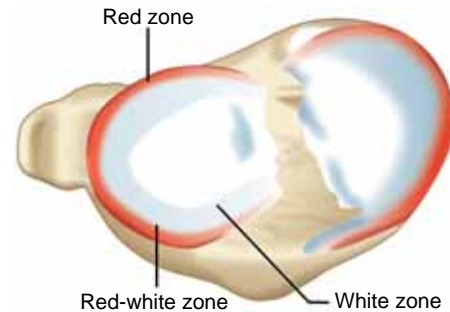


Fig. 2.172: Zones of meniscus according to blood supply.

Table 2.27: Various meniscal tear pattern

<p>Peripheral and longitudinal tears: Most common tear pattern.</p>	
<p>Bucket-handle tears: Longitudinal tear progresses to become bucket-handle tear.</p>	<p>Longitudinal tear (long) Displaced longitudinal tear (bucket-handle)</p>
<p>Radial/Vertical tears</p>	
<p>Flap or parrot-beak tears</p>	
<p>Horizontal cleavage tears</p>	
<p>Complex tears</p>	

Management

As the cartilage does not heal itself well, several surgical techniques to stimulate the growth of new cartilage have been described. Cartilage restoration treatment options depend upon the size of defect.

- Marrow stimulation:** The subchondral bone is penetrated by different techniques mentioned below to release blood, growth factors and mesenchymal cells

Table 2.28: Tests for Rotatory instabilities of knee

Tests for rotatory instability	
Pivot shift test (Fig. 2.173)	With the patient supine, and knee fully extended the examiner lifts the leg and internally rotates the tibia. The knee is gradually flexed along with application of valgus force. A sudden posterior movement of the tibia is seen and felt as the joint is fully re-located. The test is quite painful and is therefore performed under anaesthesia. Positive test is suggestive of anterolateral instability (signifies torn ACL, LCL and lateral capsular laxity/tear)
Reverse Pivot shift test	The same as pivot shift test, but the tibia is externally rotated. Positive test is suggestive of posterolateral instability (signifies torn PCL and the PLC structures of knee)
Dial test (Fig. 2.174)	With the leg dangling over the edge of the couch, one hand of the examiner stabilizes the distal femur and another hand holds the heels. The examiner flexes the knee to 30°, and externally rotates the leg maximally, holding it through the heel, and notes the position of tibial tuberosity. Same maneuver is repeated on the other side. If external rotation is more by 15° as compared to the other side, a posterolateral corner injury (PLC) is suspected. The test is repeated with the knee flexed further to 90°. Increased external rotation indicates (as compared to 30°) concomitant PLC with PCL injury.

**Fig. 2.173:** Pivot shift test.**Fig. 2.174:** Dial test.

into the chondral defect. This technique produces healing vascular response leading to development of fibrocartilage in the chondral defect. Marrow stimulation techniques are used for small size lesion preferably less than 2 cm.

- *Abrasion chondroplasty*: Motorized burr is used to remove 1–3 mm of subchondral bone.
- *Subchondral drilling*: Motorized smooth wire is used to perform subchondral drilling.
- *Microfracture technique (Current preferred method)*: In this method an arthroscopic tapered awl perforates the subchondral bone at sites least 2–to 3-mm apart.
- *Osteochondral grafting*: Cartilage transfer procedure that involves moving healthy cartilage from an area of the knee that is non-weight bearing to a damaged weight bearing cartilage area of the knee. There are two procedures mosaicplasty and osteochondral autograft transfer system (OATS). In mosaicplasty, multiple tiny plugs of healthy cartilage and bone are taken from a healthy cartilage area and moved to replace the damaged cartilage area of the knee. Multiple tiny plugs are used and once embedded, resembles a mosaic, hence the name. With OATS procedure, the plugs are larger. Therefore, the surgeon only needs to move one or two

plugs of healthy cartilage and bone to the damaged area of the knee. Full thickness defects of 1–2.5 cm are ideal for osteochondral grafting.

- *Autologous chondrocyte implantation (ACI)*: This articular resurfacing method is the first and only technique that uses true tissue engineering. The procedure requires two surgeries. During the first, the articular lesion is evaluated and normal host articular cartilage is harvested and cultured. The second procedure involves implanting the cultured cells into the chondral defect. Large osteochondral defects (> 2 cm) can be treated by ACI.

HIGH-YIELD POINTS

- The most pain sensitive structure in the joint is the capsule and least pain sensitive structure in the joint is the articular cartilage.
- Internal de-arrangement of knee is a vague term that is used sometimes by the clinicians to refer to Ligament injuries of the knee.
- Menisci are C shaped fibro-cartilagenous structures made of Type I collagen.
- Menisci move forward in extension of knee and move backward during flexion of knee.

- The most common meniscus tear associated with ACL tear at the time of initial injury is lateral meniscus, though in chronic cases medial meniscus is torn more often than the lateral meniscus due to abnormal loading in ACL deficient knee. Over all posterior horn of medial meniscus is the most common meniscal tear and most tears are of longitudinal type.
- Although more common to tear is the medial meniscus, a meniscal cyst and a discoid meniscus (that increase chances of meniscal tear) are much more commonly seen in lateral meniscus.
- Cyst in a meniscus is more common in lateral meniscus and occurs in the posterior horn. This clinically appears as swellings along the posterior joint line which disappears within joint on knee flexion (Pisani sign).
- The best clinical test for meniscal injury is considered to be Joint line tenderness but recently Thessaly test has been shown to have high sensitivity and specificity in diagnosing meniscal tear. Other less commonly used tests for meniscal injuries are duck walk test, payr test and helfer test.
- Bounce home test of the knee was earlier used to look for meniscal tear. The knee is flexed and allowed to fall and the end point is noted. Endpoint is firm (tear) or soft (intact) but never empty.
- Investigation of choice for knee ligament injury is MRI (gold standard is arthroscopy) and for cartilage injury is arthroscopy.
- Physiological locking refers to internal rotation of femur over a fixed/ grounded tibia in extended knee. Unlocking occurs when popliteus external rotates the femur and knee can then flex. However, in orthopaedics, Locking (pathological) refers to restriction of

terminal few degrees of extension of the knee. It can occur due to torn meniscus (most common), loose bodies in the knee, osteochondral fractures and from fractured osteophytes lying in the joint.

- MCL followed by ACL is most commonly injured ligaments in the knee joint but most commonly operated knee ligament is the ACL.
- ACL and PCL are supplied by the middle geniculate artery (branch of popliteal artery) and posterior articular nerve (branch of Tibial nerve).
- PCL is 1.5 times thicker than the ACL.
- ACL injuries are more common in female athletes than male athletes due to smaller notch, hormonal influences and increased ligamentous laxity.
- ACL tears most commonly in the mid-substance while PCL tears more commonly from its femoral attachment.
- PCL injury is often associated with injury of posterolateral corner ligaments of knee. The clinical test to detect both these injuries is the Dial test.
- The most sensitive clinical test for ACL injury is the Lachman test while the most specific test is the Pivot shift test (when Pivot shift test is positive, ACL injury is must to exist).
- The ligament best seen on MRI is the PCL.
- Double PCL sign on MRI is seen in the presence of a bucket handle tear of the meniscus and not PCL tear.
- The grafts usually harvested for cruciate ligament reconstruction are the hamstrings tendons (gracilis and semitendinosus) or part of patellar tendon. The latter is harvested along with small chip of bone from attachment site to enhance fixation and hence called as Bone-Patellar tendon-Bone graft.
- The femoral attachments of cruciate ligaments are rich in mechanoreceptors involved in joint proprioception; hence in reconstruction of these ligaments the native ligament stump is always preserved.
- Celery stalk appearance is seen on MRI in cases of chronic ACL tears (due to mucoid degeneration) while a celery stalk metaphysis is seen on X-ray in cases of Congenital Rubella.
- Multiligament knee injuries are defined as disruption of at least 2 of the 4 (ACL, PCL, MCL, LCL) major knee ligaments as a result of trauma.

Table 2.29: Outerbridge classification (modified) of articular injury

Grade I	Softening and swelling of cartilage
Grade II	Fragmentation and fissuring, less than 0.5-inch-diameter lesion
Grade III	Fragmentation and fissuring, greater than 0.5-inch-diameter lesion
Grade IV	Erosion of cartilage down to exposed sub-chondral bone

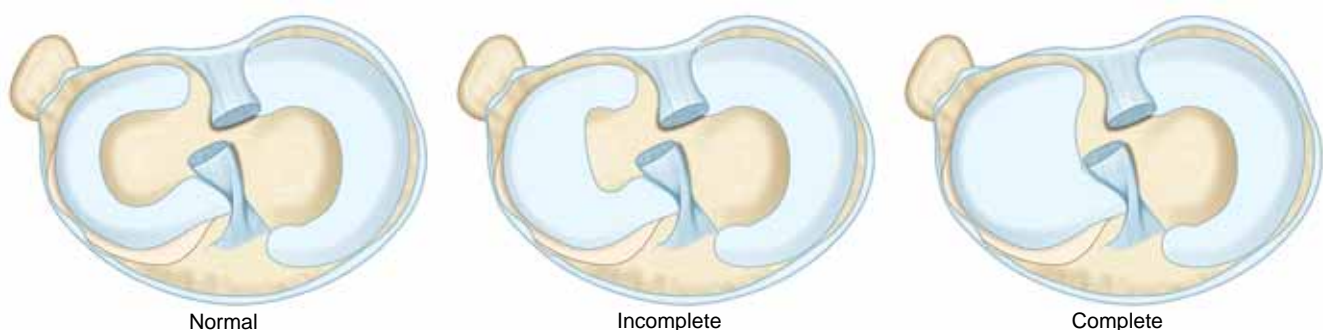


Fig. 2.175: Discoid meniscus.

- A reverse Segond fracture is an avulsion fracture of the knee, which involves the medial proximal tibia (c.f Segond fracture involves lateral tibial plateau). Unlike the Segond which mostly occurs in sports injuries, the reverse Segond fracture occurs with higher velocity injuries, such as RTA.
- *Screw home mechanism*: Tibia external rotates in extension while in flexed knee it internal rotates such that the tibial tuberosity comes to lie in line with the patella. This is called screw home mechanism. It is

due to specific bony anatomy of knee (condyles are unequal) and relative difference in lengths of the two cruciate ligaments.

- ACL tear is the most common cause of haemarthrosis in the knee joint.
- Effusion in the knee joint can be tested by following tests:
 - Buldge sign (positive with 10–15 mL of fluid)
 - Patellar tap
 - Ballotment of patella

INJURIES AROUND THE KNEE AND LEG

DISTAL FEMUR FRACTURES

Distal femur fractures include the supracondylar and intercondylar fractures and involve the femur extending distally from the diaphyseal-metaphyseal junction. These are common femoral fractures in young male (below 40 years) with good quality bone and elderly females (above 50 years) with osteoporotic bone. They account for about 6% of all femur fractures.

Mechanism of Injury

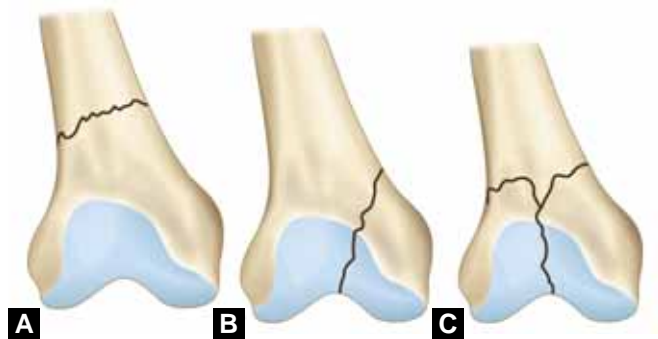
In both age groups axial force is the most common mechanism of injury. Young people sustain these injuries in high energy trauma such as road traffic accidents and fall from height whereas in elderly females a simple fall is responsible for majority of these fractures.

Types (Figs. 2.176A to C)

1. *Supracondylar*: Extraarticular fracture involving distal femoral metaphysis
2. *Unicondylar*: Fracture involving either the medial or lateral femoral condyle.
3. *Intercondylar*: Intraarticular fracture, it can be simple (T or Y type) or complex (comminuted intraarticular fractures).
4. Combination of all/any of these.

Clinical Features

Patients present with severe pain and swelling around knee. Weight bearing is not possible on the injured limb. In displaced fractures obvious deformity may be present. Abnormal mobility and crepitus can be elicited at the site of fracture. Always assess vascular status, because of proximity of the fracture to the popliteal artery which may get damaged during injury. In high energy injuries significant soft tissue damage may occur and open injuries are common in intraarticular fractures. Diagnosis is confirmed on anteroposterior and lateral X-rays of knee (Fig. 2.177A).



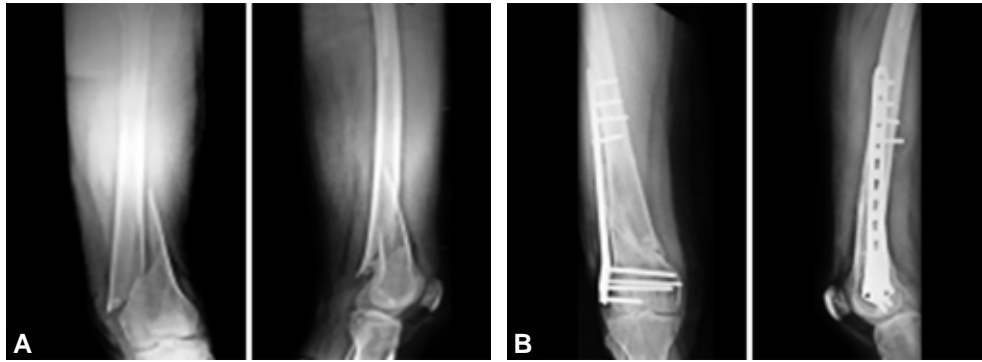
Figs. 2.176A to C: Types of distal femoral fractures. (A) supracondylar; (B) unicondylar, (C) intercondylar.

Management

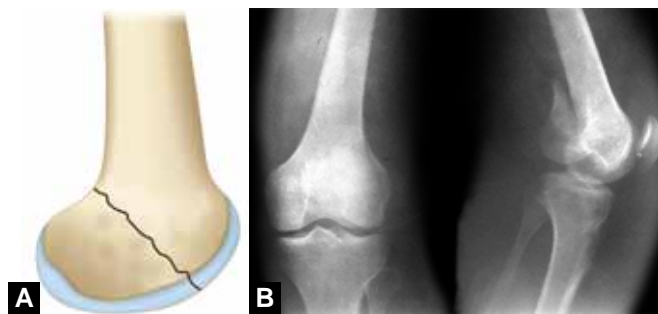
Undisplaced fractures can be treated in a long leg non-weight bearing cast for 6 weeks, but it leads to recumbency related complications and secondary joint stiffness and risks secondary displacement. Open fractures may require temporary fixation with external fixator till soft tissue injury heals (damage control surgery). Open reduction and internal fixation is required for all displaced distal femoral intraarticular fractures. Unicondylar fractures can be fixed with multiple cancellous screws (lag screw) or a buttress plate can be used. Intercondylar fractures require open reduction and internal fixation (Fig. 2.177B) with LCP (locking compression plate), dynamic condylar screw (DCS) or condylar blade plate. Supracondylar fractures can be fixed with open reduction and internal fixation with LCP or retrograde intramedullary nailing (distal femoral nail). LCPs are especially advantageous in osteoporotic bone in elderly.

Complications

- *Knee stiffness*: It may arise due to prolonged immobilization and lack of postoperative physiotherapy.
- *Osteoarthritis*: Inappropriate intraarticular reduction of the fracture can result in secondary osteoarthritis of the knee.



Figs. 2.177A and B: (A) X-ray knee AP and lateral views showing supracondylar fracture femur and (B) fixation with locked compression plate.



Figs. 2.178A and B: Hoffa's fracture.
Courtesy: Dr Rajat Kumar Garg.

- **Malunion:** Inappropriate operative reduction and secondary displacement of the fracture as in cast can lead to malunion.

HIGH-YIELD POINT

- Commonly unicondylar distal femoral fractures occur in sagittal plane. Fracture of any femoral condyle in coronal plane is called Hoffa's fracture (Figs. 2.178A and B).

TIBIAL PLATEAU FRACTURE

These fractures constitute 1% of all fractures. Like distal femoral fractures, tibial plateau fractures result from high energy injuries (RTA or fall from height) in young adults and from low energy simple fall in elderly. Axial loading with bending forces (varus/valgus) are usually responsible for tibial plateau fractures. Less commonly direct hit to proximal tibia (by a car bumper) may lead to these fractures (Bumper fractures).

Classification

Schatzker (SCH) classification (Table 2.30 and Fig. 2.179) is most commonly used to classify these fractures. Isolated fractures of lateral condyle comprise one-third of these fractures (medial condyle being stronger, fractures less commonly).

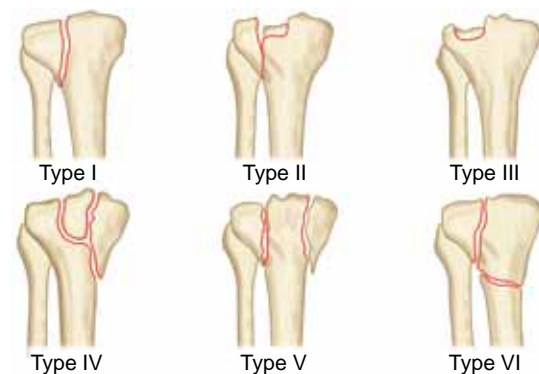


Fig. 2.179: Schatzker's classification of tibial plateau fracture.

Table 2.30: Schatzker's classification for tibial plateau fracture

Type I	Split in lateral plateau
Type II	Split and depression of lateral plateau
Type III	Only depression fracture of lateral plateau
Type IV	Fracture of the medial plateau
Type V	Bicondylar fracture
Type VI	Intraarticular fracture with metaphysiodiaphyseal dissociation.

Clinical Examination

Patients present with severe pain and swelling around the knee with inability to bear weight on the injured limb. Crepitus, abnormal mobility at fracture site is usually present. In displaced fractures obvious deformity is present. Neurovascular assessment of the involved limb should always be done as there is high incidence of injuries to the popliteal neurovascular bundle. Peroneal nerve may also be injured but it is mostly the stretching of the nerve leading to neuropraxia. Always look for the compartment syndrome as this fracture is the commonest to cause compartment syndrome in adults, presence of tense swelling and pain with passive stretching are suggestive of compartment syndrome. Compartment syndrome is particularly common in type IV Schatzker fracture. Very commonly hemarthrosis in the knee may be present. Assessment of ligament injury to knee is essential

(meniscus is injured in 50% cases, cruciates in 20–30% and collaterals in other 20–30% cases). In injuries with lacerations around the knee, it is imperative to rule out an intra-articular communication by injecting 50–75 mL of saline (saline load test) and observing if it seeps out from the wound. Diagnosis is confirmed by anteroposterior and lateral X-rays of involved knee joint. Stress views (with patient under sedation) can be done to assess injury to ligaments (collateral ligament injury).

Management

As usual, undisplaced fractures can be managed in a long leg, nonweight bearing cast for 6 weeks but it risks joint stiffness and secondary displacement. So many surgeons prefer to go with percutaneous screw fixation to achieve early mobilization. There is a general consensus for open reduction and internal fixation (with buttress plates and cancellous screws) of all displaced intra-articular fractures of the tibial plateau. The depressed fragment is elevated with instruments and metaphyseal defect is filled with bone grafts before fixation. Bicondylar (Type V) and type VI fractures are best fixed with a LCP (Fig. 2.180). Sometimes dual plating is required for these. In open injuries and where there is massive soft tissue damage posing a risk for compartment syndrome, a knee spanning external fixator is applied for temporary stabilization. Once the soft tissue condition allows definitive fixation can be pursued.

Complications

Knee stiffness, malunion and osteoarthritis are common complication like distal femoral fractures. Neurovascular injuries can involve the popliteal neuro-vascular bundle and the peroneal nerve. The latter is usually a neuropraxia. Compartment syndrome is always to be ruled out in fractures of tibial plateau.

Compartment Syndrome

Forewarned is forearmed, patients with proximal tibial fractures should be kept on strict limb elevation and ice

packs to reduce the swelling. Extravasation of blood, soft tissue swelling and fracture itself increase the pressure in the tight unyielding fascial compartments of the leg leading to compartment syndrome. Treatment is emergency fasciotomy of all compartments of the leg.

KNEE DISLOCATIONS (FIG. 2.181)

These are one of the rare most but one of the most dangerous dislocations that result from dashboard injuries and high energy motor vehicle accidents. True incidence is unknown as almost 50% of these spontaneously reduce. Hyperextension injuries of knee joint are most common mechanism of injury. Anterior knee dislocation is the most common type followed by posterior type. Popliteal artery and peroneal nerve are at particular risk in knee dislocation and neurovascular examination is vital in all cases as the reported incidence is although variable but high (20–60%). Posterior knee dislocation is most commonly associated with popliteal artery injury. If vascular injury is suspected (diminished pulses or ankle-brachial index < 0.9) urgent CT angiogram or duplex ultrasound is warranted. Vascular injury should be repaired before 6–8 hours of injury.

Multiligamentous knee injury is the sequel of knee dislocation and three or more major ligaments (ACL, PCL, MCL and LCL) are usually torn. MRI is the investigation of choice to detect ligament injury to the knee. A knee dislocation without fracture or vascular injury should be reduced closed immediately and supported with hinged knee brace. Definitive treatment involves reconstruction of torn ligaments.

PATELLA FRACTURE

Patella is an important part of extensor apparatus of knee joint. Quadriceps tendon inserts on the superior pole of patella and ligamentum patellae extends from lower pole of patella to tibial tuberosity. Thus, patella transmits the tensile force of quadriceps contraction to patellar tendon. Patella increases the moment arm of quadriceps extensor mechanism and allows knee extension with a lesser quadriceps



Fig. 2.180: X-ray knee AP and lateral views showing tibial plateau fixation with locked compression plate.

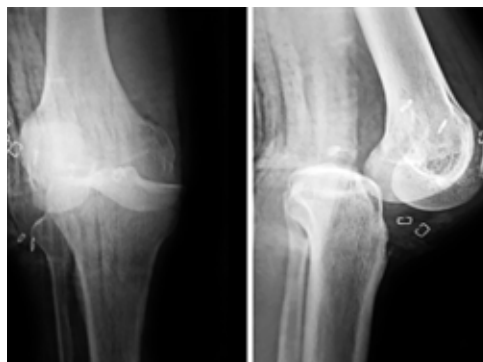


Fig. 2.181: X-ray knee AP and lateral views showing posterior knee dislocation.

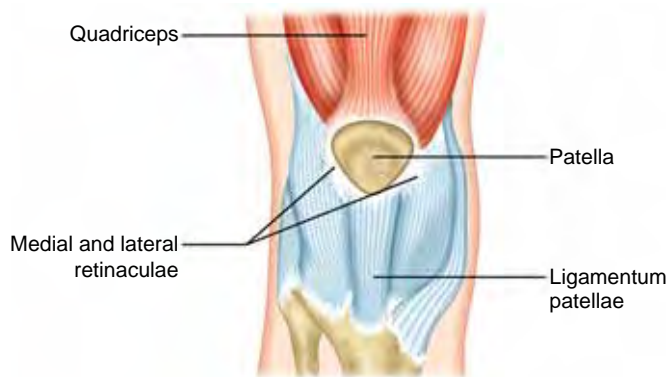


Fig. 2.182: Anatomy of the extensor apparatus of the knee.

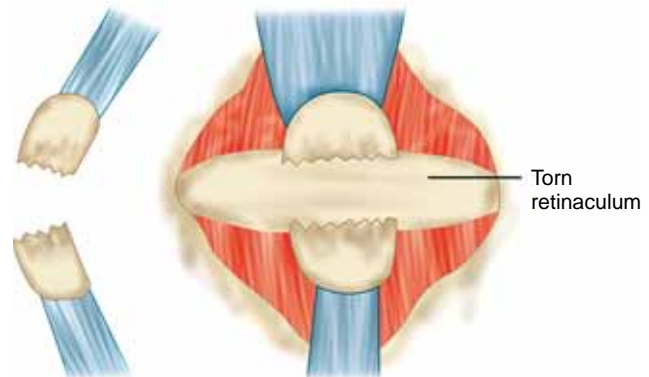


Fig. 2.183: Diagram showing torn retinacular extensions in a transverse fracture of patella.

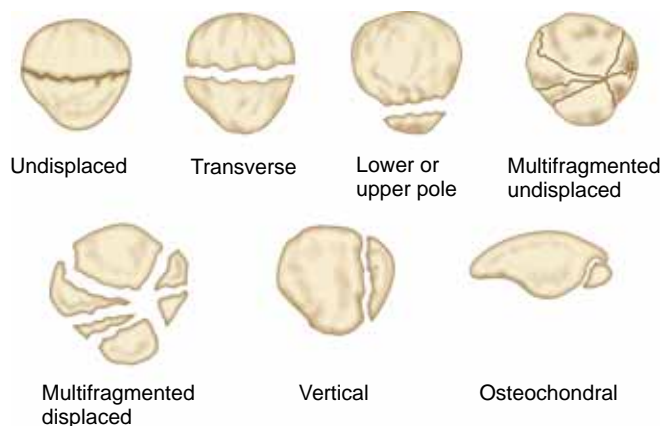


Fig. 2.184: Types of patellar fracture.

force. Medial and lateral retinaculæ are condensation of fascia and are attached to the medial and lateral margins of patella (Fig. 2.182).

Patellar fractures account for 1% of all skeletal injuries. They are more common in males between 20 years and 50 years of age.

Mechanism of Injury

Indirect Mechanism

This is more common mechanism. This occurs following sudden and strong knee flexion against a fully contracted quadriceps muscle. It usually causes transverse fracture or avulsion of the inferior pole of patella. Force often continues beyond fracture and also tears the retinaculæ (Fig. 2.183) so active “straight leg raising (SLR) test” is usually not possible as knee cannot be extended.

Direct Blow to Anterior Knee (Fall on knee or Dashboard Injury)

Its subcutaneous position makes it vulnerable for direct blow injury. In direct blow injury displacement is usually minimal due to preservation of retinacular expansions.

It usually causes comminuted or stellate type fracture. Patient can usually do active SLR.

Classification

Patella fracture may be classified on basis of displacement, viz. undisplaced or displaced; or depending upon fracture pattern, viz. stellate, comminuted, transverse, vertical (marginal) and polar (Fig. 2.184). Transverse fracture is the most common fracture pattern. In high energy injuries distal femoral fracture and proximal tibial fractures are commonly accompanied fractures with fracture of patella.

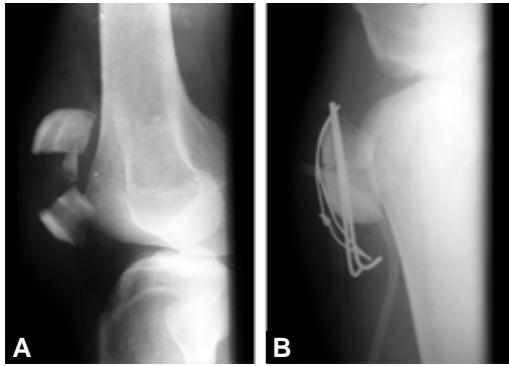
Clinical Examination

Patients present with anterior knee pain and swelling of knee joint and difficulty in walking. On examination tenderness and crepitus are present. In two part fracture, gap may be felt between the patellar fragments. Due to subcutaneous nature of bone compound fractures are common. Extensor apparatus disruption should be evaluated by checking the ability to raise the leg straight. If the patient is doing active SLR, despite patella fracture, retinacular expansions are likely intact, and fracture can be managed conservatively provided there is no significant step on articular surface. A patellar fracture patient may not be compliant with examination if a tender and large hemarthrosis is present. In this situation aspiration of hemarthrosis and injection of local anesthetic into the knee joint may be helpful. Diagnosis is confirmed on anteroposterior and lateral (Fig. 2.185A) radiographs of the involved knee. Occasionally, a patella skyline view (Figs. 2.186A and B) may be required in undisplaced fractures.

Management

Conservative

Nonsurgical management is usually successful in fractures with minimal displacement and no step-off with intact extensor mechanism (patient doing active SLR).



Figs. 2.185A and B: (A) X-ray knee lateral view showing patellar fracture and (B) tension band wiring of patella.



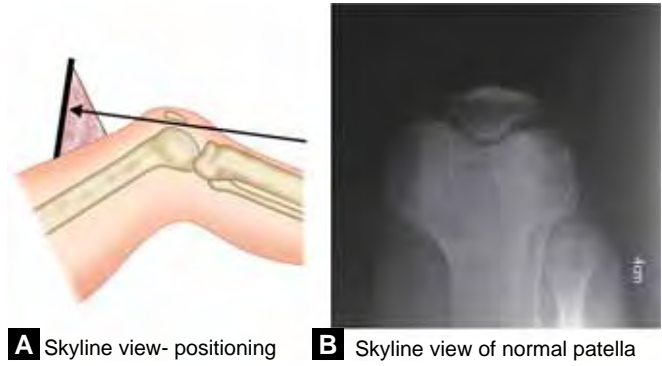
Fig. 2.187: Diagram showing a cylindrical plaster for managing an undisplaced fracture of patella.

These patients can be managed with extensor splinting/bracing or with a cylindrical cast for 4–6 weeks (Fig. 2.187). Straight leg raises and quadriceps physiotherapy is encouraged early in the cast. Early partial weight bearing is encouraged with help of crutches.

Surgery

Displaced fractures and disruption of extensor mechanism requires surgical repair. The options of surgery depend upon the fracture configuration and salvage potential of the patella. Whatever surgery is performed, retinacular disruption, if found, should always be repaired at the time of surgery. Various surgical options are as follows:

- **ORIF with tension band wiring [(TBW), Fig. 2.185B]:** In two part fractures of patella the fractures are fixed with TBW. It allows early knee bending. TBW converts the tensile forces at the anterior cortical surface of the patella into compressive forces at the articular surface (see chapter 1 for details).
- **Cerclage wiring:** If the fracture is comminuted/stellate fracture, cerclage wiring of the patella may be performed to hold the fracture fragments in place.
- **Partial patelelectomy:** It is indicated in comminuted fractures of inferior pole of patella. In patellar tendon avulsion inferior pole fragment is excised and patellar tendon is reattached.



Figs. 2.186A and B: (A) Diagram showing how a skyline view of patella is taken; (B) Skyline view showing a normal patella.

- **Complete patelelectomy:** Every attempt should be made to preserve the patella. Total patellectomy is rarely indicated in severely comminuted fracture where internal fixation is not possible. The patella is excised and the extensor mechanism is repaired end to end. In patients with complete patelelectomy, there remains an extensor lag (inability to fully extend the knee).

Complications

- **Knee stiffness and quadriceps atrophy:** This is a common complication. To prevent it early range of motion physiotherapy and strengthening exercises should be started.
- **Painful retained hardware:** This is common due to subcutaneous location of patella. It may necessitate removal of implant for adequate pain relief.
- **Extensor lag:** It is mostly seen after complete patellectomy. It may also be due to quadriceps atrophy or due to inadequate extensor mechanism repair.
- **Post-traumatic patella-femoral arthritis** is a late complication of patellar fracture.

HIGH-YIELD POINTS

- The patella ossifies from a single ossific nucleus. In a bipartite patella a secondary ossific nucleus (mostly on the superolateral aspect) fails to unite with the primary nucleus Figure 2.188. It should not be confused with fracture.
- The patella is the largest sesamoid bone in the body and has thickest articular cartilage in the body which covers proximal three-fourths of the patella. The distal pole is entirely devoid of articular cartilage and distal pole fractures are extraarticular.
- Partial rupture/avulsion of patellar tendon from lower pole of patella leads to a traction tendinitis and calcification in the patellar ligament—the Sinding–Larsen Johansson syndrome (classified under osteochondritis).
- The most common joint to sustain open injuries is the knee joint.

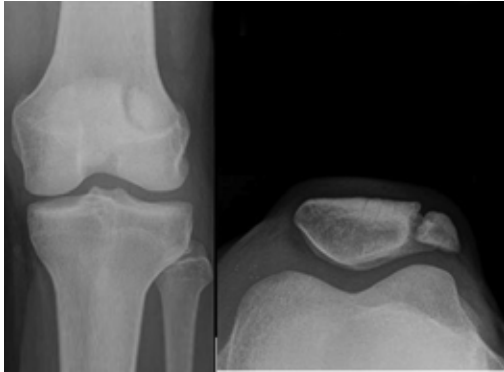


Fig. 2.188: AP and skyline views showing a separate ossicle present on the superolateral aspect of patella (Bipartite patella). Note rounded edges unlike a fracture.

EXTENSOR MECHANISM DISRUPTION

These injuries include tear of patellar or quadriceps tendon ruptures and patellar dislocations. Details have been discussed in Chapter 12.

PATELLAR DISLOCATION

Patellar dislocation is a very common sports injury. It is second most common cause of knee hemarthrosis after ACL tear. It is more common in younger age group people, particularly women.

Patterns of Dislocation

By and large a dislocation of patella is always a lateral dislocation. However, three patterns of dislocation may be seen at this joint:

- *Acute traumatic dislocation:* Single episode after a significant trauma
- *Recurrent dislocation (most common):* Multiple episodes of subluxation/dislocation of patella from the trochlear groove of femur after minor magnitude of trauma (usually a forceful flexion of the knee)
- *Habitual dislocation:* Patella subluxates laterally with every flexion and extension of the knee.

Surgical Anatomy

The patella lies in the trochlear sulcus of femur centred best at 30 degrees of knee flexion. The superior pole gives attachment to the tendon of Quadriceps femoris (the three vasti and the rectus femoris) while from the lower pole, arises the Ligamentum patellae to attach on to the tibial tuberosity. Considering a normal valgus of 6–7° at the knee joint one can well imagine that the origin of quadriceps (rectus femoris arises from anterior inferior iliac spine) and its insertion (on the patella) lie in a line placed lateral with respect to the center of patella. Hence, the resultant vector of pull with quadriceps contraction is directed

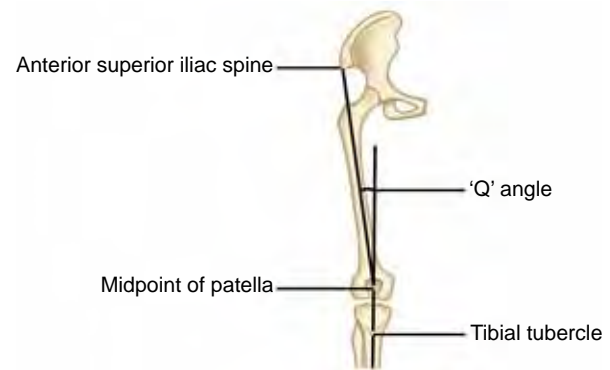


Fig. 2.189: Measurements of Q-angle.

laterally, making patella-femoral joint an intrinsically unstable joint.

There are two mathematical ways of measuring the lateral pull of quadriceps on patella:

1. **Quadriceps angle (Q-angle)** (Fig. 2.189)—It may be defined as the angle subtended between a line drawn from the anterior superior iliac spine to the center of the patella, and a line from the center of the patella to the tibial tubercle. Normally the angle is 14° in males and 17° in females (on a standing radiograph). More is the Q angle (as when the tibial tuberosity is laterally shifted), more would be the lateral pull of quadriceps and more unstable would be the patella-femoral joint.
2. **TT-TG distance** (Tibial tuberosity to trochlear groove distance)—This is measured on CT scan/MRI and expresses lateral deviation of tibial tuberosity with respect to trochlear groove. Normally it is less than 20 mm. A higher value pre-disposes the patient to lateral patellar instability and recurrent dislocation of patella.

Now, to stabilize this unstable joint and counter balance the lateral pull of quadriceps, following static and dynamic stabilizers are there:

Static stabilizers: Shape of the trochlea, MPFL (medial patella-femoral ligament, binds medial side of patella to the medial epicondyle of femur) and the medial retinaculæ

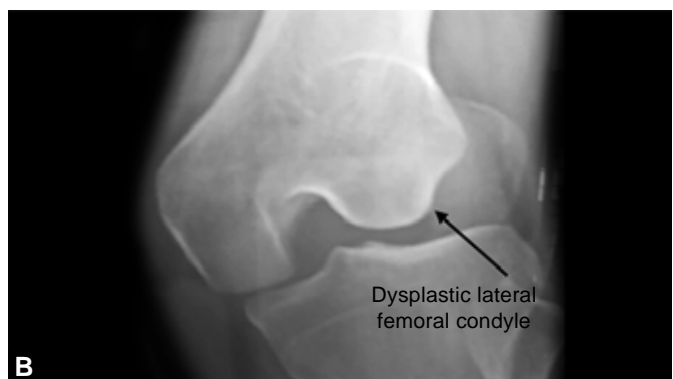
Dynamic stabilizers: Vastus medialis (its oblique fibres called as Vastus medialis obliquus—VMO)

Pathophysiology: In acute dislocation a traumatic injury (usually a sudden violent contraction of quadriceps with flexed knee and externally rotated tibia) ruptures one of the restraint (a soft tissue restraint is usually torn, most commonly being the MPFL) so that the patella subluxates laterally.

A recurrent or habitual dislocation occurs in those in whom a pathological factor exists such that one or more of the restraints are compromised. This may occur either due to non-healing of a restraint torn during acute injury or due to a genetic or developmental factor like ligament laxity, trochlear dysplasia (Figs. 2.190A and B) etc. The list of factors that predispose to recurrent dislocations are given in Table 2.31.

Table 2.31: Predisposing factors for recurrent dislocation of patella

I.	Problems in soft tissue restraints
a.	Deficient medial restraints
i.	MPFL insufficiency (not healed after previous trauma), generalised ligament laxity
ii.	VMO insufficiency (wasting due to any pathology around knee)
b.	Tight lateral restraints (e.g. tight lateral retinaculum or ilio-tibial band)
II.	Problems in bony restraints
a.	Trochlear dysplasia (producing a shallow trochlear groove)
b.	Patella alta (high riding patella not well seated in trochlea) (Fig. 2.191)
III.	Increased lateral force vector of quadriceps (increased Q angle)
a.	External tibial torsion (inborn external twist in tibia that shifts tibial tuberosity outwards, increasing Q angle)
b.	Genu valgum (tibial tuberosity shifts outwards in a valgus leg and Q angle increases)
c.	Increased femoral anteversion (such people have a femur that is more in internal rotation that increases Q angle)



Figs. 2.190A and B: X-ray knee skyline and AP views showing trochlear dysplasia due to dysplastic lateral femoral condyle. Patella is dislocated due to trochlear dysplasia.



Fig. 2.191: X-ray lateral view of knee showing patella alta. *Courtesy: Dr Ravish Chabra (JN Medical college, AMU)* LP: Length of patella; PT: Patellar tendon



Fig. 2.192: Patellar apprehension test.

Clinical Features

After the acute dislocation patient presents with painful and swollen knee due to hemarthrosis. Tenderness can usually be elicited on medial aspect of knee (due to torn MPFL). By the time patient comes to the hospital patella has usually been spontaneously reduced. Merchant's view (45° flexion weight bearing view) may show an osteochondral fracture of medial facet of patella. In case this patient gives a history of previous dislocation, he should

be assessed for hyperlaxity of joints. Patellar apprehension test (Fig. 2.192) is done to assess patellar stability. With knee in 30–45 degree flexion a lateral force is applied to patella. Apprehension is noticed in patients with recurrent dislocation. There is increased passive lateral translation of patella (compared with contralateral side). "J-sign" may be positive. It refers to lateral patellar deviation during terminal knee extension. MRI is the investigation of choice to assess the integrity of medial patellar stabilizers (MPFL, medial retinaculum and VMO).

Management (Flowchart 2.6)

Acute Dislocation Episode

If patella is still dislocated at presentation, closed reduction should be done by simply pushing it medially. Patients with acute episode of first patellar dislocation should be immobilized initially in knee extension brace for 3–4 weeks to allow soft tissue structures to heal. Weight bearing as tolerated with help of crutches should be started. With subsidence of pain VMO strengthening exercises should be started.

Surgery for first time patellar dislocation is indicated in these cases:

- If MRI shows complete tear of MPFL or VMO
- If there is concomitant osteochondral fracture
- If merchant view shows still subluxated patella even after a closed reduction attempt.

Recurrent Dislocation Patient

Management of recurrent/habitual dislocation of patella is essentially surgical (Flowchart 2.6). The procedures that are employed are broadly categorized into two categories:

Proximal realignment procedures: These procedures aim at reconstruction of soft tissues restraints (like MPFL reconstruction with a semitendinosus or gracilis tendon graft) and are indicated in all patients to strengthen the medial supports and prevent a lateral dislocation.

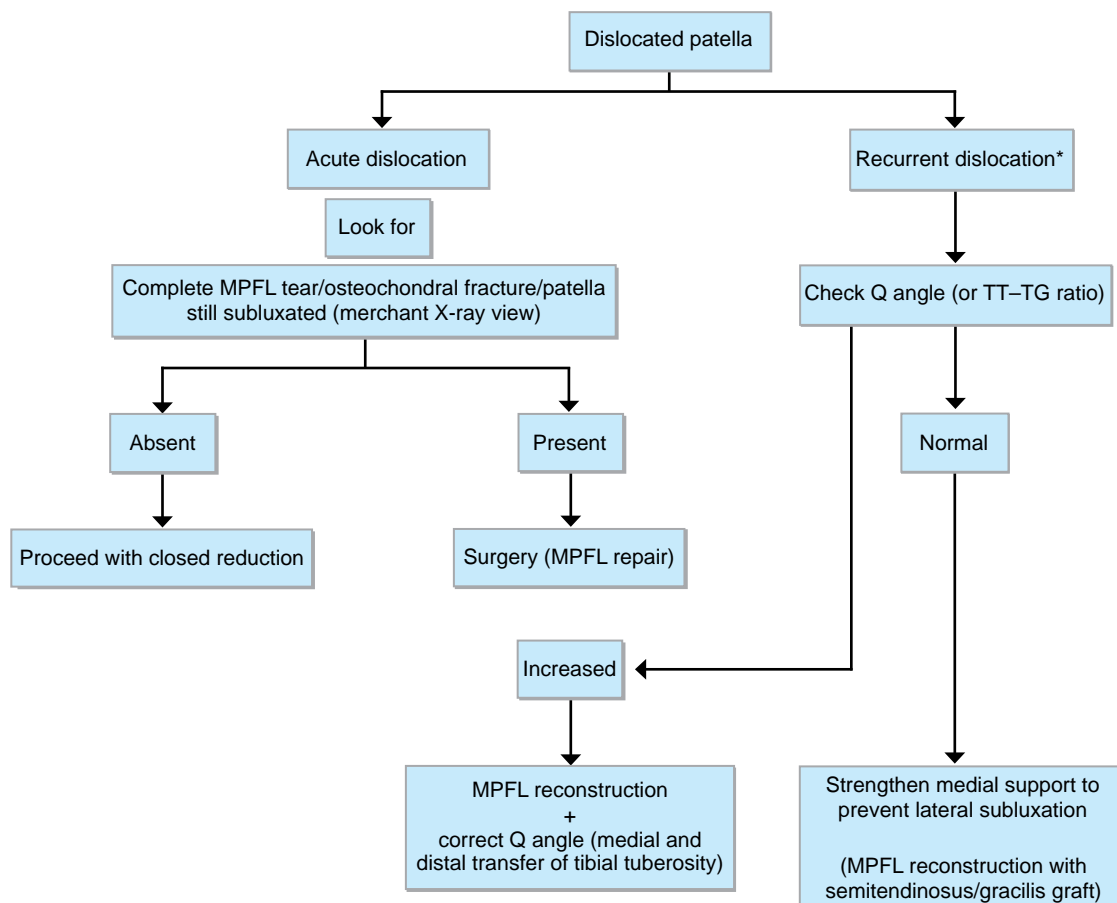
Distal realignment procedures: These procedures are added in patients with increased Q angle acting as a predisposing factor. They aim at realigning the extensor mechanism so as to produce a mechanically more favourable angle of pull of Quadriceps (i.e. they aim at decreasing the Q angle). This is done by transferring the tibial tuberosity to a distal and medial location (modified Elmslie Trillat procedure).

Patients in whom severe trochlear dysplasia is acting as a predisposing factor require additionally reconstruction of the trochlea, a procedure called as Trochleoplasty.

HIGH-YIELD POINTS

- Miserable malalignment syndrome—it encompasses three characteristics; increased femoral anteversion, genu valgum and external tibial torsion that leads to an increased Q-angle and predispose to patellar dislocation.

Flowchart 2.6: Management algorithm for Patellar dislocation.



*Trochleoplasty is to be added in patients with trochlear dysplasia

- Crossing sign and double contour sign are X-ray signs (lateral view of knee) present in patients having trochlear dysplasia.
- In the initial knee flexion ($< 30^\circ$) soft tissue structures mainly the MPFL and VMO play crucial role in stabilizing patella but after 30° , patellar stability depends mainly on shape of trochlea
- First time dislocation also predisposes to recurrent dislocation due to disruption of MPFL.
- *Insall-Salvati ratio* (see Fig. 2.191): This is the ratio of the patella tendon length (PT) to the length of the patella (LP). Normal ratio is between 0.8 and 1.2. Ratio more than 1.2 is suggestive of high riding patella (patella alta). Ratio less than 0.8 is suggestive of low lying patella (patella baja).

LOOSE BODIES IN KNEE JOINT

A loose body is a free floating piece made of bone or cartilage or it can be a foreign object in a joint. The knee is the most common site for loose bodies. They can cause catching and locking (pseudo locking) sensation in the joint. Causes of loose bodies are as following:

- *Osteoarthritis*: Most common cause of loose body in the knee joint.
- *Osteochondritis dissecans*: Most common cause of loose body in knee joint in adolescents and young population.
- *Synovial chondromatosis*: Most common cause of multiple cartilaginous loose bodies.
- Charcot's joint
- Trauma/surgery

Treatment of loose body causing symptoms is arthroscopic removal.

FRACTURES OF SHAFT OF TIBIA AND FIBULA

Tibial fractures are very common long bone fractures. Tibial shaft fractures are commonly associated with fracture of shaft of fibula as the energy of trauma is transmitted along the interosseous membrane to fibula also. Like distal femoral and tibial plateau fractures these fractures also have bimodal age distribution. First age group is young adults with age less than 40 years who sustain these fractures in high velocity road traffic accidents or fall from height. Second age group consists of elderly women over 70–80 years of age with osteoporotic bones who sustain these fractures due to simple fall at home.

Anterior and medial aspect of tibia is covered by thin soft tissue cover of skin and subcutaneous tissues. Therefore, open fractures are extremely common.

Fracture Geometry (Fig. 2.193)

Like any long bone fracture tibial shaft fracture may be spiral, oblique, transverse, comminuted fracture and segmental.

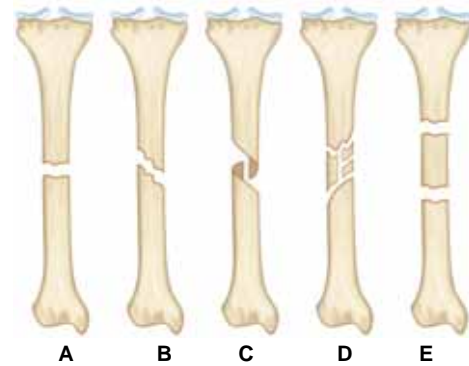


Fig. 2.193: Fracture geometry. (A: Transverse, B: Oblique, C: Spiral, D: Comminuted, E: Segmental).

Clinical Features

Patients present with pain and swelling of leg and inability to bear weight on the injured limb. Crepitus, abnormal mobility and deformity are present at site of fracture. High energy injuries are often associated with open fractures and compartment syndrome. Diagnosis of compartment syndrome should be made on clinical grounds of tense compartment and pain on passive stretching of muscles. Neurovascular examination should be done and recorded in all patients of fracture of shaft of tibia and fibula who are victim of high energy injuries. Peroneal nerve is particularly at risk in fibular neck fracture.

All patients of suspected fracture of tibia should be splinted before transporting the patient for radiological examination. This avoids the additional trauma to soft tissues. All open fractures with bone ends protruding outside the skin should be reduced to avoid desiccation of bone. If reduction is not possible in emergency room then protruded bone ends should be covered with saline gauze pieces.

Radiology

Diagnosis is confirmed by anteroposterior and lateral X-rays of involved leg (Fig. 2.194). Ankle and knee joints of the involved leg should also be X-rayed, as there may be intraarticular extension and associated dislocation of proximal or distal tibio-fibular articulation.

Management

High energy tibial shaft fractures should be assessed on the basis of ATLS guidelines. If patient does not have any life-threatening injury fractured limb should be splinted and patient can be planned up for definitive management.

Conservative

A low energy undisplaced/minimally displaced fracture can be treated in a nonweight bearing long leg cast in 10° knee flexion for 4 weeks followed by patellar tendon



Fig. 2.194: X-ray knee with leg AP and lateral views showing spiral fracture of tibia and fibula.

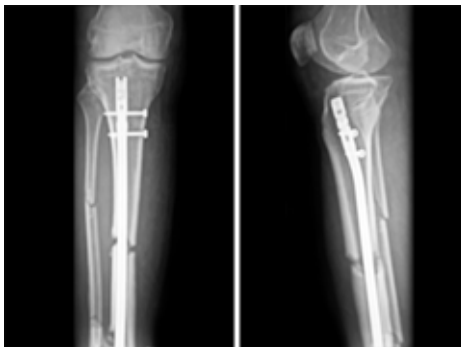


Fig. 2.196: X-ray knee with leg AP and lateral views showing CRIF of tibial fracture with intramedullary nailing.

bearing cast (Fig. 2.195) or functional brace for another 4–6 weeks. Acceptability criteria for reduction of tibial shaft fracture are:

- Varus/Valgus angulation < 5 degrees
- Anterior/Posterior angulation < 10 degrees
- Rotation < 10 degrees
- Shortening < 1.5 cm

Weight bearing and range of motion exercises are started at 4 weeks. In children majority of fractures of shaft of tibia and fibula are treated with close reduction and long leg cast application.

For closed diaphyseal tibial fractures close reduction and intramedullary nailing (Fig. 2.196) is gold-standard treatment. Reduction is achieved under guidance of image intensifier and fixed with intramedullary nail. Fibula is nonweight bearing bone (transmits just 15% of load) and no internal fixation is required for fibular fracture. In children unstable tibial shaft fractures may require close reduction and percutaneous pinning or flexible intramedullary nailing (elastic nails like Enders nail or TENS).

Metaphyseal tibial fractures are best treated with open reduction and internal fixation with plating. Minimally invasive plate osteosynthesis (MIPO, see Section 14: Recent Advances) is a relatively new technique of plating of metaphyseal fractures of long bones in which fracture site is not opened and reduction is achieved by indirect technique and confirmed under C-arm. Small incisions



Fig. 2.195: A sketch showing PTB cast applied for Tibia fracture.

are given just at the screw insertion sites and at the site of insertion of plate.

Open tibial shaft fractures are most common open fractures. In low-grade open injury (All Gustilo Type I and some most Type II) thorough surgical wound debridement and primary closure of wound can be done simultaneously with definitive fixation of fracture with intramedullary nail or plate.

High-grade open injuries (All Gustilo Type III and some Type II) require thorough surgical wound debridement and temporary fixation of fracture with external fixator. Serial debridement is required until the wound becomes healthy. External fixator is converted to definitive fixation (intramedullary nail or plate) after optimization of patient health and when wound becomes healthy for closure (delayed primary closure or skin graft or flap). In rare situations even an external fixator can be continued till bone union.

HIGH-YIELD POINTS

- *Toddler's fracture:* It is seen in children below 3 years. It is a nondisplaced/minimally displaced spiral or oblique fracture of tibial shaft only and fibula remains intact. It is also known as childhood accidental spiral tibial (CAST) fractures.
- In tibial shaft fracture with intact fibula functional bracing is relatively contraindicated, due to high chances of varus deformity.
- Open tibial fractures do not preclude the possibility of the development of a compartment syndrome. Compartment syndrome should be suspected in all tibial shaft fractures. (Open fracture does not mean decompressed compartment).

Complications

- *Delayed union/Nonunion (Fig. 2.197):* There is no consensus on definition of delayed union which differentiates it from nonunion. Factors which favor nonunion include open fractures, infection, high energy trauma, comminuted and segmental fractures, bone

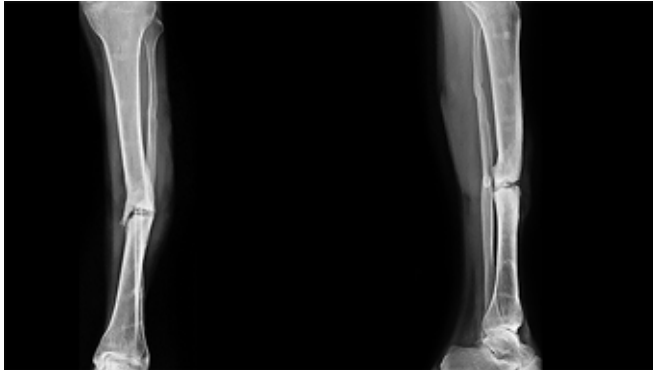


Fig. 2.197: X-ray leg AP and lateral views showing nonunion of midshaft fracture of tibia.

loss, conservative treatment of displaced and unstable fractures, inadequate reduction and postoperative fracture gap, delayed surgery, smoking, diabetes and alcohol consumption. Fractures of distal third of tibia are more prone to undergo nonunion than proximal fractures due to precarious blood supply and constitute the most common site where non union is seen in clinical practice.

Intramedullary nailing with bone grafting is done for nonunion of diaphyseal tibial shaft fractures. If nonunion occurs with previous intramedullary nailing then removal of nail, overreaming of canal and insertion of a larger diameter nail is required (exchange nailing).

Nonunion due to small segmental bone loss can be treated by fibular bone grafting. Larger segmental bone defect requires either bone lengthening by Ilizarov technique or vascularized bone graft.

- **Malunion:** Angular and rotational deformities and shortening may occur following inadequate reduction or loss of reduction in cast. In general varus deformity is more troublesome than valgus deformity. Malunion most commonly occur in distal third of tibial shaft fractures. Patients with significant deformity causing functional disability may require correction by osteotomy.
- **Anterior knee pain** is a common complication of intramedullary nailing. With time pain decreases but in few patients it may be persistent and problematic.
- **Neurovascular injury and compartment syndrome:** Victims of high velocity road traffic accidents should be thoroughly assessed for associated neurovascular injury. Peroneal nerve is most commonly injured nerve by intramedullary nailing. Usually it is transient and recovers with time. Compartment syndrome may occur following both close and open tibial shaft fractures. Diagnosis should be made on high index of suspicion. Pain out of proportion and pain on passive stretch are the earliest symptoms of compartment syndrome. Anterior compartment is most commonly involved compartment. Treatment is urgent fasciotomy of the involved compartment.



Fig. 2.198: Dynamic and static holes of an inter-locking nail.

- **Infection:** Superficial and deep infections may complicate the surgical treatment of tibial shaft fracture. Increased risk is seen in open fractures and risk increases with increase in Gustilo grading of open fractures. Superficial infection often responds to IV antibiotics. Deep infection presents with increasing pain and wound drainage. Treatment of deep infection is serial debridement and irrigation of the wound and IV antibiotics. Removal of intramedullary nail and placement of antibiotic impregnated cement nail may be needed in recalcitrant cases.

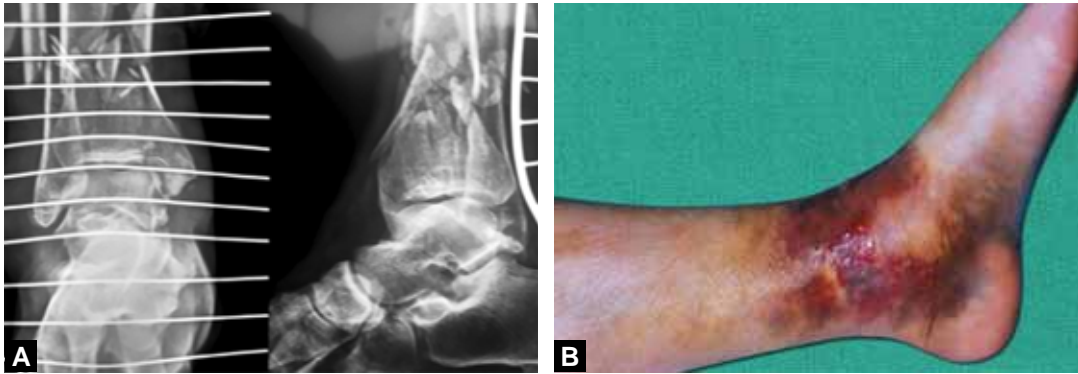
HIGH-YIELD POINTS

- Newer nonsurgical methods of treating delayed and nonunion are use of low intensity pulsed ultrasound, electromagnetic stimulation and use of osteoinductive bone morphogenic proteins (BMPs).
- **Dynamization:** It is a method of accelerating bone union in cases of delayed union. The inter-locking nails have two types of holes (Fig. 2.198)—static (circular) and dynamic (oval). In dynamization statically locked screw (placed in circular holes) is removed leaving only dynamic screw in nail. This increases compression at fracture site on weight bearing as bone can now translate by few millimeters on the nail and promotes healing.

PILON FRACTURE (TIBIAL PLAFOND FRACTURES)

The distal tibial articular surface is referred to as Tibial plafond. Pilon fracture of tibia is fracture of tibial plafond with proximal extension (Fig. 2.199A). These fractures are usually caused by high energy axial force such as fall from height. High velocity pilon fractures are often associated with severe soft tissue injury (Fig. 2.199B) and fracture comminution.

Patients present with pain, swelling, ankle deformity and inability to bear weight. Diagnosis is confirmed by anteroposterior, lateral and mortises view of ankle. Involved leg and foot should also be X-rayed.



Figs. 2.199A and B: (A) X-ray ankle AP and lateral views showing pilon fracture and (B) severe soft tissue injury is usually seen with pilon fracture.

Treatment

Minimally displaced fractures are treated by nonweight-bearing short leg cast for 6 weeks. Time of surgical intervention is largely guided by condition of soft tissues. Edema, bruises, blisters, etc. indicates significant soft tissue injury and surgical intervention in these cases is associated with high rate of complications like wound breakdown and infection. Temporary fixation of fracture by external fixator in distraction mode (Ligamentotaxis) is done in this situation and definitive surgery should be delayed until wrinkles appear around ankle (wrinkle sign) which indicates subsidence of edema. Once soft tissue

injury recovers definitive internal fixation is done using locked compression periarticular distal tibial plates.

Complications

Superficial skin necrosis and sloughing is the most common complication of pilon fracture. Sloughing of full thickness skin and wound dehiscence is also not uncommon in high energy injuries. It requires wound debridement, irrigation and IV antibiotics. Post-traumatic arthritis is also common due to intraarticular nature of the fracture. Compartment syndrome should be looked for and if signs are present it should be managed aggressively.

INJURIES OF THE ANKLE AND FOOT

ANATOMY

Normal ankle joint is required for rhythmic effortless gait and to withstand up to 1.5 times body weight while walking and more than it during running. Three bones (tibia, fibula above and talus below) together constitute the ankle joint which is a modified hinge joint. The distal articular surface of tibia along with the medial and lateral malleoli form a convex surface proximally referred to as ankle mortise. The dome of the talus (convex) fits into the mortise (concave) formed by the tibia and fibula to make a hinge (Fig. 2.200) and forms the ankle joint. The subtalar (talo-calcaneal) joint lies distal to the ankle joint and is formed by the talus above articulating with the calcaneum below.

Three groups of ligaments (medial, lateral and syndesmosis) play fundamental role in providing stability to ankle (tibiotalar) and subtalar (talo-calcaneal) joint. Lateral ligament complex (Fig. 2.201) consists of anterior talofibular ligament (ATFL), posterior talofibular ligament (PTFL), and calcaneofibular ligament (CFL). Medially ankle joint is stabilized by deltoid ligament complex (Medial ligament complex). It consists of two parts, superficial (crosses both ankle and subtalar joint) and deep (crosses only ankle

joint). The superficial part consists of tibiocalcaneal, tibionavicular, posterior superficial tibiotalar and tibiospring ligaments. The deep part consists of anterior tibiotalar and posterior deep tibiotalar ligaments. Anatomy is not consistent and all structures are not always present (Fig. 2.202). Deltoid ligament is considered to be the strongest ankle ligament. Syndesmosis between distal tibiofibular joint consists of anterior-inferior tibiofibular (AITFL), posteroinferior tibiofibular (PITFL), transverse tibiofibular ligaments and the interosseous membrane.

ANKLE SPRAIN

Ankle sprains refer to ligament injuries in the ankle. Ankle joint is the commonest site for a ligament injury in the body and ankle sprains are the commonest sports injuries. Stretching of ligaments beyond normal range results in sprain. More than three-quarter cases of ankle sprain involve lateral ligament complex (inversion ankle sprain). ATFL is the weakest of lateral ligament complex and most commonly injured ligament in ankle sprain (ATFL is the most commonly injured ligament in the body). CFL is the second most commonly injured ligament in ankle sprains.

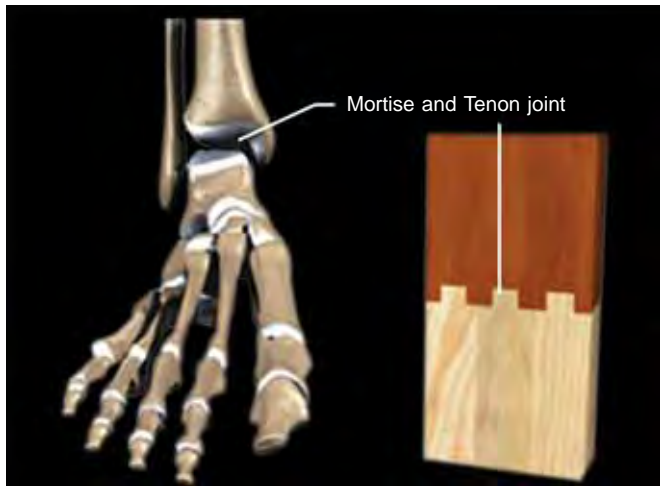


Fig. 2.200: Ankle mortise.

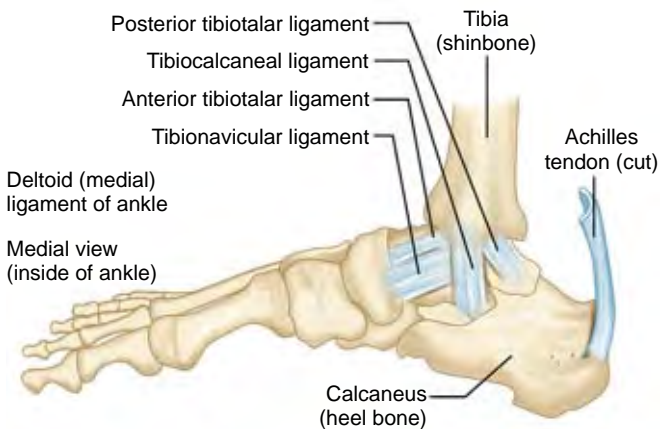


Fig. 2.202: Diagrammatic representation of the Deltoid ligament (medial ligament) of ankle joint.

Mechanism of Injury

Anterior talofibular ligament is the primary restraint against plantar flexion and internal rotation of foot. So most common mechanism of injury in lateral ankle sprains occurs with forced plantar flexion and inversion of the ankle joint (inversion ankle sprain). As in stepping in a hole or jumping on uneven surface. Medial ankle sprains are less common and caused when foot is turned outwards (eversion ankle sprain, i.e. deltoid ligament injury).

Clinical Presentation and Examination

Patients with ankle sprain present with pain and swelling around the ankle joint following a twisting injury of foot. Swelling, bruises and tenderness may be present on the lateral aspect and front of ankle. Walking may be difficult. Abnormal motion and instability may be elicited in completely torn ligament injury. Anterior Drawer test of ankle joint (The examiner stabilizes the anterior distal leg with one hand and grasps the patient’s calcaneus and

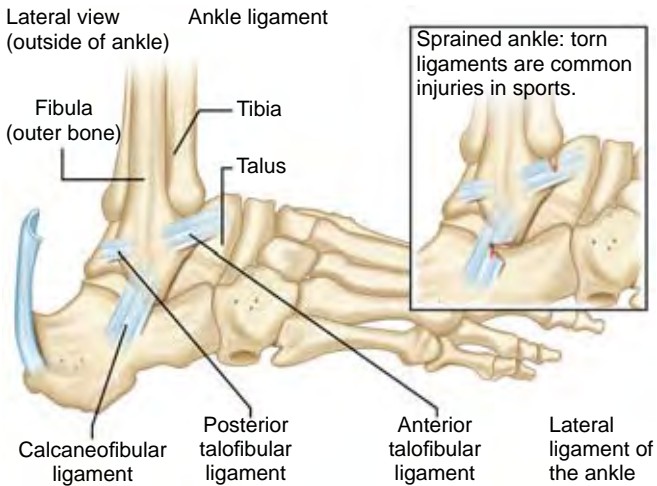


Fig. 2.201: Lateral ligament complex of ankle joint.

Table 2.32:Lauge-Hansen grading of injury		
Grade I injury	Grade II injury	Grade III injury
Ligaments are stretched only	Partial tear of ligaments	Ligaments are completely torn

rear foot with other hand. Then examiner pushes the rear foot anteriorly with foot in slight planter flexion. A positive test is indicated by forward talus translation) (specific for ATFL) and inversion stress tests are provocative tests for testing integrity of the lateral ligaments that are commonly injured. The injury can also be graded by Lauge Hansen grading method (Table 2.32).

Treatment

Diagnosis is made on clinical grounds. X-rays may be required if bony tenderness is present. MRI is the best diagnostic modality for ligament injuries. Treatment of an acute ligament sprain is RICE therapy (rest, ice, compression and elevation). This helps in reducing swelling and pain and fastens the healing of ligaments. Weight bearing may be allowed as tolerated. Braces which limit inversion may be helpful. More severe injuries may best be benefitted by immobilization in a below knee cast.

Surgery is reserved for the patients who do not respond to a fair trial of conservative treatment and for persistent instability after ankle injury and involves reconstruction of the torn restraint.

FRACTURES AROUND THE ANKLE

These are common fractures especially in young active persons involved in sports and in elderly females. These fractures can be unimalleolar, bimalleolar or trimalleolar. Various eponyms are used to describe some common fractures in this area as given in Box 2.1. These fractures are usually caused by low energy twisting injury (mechanism of injury is same to that of ankle sprain). Direction of force and

Box 2.1: Some common fracture eponyms around ankle

Pott's fracture: A bimalleolar (medial and lateral malleolus) fracture around ankle

Cotton's fracture (Fig. 2.203): A trimalleolar fracture (in addition the posterior malleolus of tibia fractured)

Maisonneuve fracture: A fracture of medial malleolus in association with a fracture of the proximal third of fibula. This is an external rotation type of ankle injury (see Lauge Hansen classification).

Le-Fort Wagstaffe fracture: Avulsion fracture of the anterior tibio-fibular ligament from the anterior surface of fibula. This is a Supination-external rotation injury (See Lauge Hansen classification).

Tillaux-Chaput fracture: Avulsion of the anterior tibio-fibular ligament from the anterior tibial margin (tibial counter-part of the Le-fort fracture). This is a Salter Harris type III injury (Fig. 2.204). This is seen in adolescents and rare in adults.

Bosworth fracture dislocation: In this injury the fibula becomes entrapped behind the tibia and becomes irreducible. ORIF is required to treat these injuries.

Pronation-dorsiflexion injury (Fig. 2.205): This is displaced fracture of the anterior articular surface of tibia. It is thought to be a variant of Pilon fracture.



Fig. 2.203: X-ray of ankle AP view showing both malleoli fractured and Lateral view showing the posterior malleolus of tibia fractured additionally (Cotton's fracture).

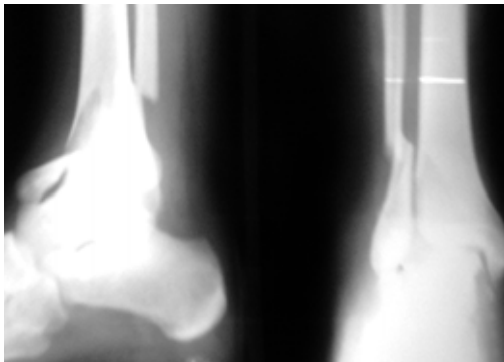


Fig. 2.205: X-ray of ankle showing pronation dorsiflexion injury. Note large chip of anterior tibial articular surface lying in front of the ankle.

position of foot at the time of injury determines the fracture pattern as described by Lauge and Hansen. Before going through the detail of this classification you must know about deforming forces (Figs. 2.206A and B).

- **Inversion:** Inward twisting of foot
- **Eversion:** Outward twisting of foot
- **Supination:** Inversion plus plantar flexion
- **Pronation:** Eversion plus dorsiflexion.

Lauge-Hansen classification: It is based on the mechanism of injury. Four main types are described. The first word in each type describes the position of the foot at the time



Fig. 2.204: Schematic representation of Tillaux fracture (Salter Harris Type III injury).

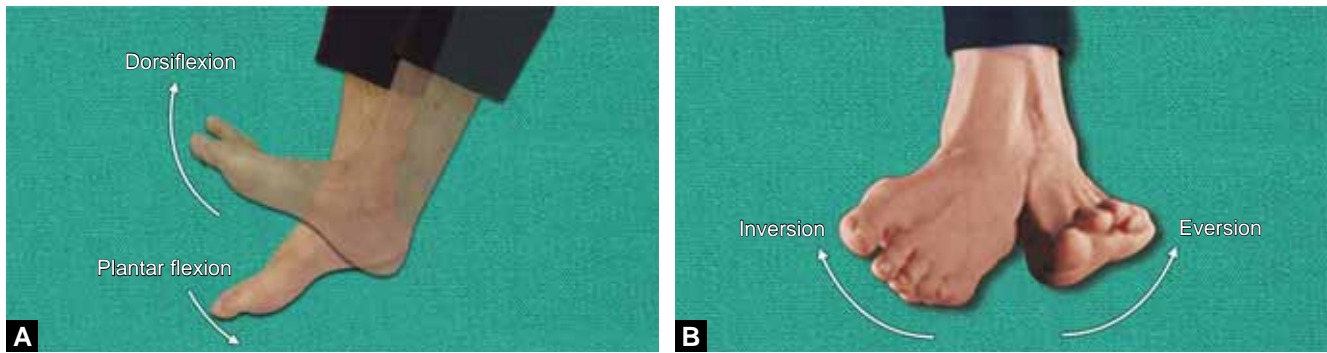
of injury and the second word in each type describes the direction of the deforming force. Different combinations can lead to a different sequential injury pattern, the final injury depending upon the magnitude of deforming force. The classification has been summarized in Table 2.33. The most common type out of all is the Supination-external rotation injury, comprising 40-75 % of all malleolar fractures.

Clinical Presentation

Patient usually gives a history of a twisting injury followed by severe pain, swelling and inability to bear weight. On examination the ankle will be swollen and tender with crepitus. Condition of skin and neurological status should be assessed. Open fractures and dislocations require urgent intervention.

Radiological Features

Anteroposterior and lateral view of the ankle are mostly sufficient to make the diagnosis. Fracture pattern, amount of displacement, and comminution, articular congruity, and disruption of syndesmosis (normally there is a small overlap between distal tibia and fibula; in syndesmotic injury the overlap is decreased) are the things which should be noted in the radiograph. Mortise view or AP view



Figs. 2.206A and B: (A) Dorsiflexion and plantar flexion; (B) Inversion and eversion.

Table 2.33: Lauge-Hansen classification (Figs. 2.207 and 2.208)

I. Supination-Adduction (SA)

Stage I: Avulsion fracture of fibular tip

Stage II: Vertical fracture of medial malleolus

II. Supination-external rotation (SER) (most common type)

Stage I: Sprain of anterior tibiofibular ligament

Stage II: Spiral fracture of distal fibula (runs from antero—inferior to postero—superior)

Stage III: Tear of posterior tibiofibular ligament ± fracture of posterior malleolus

Stage IV: Transverse fracture of medial malleolus or tear of deltoid ligament

III. Pronation-Abduction (PA)

Stage I: Tear of deltoid ligament or transverse fracture of medial malleolus

Stage II: Rupture of syndesmotoc ligaments

Stage III: Transverse fracture of the fibula above the level of the syndesmosis

IV. Pronation-external rotation (PER)

Stage I: Tear of deltoid ligament or transverse fracture of medial malleolus

Stage II: Tear of Anterior tibiofibular ligament

Stage III: Spiral fracture of fibula above the level of the syndesmosis (runs from anterosuperior to posteroinferior)

Stage IV: Tear of Posterior tibiofibular ligament or avulsion fracture of posterior malleolus

of ankle in 15° internal rotation of ankle is the best view to see the ankle articular surfaces. Normally, in mortise view medial clear space should be equal to superior clear space and equal to or less than 4 mm. Lateral clear space changes with rotation and in mortise view it should be less than 6 mm (Fig. 2.209).

Management

The aim of the treatment is to achieve bone union and maintenance of tibiotalar joint congruency. Undisplaced fractures around the ankle are managed by below knee plaster cast immobilization for 6 weeks. After 6 weeks cast is removed and protected weight bearing can be allowed in a brace. Isolated minimally displaced lateral malleolus fractures are also treated conservatively in a below knee cast. Modern air-cast boot are also available for comfortable conservative management of ankle sprain and stable undisplaced/minimally displaced ankle fractures.

Operative Treatment

Displaced fractures that disrupt the articular part of mortise, cause syndesmotoc widening or are associated

with an obvious subluxation or dislocation are candidates for surgical fixation.

In displaced fractures open reduction of the fracture is done and fracture is fixed internally using plates and screws. Anatomical reduction of the fracture is must to maintain the congruity of the ankle mortise. Any subluxation of the joint should be accurately reduced. Intraoperatively reduction is assessed under image intensifier. Medial malleolus fractures are fixed with compression screw (malleolar screws) or tension band wiring (Figs. 2.210A and B). Displaced lateral malleolus fractures are managed with buttress plating (for spiral or oblique or comminuted fractures) and compression screws or tension band wiring (for transverse fracture).

If there is a syndesmotoc injury (after fixing the fractures fibula is pulled laterally using a hook, the joint will open up in case of syndesmotoc disruption. This is also known as Cotton's test.) it should be fixed with a syndesmotoc screw (a transverse screw from fibula to tibia). Posterior malleolus (fracture of posterior lip of tibial plafond) fracture is usually a part of trimalleolar fracture (Cotton's fracture). If posterior fracture fragment involves more than 25–30% of articular surface operative fixation with compression screw is required.

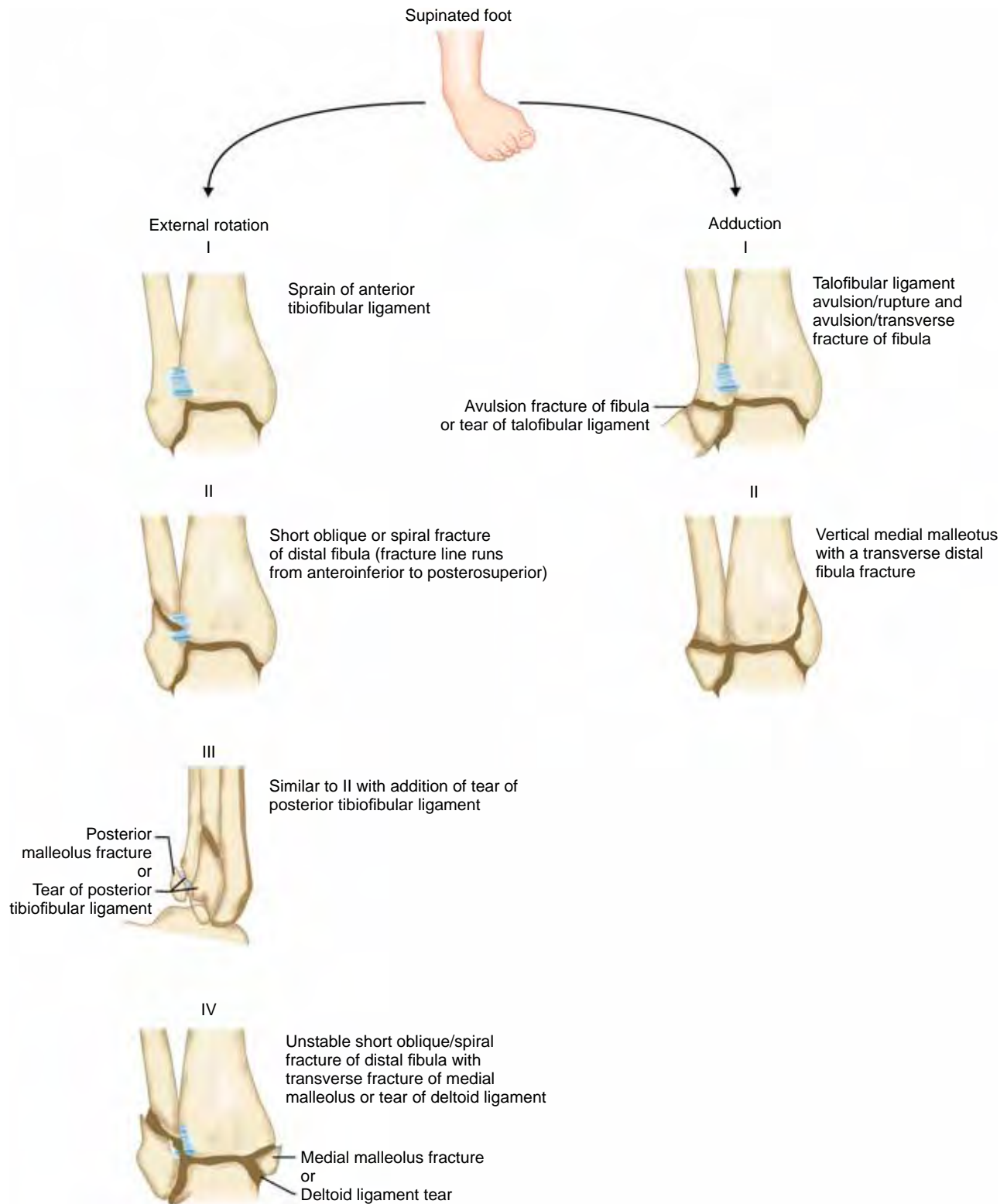


Fig. 2.207: Schematic depiction of stages of Supination injuries around ankle.

Caution is to be exercised in the presence of marked edema or blisters. In such cases operative fixation should be delayed. Leg is splinted and elevated until the skin condition improves.

Complications

- *Wound breakdown and infection:* Wound breakdown is particularly common in diabetics. Superficial wound

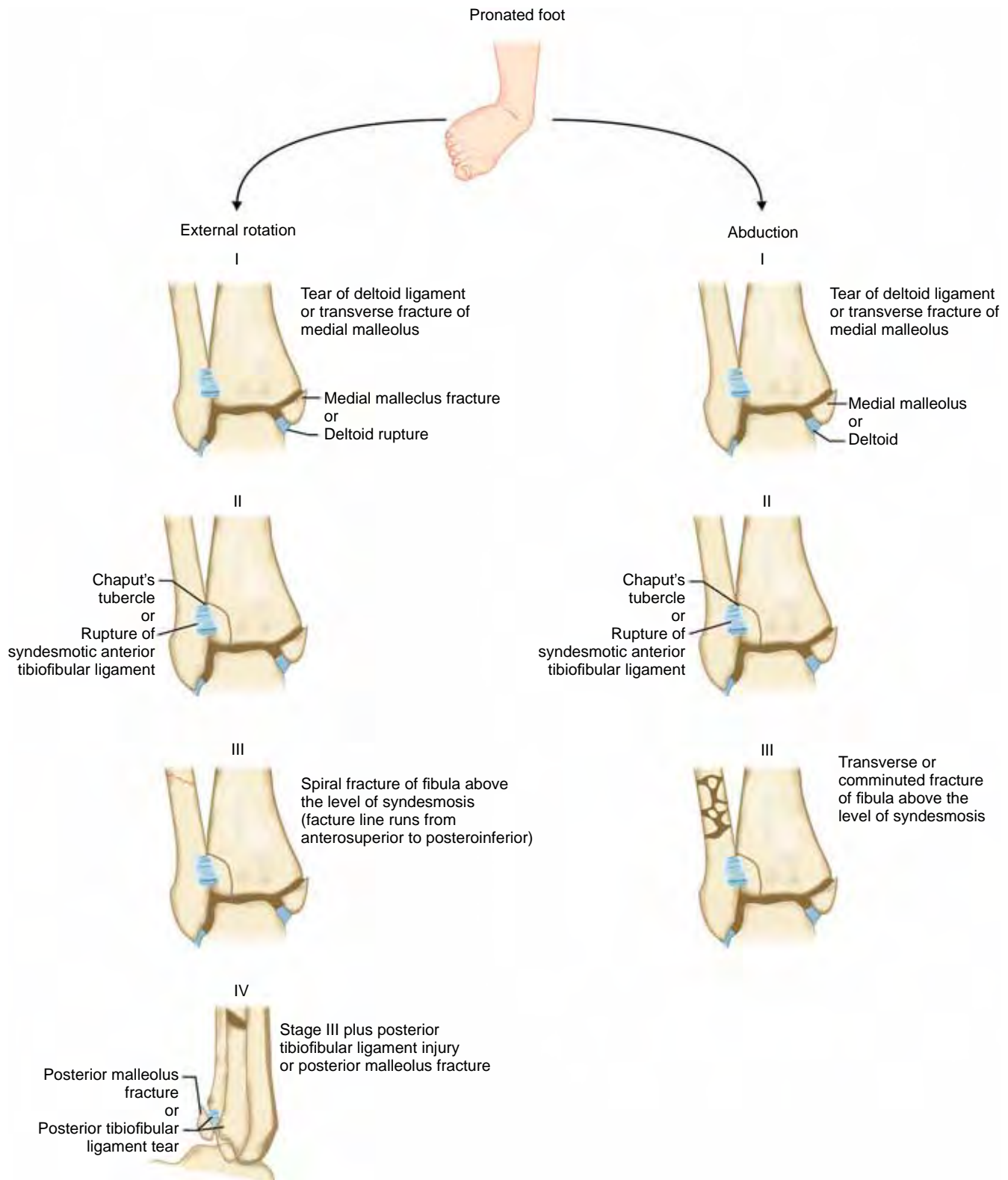


Fig. 2.208: Schematic depiction of pronation injuries around ankle.

breakdown (stitch line necrosis) may be treated with wound cleaning (removal of devitalized tissue and dry crust) and moist dressing. Deep tissue infection requires serial irrigation and debridement.

- Nonunion is less common with operative intervention. Inadequate reduction, loss of reduction or soft tissue or periosteum interposition (most common cause) between fracture fragments during reduction may lead



Fig. 2.209: Mortise view of ankle.

to nonunion. Asymptomatic nonunion does not need treatment. Painful nonunion requires open reduction and internal fixation with compression screw with bone grafting. Fibular nonunion is rare.

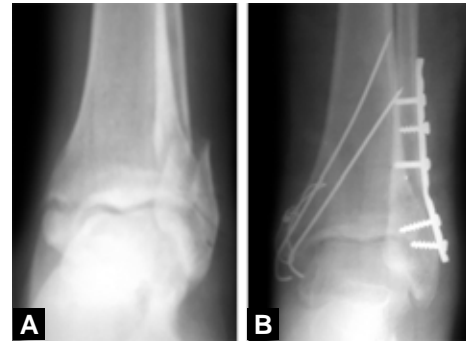
- Joint stiffness may occur following prolonged immobilization in plaster. Plaster should be applied in correct (neutral) position and physiotherapy should be started after removal of plaster.
- Osteoarthritis is a late complication of malunion/inadequate reduction. Usually it can be managed with analgesics, severe cases may require ankle arthrodesis (fusion of talus and tibia).

HIGH-YIELD POINTS

- “Ottawa ankle rule” is used to avoid unneeded radiographs after ankle injury (i.e. which patient needs X-ray after ankle injury?). Ankle X-ray is required if there is pain in malleolar region plus bony tenderness along the distal posterior edge (or tip) of medial or lateral malleolus or inability to bear weight for four steps.
- *Ottawa foot rule*: X-ray foot is required if there is any pain in the midfoot zone plus bony tenderness at the base of the fifth metatarsal or at the navicular bone or inability to bear weight for four steps.
- *High ankle sprain*: These are sprain of syndesmotic ligaments and are less common.

FRACTURE OF TALUS

Talus is the second largest tarsal bone and also the second commonest tarsal bone to fracture (after calcaneum). It has a head, neck, body and a dome. Fracture of the neck of the talus is the most common injury encountered in talus. More than half of its surface is articular and it is an important major weight bearing bone. A major blood supply to the body of talus is contributed by artery of tarsal sinus, the branches of which enter via the neck (Fig. 2.211) and travel proximally to supply the body. Thus, talus has precarious retrograde blood supply and a fracture of the talar neck can cause a break in the blood supply resulting in AVN of the body.



Figs. 2.210A and B: (A) X-ray ankle AP view showing bimalleolar fracture and tension band wiring of medial malleolus fracture and (B) compression plating of lateral malleolus fracture.

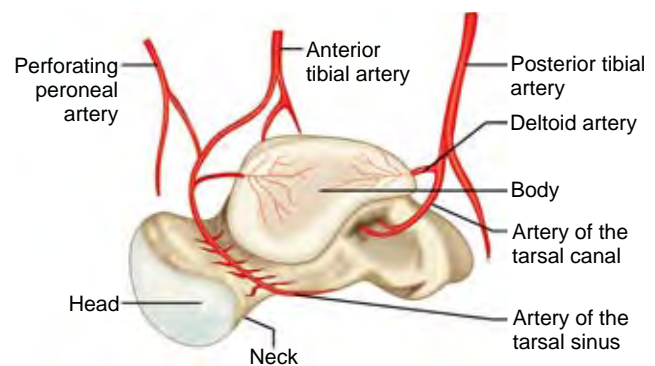


Fig. 2.211: Schematic depiction of parts of talus and blood supply of talus.

Mechanism of Injury

Talus is fractured by forced dorsiflexion (in hyperdorsiflexion talar neck abuts against anterior tibia) of foot when the weak talar neck gives way. This fracture has been described as Aviator's fracture because in pilots who rest their feet at the rudder bar, forced dorsiflexion may cause talus fracture on impact. High energy motor vehicle injuries and fall from height are more common mechanisms of injury. Talus fractures are most commonly seen in young adults.

Clinical Features

Talar fractures usually present with swelling and pain of hind and midfoot. In displaced fractures gross deformity may be present. Ankle movements are painful and weight bearing is not possible. Diagnosis is confirmed by antero-posterior, lateral and oblique X-rays of foot and ankle (Fig. 2.212). Canale view (Fig. 2.213) is the specialized X-ray view that provides the most optimum view of the talar neck.

Treatment

Undisplaced fractures can be managed with a plaster cast (applied in equinus) for 8–10 weeks. After 4 weeks X-ray is repeated to see the reduction and fracture position. If



Fig. 2.212: X-ray ankle lateral view showing talus fracture with ankle dislocation.



Fig. 2.213: Positioning for Canale view, specialized view for talar neck.



Fig. 2.214: AVN of the body of talus [note dense sclerosis (arrow) in the body of talus].



Fig. 2.215: Note zone of lucency in the sub-chondral area beneath dome of talus. It indicates viability and goes against development of AVN (Hawkin's sign).

fracture displaces in cast in follow-up X-ray ORIF should be considered. Displaced fractures are primarily managed by open reduction and internal fixation with screws. Treatment should be urgent to minimize the chances of development of AVN.

Complications

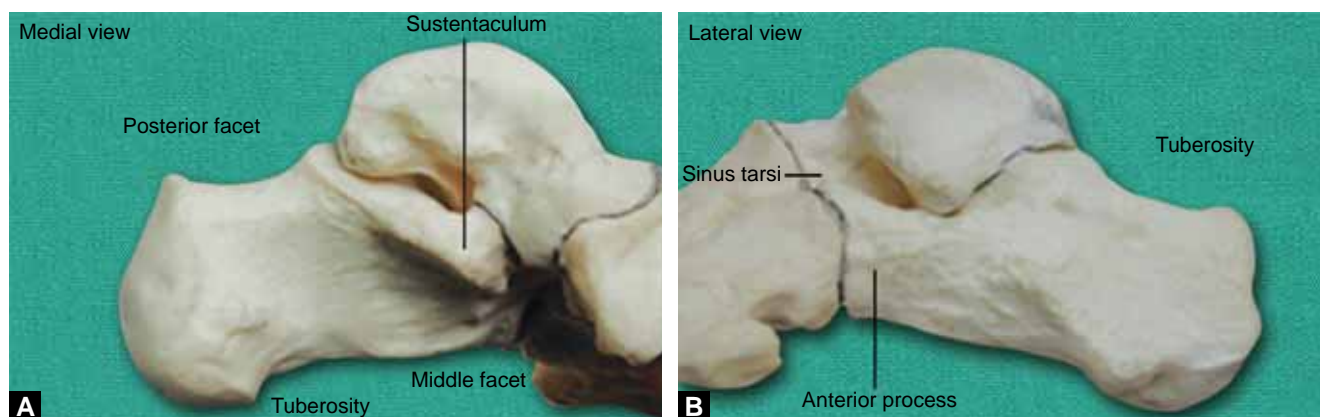
- *Avascular necrosis of body of Talus (Fig. 2.214):* This is a common and dangerous complication of talar neck fracture. Talar neck fractures are classified into four types by Hawkin's classification based on displacement. Chances of AVN increases with severity of displacement of fracture. On X-ray between 6 weeks and 8 weeks necrosed bone shows increased density (the earliest sign on X-ray) compared to surrounding bone. Actually this is due to viable surrounding bone which becomes porotic with disuse. By this time if a subchondral lucency is seen in the talar dome instead of increased density it indicates viability of bone and excludes AVN (Hawkins sign Fig. 2.215).
- *Malunion:* Displaced fracture if not adequately reduced and fixed may lead to malunion commonly in the varus position. This leads to excessive weight bearing on the lateral side of the foot making condition often

painful and ending up at times in osteoarthritis of the sub-talar and ankle joint.

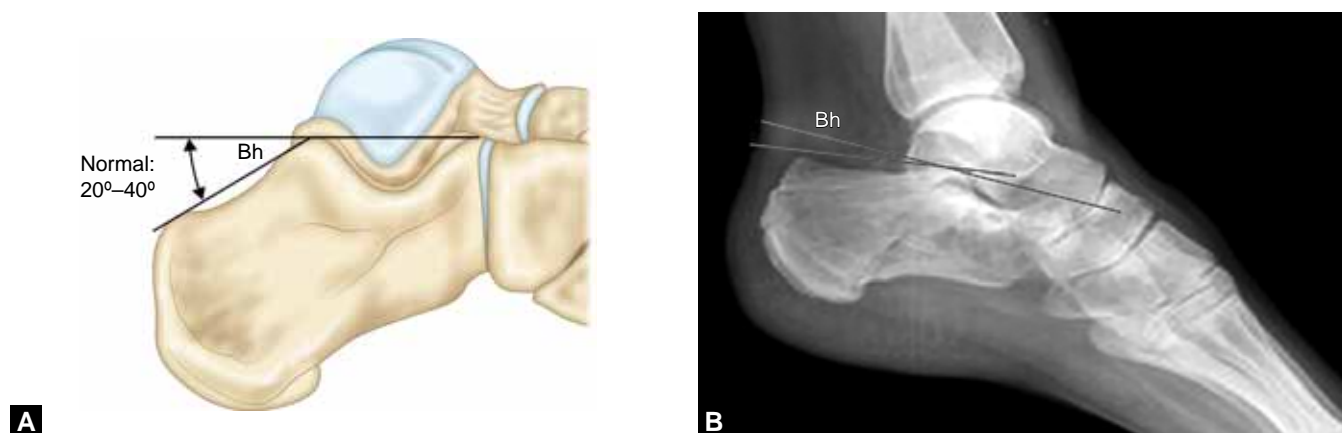
- *Non union:* This may complicate 15% of cases and may necessitate open reduction and bone grafting.
- *Osteoarthritis of ankle:* Damage to articular cartilage, malunion of fracture or osteonecrosis of talus can lead to secondary osteoarthritis of the subtalar (most common complication of talar fractures) and the ankle joint. Advanced arthritic changes with severe pain may require ankle/subtalar arthrodesis or total ankle arthroplasty.

CALCANEUM FRACTURE

Calcaneum is the heel bone which articulates with the talus superiorly and the cuboid anteriorly. It is the largest and most commonly fractured tarsal bone. The articular surface of the calcaneum that articulates with the talus is divided into three facets—anterior, middle (formed over the sustentaculum tali) and the posterior. Sustentaculum tali is an eminence on the medial side of calcaneum that supports the middle articular facet and under which the flexor hallucis tendon passes (Figs. 2.216A and B). The extraarticular part of the calcaneum forms the tuberosity where the tendo-Achilles inserts.



Figs. 2.216A and B: Calcaneal anatomy.



Figs. 2.217A and B: (A) Diagrammatic depiction of Bohler's angle (h) in normal patient (B) Angle decreased in a patient with fracture of calcaneum.

Mechanism of Injury

It is usually a fall from height with landing on heel (axial loading) and hence also called as Lover's fracture or Don Juan fracture (named after persons who jumped from balcony after being caught in a love affair). Less commonly motor vehicle accidents may be the cause when the break pedal impacts the plantar aspect of the foot. Axial loading causes crushing and shearing of bone and up to 75% calcaneal fractures are intraarticular fractures.

Clinical Features

Patients present with severe pain in heel with variable swelling and broadening of heel. The patient becomes unable to bear weight. Always look for other associated fracture of dorsolumbar spine, pubic rami and atlantoaxial injuries which are caused by same mechanism of injury, i.e. axial loading. Bilateral fractures are present in 5–10% cases so the other side must also be examined. Prior to surgery look for skin wrinkles on dorsiflexion and eversion of ankle. It is a rough guide to indicate that swelling has reduced to an acceptable level and surgery can be done (Wrinkle test).

Radiological Investigation

Anteroposterior and lateral view of ankle is sufficient to diagnose calcaneal fracture. Harris view (axial view of hind foot) and Broden's view (internal rotation of leg view used mostly for intra-operative assessment) are special views to look into finer details of the tuberosity and articular surface respectively. The lateral view demonstrates two important angles: (1) the tuber angle of Bohler and (2) the crucial angle of Gissane.

Bohler's angle (normal is 20°–40°) is formed between two lines, one line joins the highest point of the anterior process to the highest point of the posterior facet and another line is drawn tangential to the superior edge of the tuberosity. A decrease in Bohler's angle indicates collapse of posterior facet (Figs. 2.217A and B).

Angle of Gissane (normal is 100°–145°) is formed by a line along the lateral margin of the posterior facet and another line extending anterior to the beak of the calcaneus (Fig. 2.218). An increase in this angle represents collapse of posterior facet.

CT scan is the investigation of choice for calcaneal fractures. Saunders classification is used to classify these fractures and is based on the number and location of articular fragments on a coronal CT image.

Treatment

Nondisplaced/minimally displaced extraarticular fractures and undisplaced intraarticular fractures can be managed with nonweight bearing in a cast for 6–8 weeks. Range of motion exercises should be started as soon as pain subsides. Conservative treatment is also indicated in calcaneal fracture in insulin dependent diabetics and severe peripheral vascular disease due to risk of wound related complications. Displaced extraarticular and collapsed/displaced intraarticular fractures need open reduction and internal fixation with plate (Figs. 2.219A and B). Aim of the treatment is to maintain the articular anatomy of the articular facets. If the facet is collapsed it should be lifted and should be supported with bone grafts and fixed with plate.

Complications

- Widening of heel and some degree of heel pad pain are almost always present after calcaneal fracture. It may occur following both operative and conservative treatment of calcaneal fractures.
- *Stiffness of ankle and subtalar joint:* This is common after plaster immobilization. Early range of motion exercises should be started to prevent it.
- Calcaneal malunion is common following conservative treatment of displaced intraarticular fractures and may end up in subtalar and/or calcaneocuboid arthritis if the fracture is intraarticular.



Fig. 2.218: X-ray showing depiction of Angle of Gissane.



Figs. 2.219A and B: (A) X-ray of ankle lateral view showing calcaneal fracture (arrow) and (B) its fixation with calcaneal plate.

- *Wound dehiscence:* This is the most common complication following operative management of calcaneal fractures. Diabetics, smokers and patients with severe peripheral vascular diseases are particularly at risk of wound-related complications.
- Malunited calcaneal fracture with lateral protuberance may cause peroneal tendinitis. It is more commonly seen following nonoperative treatment. Bony spurs after malunion may also compress the posterior tibial nerve in the tarsal tunnel causing tarsal tunnel syndrome. Operative reduction of mass may be required if pain persists and conservative treatment fails. A displaced fracture of calcaneal tuberosity that malunites may lead to tendoachilles slackening.

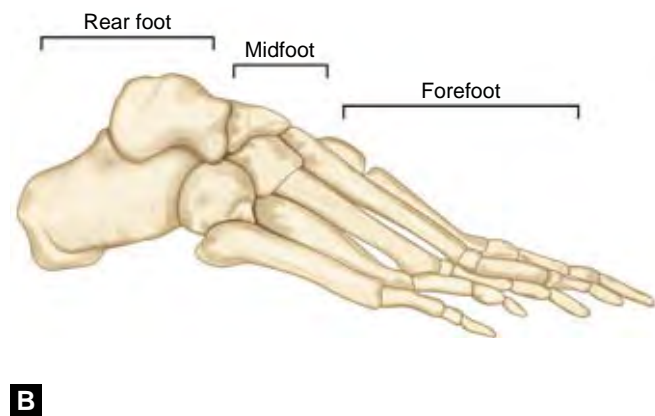
MIDTARSAL INJURIES

The midfoot (Figs. 2.220A and B) consists of the calcaneocuboid joint, talonavicular joint and the lesser tarsal bones, i.e. navicular, cuboid, and medial, middle and lateral cuneiform bones. Injuries to midfoot are uncommon and range from simple sprain to displaced fractures and frank dislocation. Midtarsal (or transverse tarsal) joints, i.e. calcaneocuboid and talonavicular are also called Chopart's joint and Chopart's dislocation is plantar dislocation of calcaneocuboid and talonavicular joints. Isolated fractures of navicular are rare injuries but more common than those of cuboid and cuneiforms.

Clinical Features

Patients present with swollen and tender midfoot. Foot movements and weight bearing are painful. Fracture dislocations may produce obvious deformity. Diagnosis is confirmed by anteroposterior, oblique and lateral X-rays of foot.

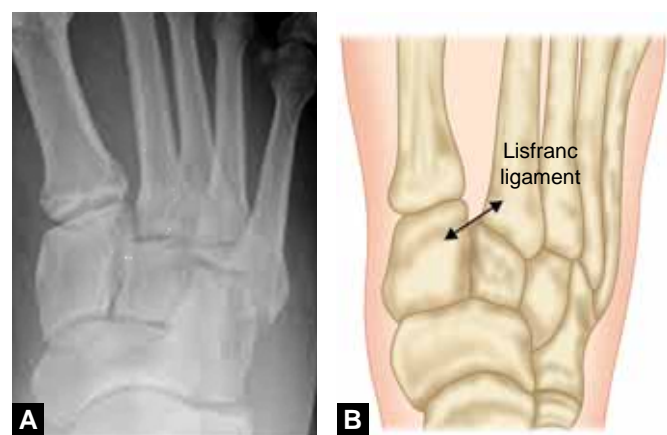
Nondisplaced fractures and fracture sprain (avulsion fractures of tarsal bones) are treated by below knee walking cast for 4–6 weeks. Displaced fractures, and fracture dislocations require close reduction (open reduction if close attempt fails) and internal fixation with K wires or screws.



Figs. 2.220A and B: Midfoot joints.



Fig. 2.221: Forced hyperflexion causing Lisfranc injury in foot.



Figs. 2.222A and B: X-ray of Lisfranc dislocation showing Fleck sign (encircled) due to rupture of Lisfranc ligament.

LISFRANC DISLOCATION (TARSOMETATARSAL DISLOCATION)

The Lisfranc joint consists of the tarsometatarsal joint complex, which includes the three cuneiforms, cuboid and their articulations with the five metatarsal bones. Dislocations of the Lisfranc joint are the commonest dislocations of the foot. These injuries usually result from high energy injuries like forced hyperflexion in road traffic accidents (Fig. 2.221) and fall from height.

Patients present with severe midfoot pain, swelling, deformity and inability to bear weight. This is one of most severe injuries of midfoot and all patient should be assessed for compartment syndrome of foot (tense foot, severe pain on passive toe movement). Diagnosis is made with anteroposterior, lateral and oblique radiographs of foot. On X-ray, there is increased space between the medial cuneiform and the second metatarsal (due to rupture of Lisfranc ligament that runs between these points) called as Fleck sign (Figs. 2.222A and B). This dislocation has to be reduced accurately either by closed or open means and has to be fixed with K wires or screws. Secondary midfoot arthritis (due to articular damage) is a common complication.

METATARSAL FRACTURES

These are common fractures of foot. These are usually caused by direct blow (fall of heavy object) and twisting of foot. Patients usually present with pain and swelling of foot and painful weight bearing. Diagnosis is made on anteroposterior, lateral and oblique X-rays of foot.

Foot becomes swollen and tender. Anteroposterior and oblique view of X-ray foot is sufficient for the diagnosis. Most single metatarsal fractures are usually minimally displaced. Undisplaced and minimally displaced metatarsal fractures are managed with splint/below knee cast for 3–4 weeks with progressive weight bearing as tolerated. Open fractures, multiple metatarsal fractures and displaced fractures are treated with close/open reduction and internal fixation with K wires.

Fractures of Base of Fifth Metatarsal

These are common injuries. Peroneus brevis tendon and lateral band of plantar fascia insert onto the base of fifth metatarsal. Sudden inversion of foot may cause traction at the base of fifth metatarsal due to pull by peroneus brevis tendon or band of plantar fascia resulting in fractures involving three different zones (Fig. 2.223). Jones fracture

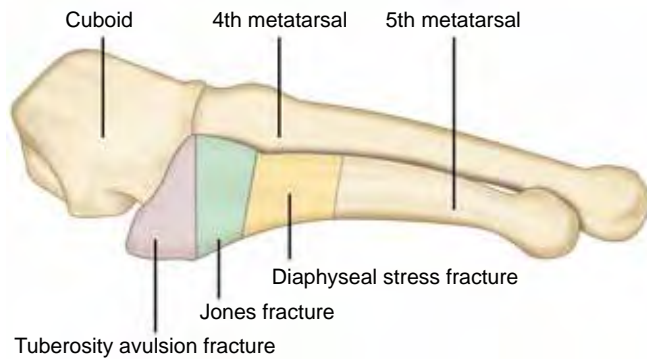


Fig. 2.223: Fractures of base of fifth metatarsal.



Fig. 2.225: X-ray of foot showing avulsion of the fifth metatarsal base (Pseudo-Jones or Dancer's fracture).

is base of fifth metatarsal fracture at junction of metaphysis and diaphysis (Fig. 2.224). It is caused by direct blow on base of fifth metatarsal of a plantar flexed foot. Pseudo-Jones or Dancer's fracture is an avulsion of the tip of the fifth metatarsal (Fig. 2.225).

Patients present with pain and tenderness on base of fifth metatarsal at lateral border of foot with painful weight bearing. Diagnosis is confirmed on X-rays. Nondisplaced avulsion fractures are treated by walking cast for 3–4 weeks with weight bearing as tolerated. Acute nondisplaced Jones fractures may be managed with nonweight bearing cast for 6–8 weeks. Since rate of nonunion is high, many surgeons prefer to treat these injuries with close/open reduction and internal fixation with compression screw.

March Fracture

It is a stress fracture of the distal part of the shaft of metatarsals. Second followed by third metatarsals are most commonly involved. It is common in military recruits, dancers, etc. due to repetitive stress of foot striking on the ground. Patient presents with pain which is activity related and often point tenderness at the site of stress fracture can be elicited. Initially X-rays rarely show any sign but over time incomplete subperiosteal fracture or a slight area of



Fig. 2.224: X-ray of foot showing Jones fracture involving meta-diaphysis junction of the base of fifth metatarsal.



Fig. 2.226: X-ray of foot AP view showing stress fracture of 3rd metatarsal (see callus formation due to healing of fracture) *Courtesy: Learning Radiology.com.*

periosteal reaction is seen (Fig. 2.226). MRI (investigation of choice) and bone scan are modalities to show stress fracture when they are negative on X-rays.

Treatment is cessation of offending activity. A non weight bearing short leg cast is given for 3–4 weeks.

FRACTURES OF PHALANXES

These are usually caused by fall of heavy objects on foot. No immobilization is required. The injured toe is usually strapped (buddy strapping) with the adjacent toes and patient is encouraged to walk.

HIGH-YIELD POINTS

- Talus is the only bone which does not have any muscular attachment.
- Peri-talar dislocation/subtalar dislocation refers to dislocation of talus from its distal articulations viz. subtalar joint and talo-navicular joint. In total talus dislocation the talus is dislocated from all articulations including the ankle joint.
- Navicular stress fractures are common in runners. Patients present with mid-dorsal pain. Treatment is nonweight bearing cast immobilization for 6 weeks.

- *Nutcracker injury*: Forceful abduction of foot may lead to fracture-dislocation of the second metatarsal base with an associated cuboid crush fracture known as “nutcracker” injury.
- Second metatarsal is the longest of all metatarsals and most common site for stress fracture in the foot. Fifth metatarsal is most commonly fractured metatarsal.
- Neutral triangle of calcaneum (Fig. 2.227) is an area of sparse trabeculations within the calcaneum trabeculae. This is the weakest area of calcaneum and fractures usually occur through this area.
- Calcaneum is the second most common site for stress fractures in foot after metatarsals.
- Although calcaneal fractures are common in fall from height but the commonest fractures in fall from height are D12 > L1 vertebra.
- Ankle joint is the least common site for recurrent dislocations.



Fig. 2.227: X-ray depicting the neutral triangle in calcaneum.

- Watson Jones procedure is a surgery for treating chronic lateral ankle instability where the lateral side is reconstructed with the peroneal tendons.

SKULL AND FACIAL INJURIES

SKULL FRACTURES

Table 2.34 describes some common fracture patterns seen in the skull. The most common skull bone to fracture is the Temporal bone. Fractures in the bone can be longitudinal or horizontal (based on the relation of fracture line with the long axis of the bone). Longitudinal fractures are more

common and can produce rupture of tympanic membrane with bloody discharge from ear (hemotympanum). Transverse fractures on the other hand are more known to produce a facial nerve paralysis as they extend into the petrous part of the temporal bone.

Apart from these there can be fractures of the cranial fossa (anterior, middle and posterior). Anterior fossa

Table 2.34: Some common fracture patterns in skull bones

Linear fracture: Most common type of skull fracture. These fractures look like a thin line that involves either the inner or outer table or the full thickness of the skull. There is no displacement of bone.

Depressed fractures/Signature Fractures: In signature fractures the broken bones are displaced inward. They occur when a heavy object with small striking surface (e.g. hammer) hits the head. The outer table is driven inwards while the inner table is fractured irregularly.

Ring fracture: These fractures particularly occur following a fall from a height (with “feet first” impact) and involve the posterior fossa around the foramen magnum.

Gutter fractures: They are formed when part of the thickness of the bone is removed so as to form a gutter, e.g. oblique bullet wound.

Spider web fractures/Mosaic fractures: These comprise multiple comminuted fractures in the form of depressed fracture lines with radiating fissures.

Hinge fracture/Motorcyclist fracture: This fracture is seen in patients with fall from height or seldom in motorcyclists who land up with high velocity road traffic accidents that gives a blow to the side of the head. The force is transmitted via the helmet to the base of the skull producing a transverse fracture of the floor. At autopsy the base of the skull is found to be divided into two halves, anterior and posterior, each moving independent of each other as if connected via hinge, hence also called as “Hinge fracture”.

Pond/indentation fractures (Ping pong skull): These are a type of shallow depressed fracture, which occur in infant skulls which are elastic and are able to be indented without a frank break in the bone. In a pond fracture, the inner table and the dura are intact. Fracture is usually caused by a fall when the skull hits the edge of a hard blunt object, such as a table. The skull appears deformed, with a shallow trench on the surface of the skull.

Diastatic skull fractures: Diastatic fractures occur when the fracture line traverses one or more sutures of the skull causing a widening across the sutures. These are also usually seen in infants and young children as the sutures are not yet fused.

fractures can lead to bilateral ecchymosis with swelling of the upper lids (Raccoon's sign/Panda sign). Olfactory nerve is the commonly involved nerve in these fractures. Middle fossa fractures can cause a CSF rhinorrhoea apart from damaging the sixth, seventh and eighth cranial nerves. The posterior cranial fossa fractures on the other hand tend to involve the ninth to eleventh cranial nerves. Not uncommon in these fractures is to find the classical Battle's sign (delayed ecchymosis over the mastoid region).

MAXILLOFACIAL FRACTURES

The most common facial bone to fracture is the nasal bone followed by the zygomatic bone. Fractures that involve the middle third of the face (between supra orbital ridge and upper jaw) are classified by the Le Fort classification into three types. Type III fractures are the severe most causing complete disruption of the attachment of the facial skeleton to cranium. Type II and III may also injure the cribriform plate causing CSF rhinorrhoea. For details on the classification and these fractures kindly refer to ENT textbook.

MANDIBULAR FRACTURES

Mandibular fractures mostly result when there is a blow to the chin. The commonest site is through the neck of the condyle. On clinical examination one may find Coleman's sign i.e. hematoma in the floor of the mouth in fractures involving the body of mandible. Most fractures are displaced because of the pull of masseter. Early reduction and fixation is the aim under a cover of broad spectrum antibiotics.

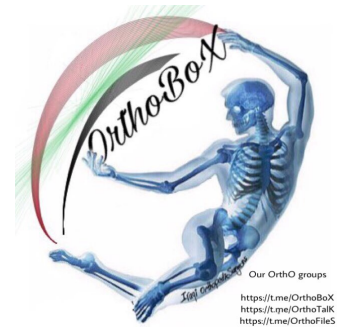
NASAL FRACTURES

A blow to the nose from front results in Jarjaway's fracture. The fracture line starts just above the anterior nasal spine and runs horizontally backwards ending near the junction of septal cartilage with vomer. A blow from below to the nose results in the Chevallet fracture. Here the fracture line runs vertically upwards from the nasal spine to end at the junction of the bony and cartilaginous septum. For details on other fracture patterns and appropriate management on these areas, reader is suggested to read ENT textbook.

CHAPTER

3

Spine



BEHAVIOR OF SPINE

RELEVANT ANATOMY (FIGS. 3.1A AND B)

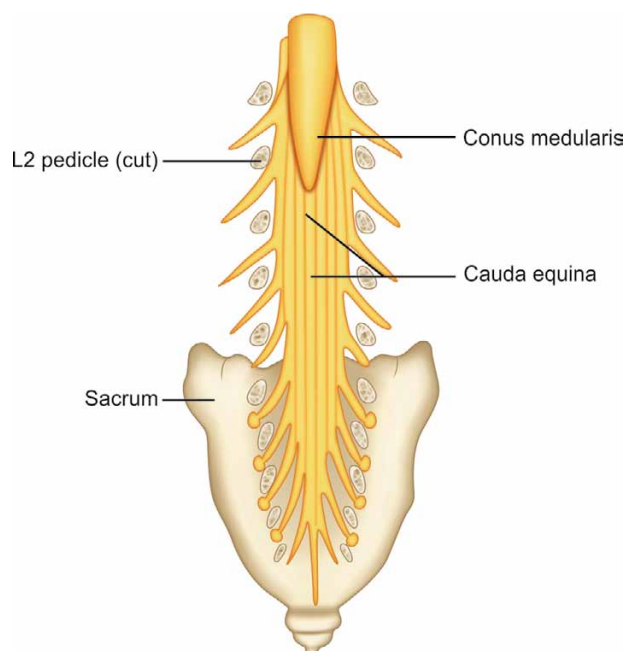
Spinal cord is approximately 45 cm long neural structure extends from the foramen magnum, where it is continuous with medulla oblongata and terminates mostly at the lower border of L1 as “Conus Medullaris”, which technically refers to the sacral segments of the cord. Cauda Equina (eq. Horse’s tail) refers to the hanging nerve roots in the canal that are arising from respective spinal cord segments. Filum terminale is the fibrous septum that extends from the distal end of conus and then closely adhering to the dura mater it inserts into the first coccygeal segment.

Now, in an adult the spinal cord generally ends at the lower border of L1. However, in the fetus, the situation is quite different (Fig. 3.2). Here, the cord is as long as the vertebral column. But due to differential growth between the vertebral column and the spinal cord, in an adult the cord ends earlier as the vertebral column grows more.

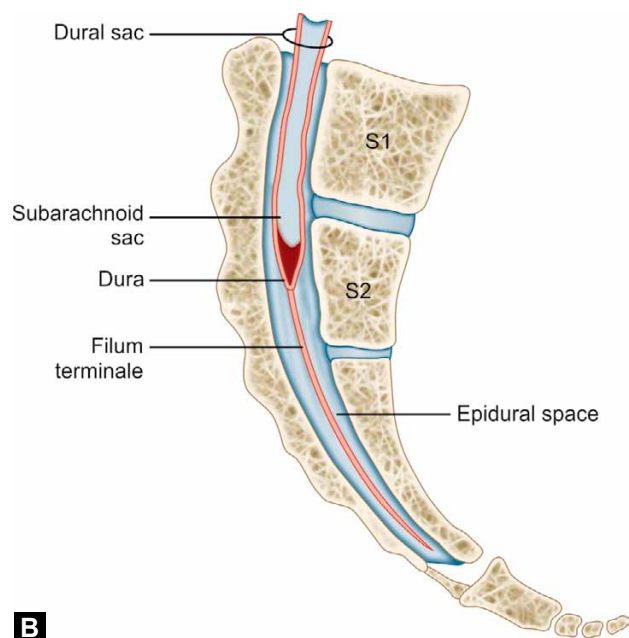
Each segment of spinal cord gives rise to a nerve, called a spinal nerve. Each nerve would leave the vertebral column through the intervertebral foramen beneath the corresponding vertebrae (e.g. L1 nerve root leaves beneath L1 vertebrae). Now, since the cord is ending at the lower border of L1, the nerve roots generally have to descend a bit of distance in the canal before they can exit; and this gives rise to the hanging nerve roots lying in the canal below L1 which arose from corresponding spinal segments but had to descend down their corresponding vertebral levels to exit the column and hence the “Cauda Equina” formation.

Cross-sectional Anatomy of Spinal Cord (Fig. 3.3)

On cross section, the core of the spinal cord has a butterfly like pattern that comprises the gray matter that is



A



B

Figs. 3.1A and B: Diagram depicting the terminal anatomy of spinal cord: (A) Coronal view (B) Sagittal view.

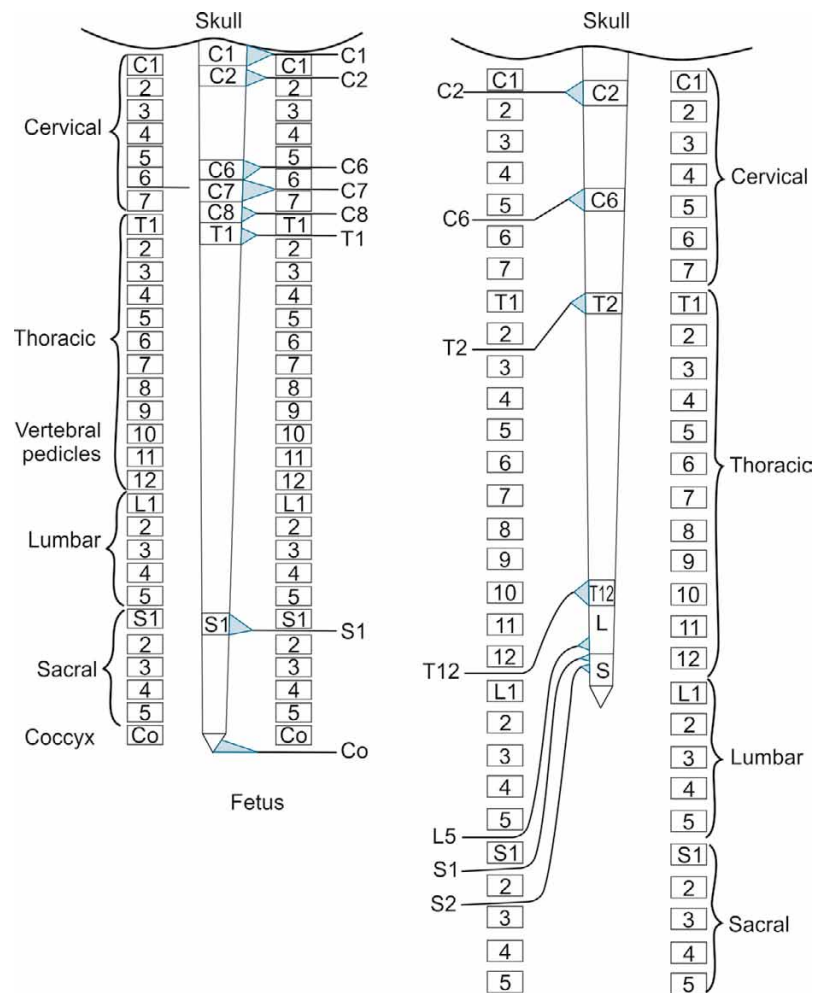


Fig. 3.2: Variable lengths of vertebral and column and spinal cord.

surrounded by the white matter. The gray matter comprises cell bodies of the neurons and hence is unmyelinated while the white matter comprises axons and is the myelinated component. In other words, gray matter is the thinking part of the cord while white matter has the connecting ascending and descending tracts that relay the information between higher centers and the end organs.

LOCALIZING A SPINAL LESION

Three concepts are pivotal to localization of any injury in the spinal cord:

1. The concept of upper and lower motor neuron (LMN) lesion
2. The understanding of a reflex
3. The knowledge of dermatomes and myotomes.

Upper and Lower Motor Neuron Lesions

Upper motor neurons (UMNs) refer to the nerve cells that extend from brain cortex to the anterior horn cells of the spinal cord while the LMNs refer to the cells extending

from the anterior horn of cord to the neuromuscular junctions. To simplify one may say that UMNs are basically the brain and spinal cord while the LMNs are the nerves (Fig. 3.4). The features of both types of lesions are depicted in Table 3.1. Thus, one would find exaggerated reflexes and hypertonia when injury involves the central nervous system while areflexia and flaccidity is a prime feature of peripheral nervous system lesions.

The concept behind such a presentation is very simple. Let us assume that the spinal cord is transacted at C6 level, then the inhibitory impulses generated by the higher centers are unable to reach the lower cord and the neurons distal to the injury level start firing (owing to their innate excitatory tone). As a result, below the level of injury the muscles get hypertonic and reflexes become exaggerated. However, one must note that even in UMN lesion, at the level of the cord lesion, the reflexes are absent and the muscles are atonic. This is the complete presentation of UMN lesion. LMN lesion is absolutely different. In this, there is an injury to a nerve (Fig. 3.4) and the reflex contributed by the injured nerve or the muscle supplied by that nerve undergoes flaccid paralysis. However, in

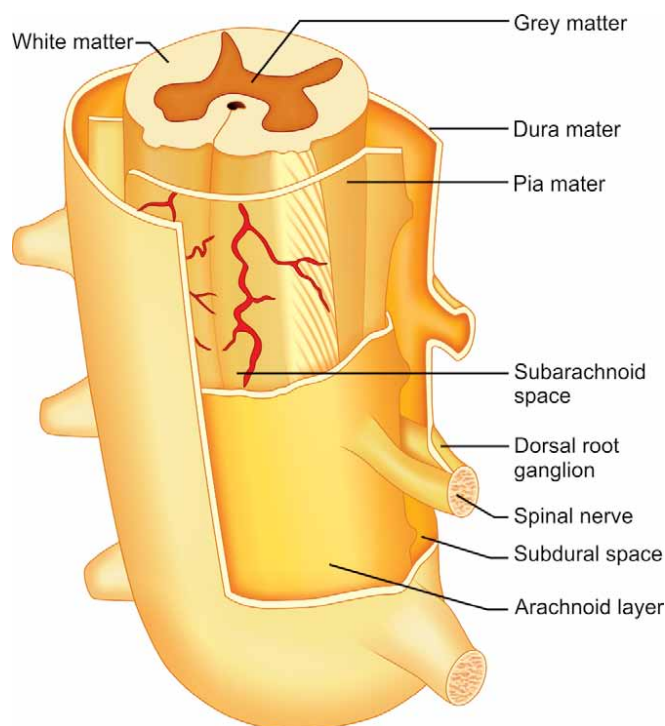


Fig. 3.3: Cross-sectional anatomy of spinal cord.

Table 3.1: Differences between UMN and LMN lesion

Upper motor neuron	Lower motor neuron
<ul style="list-style-type: none"> Weakness is often symmetric Increased DTRs (after spinal shock) Muscle tone increased No fasciculations Automatic bladder 	<ul style="list-style-type: none"> Often single muscle group (with atrophy) Decreased DTRs Muscle tone decreased Fasciculations Autonomous bladder

(UMN: Upper motor neuron; LMN: Lower motor neuron; DTR: Deep tendon reflexes).

LMN lesion, the spinal levels below the level of nerve injury are going to remain unaffected unlike UMN lesions, where the lower levels get hypertonic.

Reflexes

Most people would think of a reflex as an involuntary muscular contraction to a stimulus. Technically, a reflex is a simple sensory-motor pathway that involves a single spinal segment; which means in a reflex the stimulus is carried to spinal cord via the dorsal root and the action returns to the contracting muscle by only involving the single spinal segment (Fig. 3.5). A reflex does not need relaying with the higher centers and can function on its own. As opposed to this, the pathway for voluntary motion is absolutely different. The stimulus is carried from cord to brain via the white matter ascending tracts, processed in brain and then relayed down to the appropriate muscles via the descending corticospinal tracts. Hence, the crux difference between a reflex and voluntary motion is that

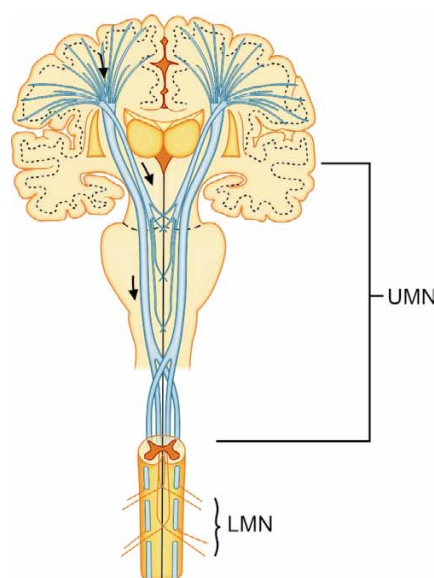


Fig. 3.4: The upper and lower motor neurons.

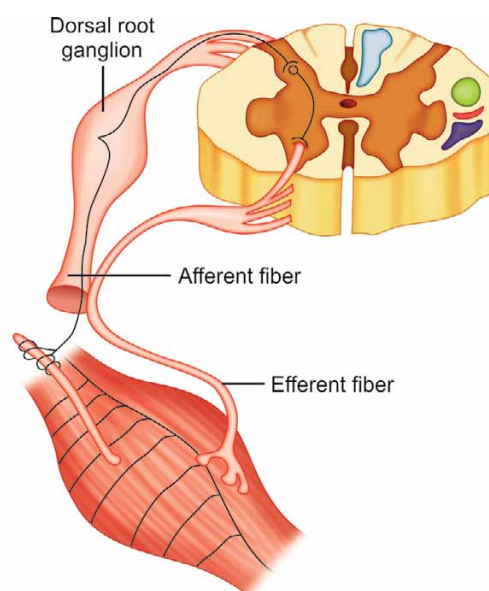


Fig. 3.5: Reflex arc.

reflex does not need the ascending or descending tracts of the white matter of cord to function unlike voluntary actions which rely on these connecting tracts. Imagine a patient with cord injury at D12 level. The cord below D12 will demonstrate UMN lesion and hence knee reflex that arises from L2 to L3 will be exaggerated, which means if one strikes the ligamentum patellae with a knee hammer, the quadriceps contracts or more appropriately hyper contracts (exaggerated reflex). However, if you ask this person to voluntarily contract his quadriceps he cannot, because in this situation the impulse goes to the brain and is sent down by the connecting white matter tracts. But since the cord is transacted at D12 level, no information can go down that level which means that patient voluntarily

cannot contract quadriceps. This is what paraplegia is, i.e. when voluntary motion is not possible below the level of lesion but reflexes will be intact because they involve a single spinal level.

Hence, the moral is that if we know the level of various reflexes, and their behavior in response to injury, we can locate any spinal lesion. At the level of cord transection (UMN lesion) reflexes are absent but below that level the reflexes are present (because they transcend single spinal segment) and in fact exaggerated. However, when a nerve is transected (LMN lesion), the reflex innervated by that particular nerve is absent, while the distal reflexes remain elicitable and are normal. Levels of some important reflexes are given in Table 3.2.

Note: The concept of a reflex discussed above holds true for deep tendon reflexes (DTRs) only as these are mono-synaptic. The superficial reflexes are polysynaptic having multiple interconnections in the cord itself and they do not behave in the same manner. Superficial reflexes above the level of injury are spared while those at and below the level of injury are absent.

Dermatomes/Myotomes

A myelomere is a segment of spinal cord that gives rise to a pair of dorsal and ventral roots that join to form a spinal nerve, total being 31 pairs. Let us understand how this spinal nerve is different from a peripheral nerve (e.g. median nerve, radial nerve, etc.). Consider the T4 spinal nerve. The nerve arises from spine and divides into ventral and dorsal rami and then the rami divide into motor and sensory branches. The sensory branches would supply the skin over the nipples and the motor branches would supply the intercostal muscles. However, the situation is very different for the spinal nerves that have to supply the limbs. The spinal nerves C5–C8, T1 leave the cord and then join in front of scapula to form the brachial plexus for the upper limb while it is the lumbosacral plexus formation

that takes place for the lower limbs. The nerves that leave the plexus are the peripheral nerves although these peripheral nerves actually are carrying the fibers of spinal nerves only. So technically the plexuses mix up the spinal nerve fibers and redistribute them into peripheral nerves. For example, “Deltoid” is supplied by C5 spinal nerve but the fibers reach the muscle via the axillary nerve which is a peripheral nerve. Similarly, although the sensation over little finger is supplied by C8 spinal nerve, the fibers actually are traveling via the ulnar nerve.

A dermatome refers to that area of skin which is supplied by a single spinal nerve, may the fibers travel via any number of peripheral nerves, and a myotome refers to that muscle which is supplied by a single spinal nerves. If we know the level of various dermatomes and myotomes and their behavior to injury, we can localize any spinal lesion. Understanding their behavior is very simple. In case of cord injury (UMN lesion), all dermatomes, may it be one at the level of injury or all below the level of injury demonstrate sensory loss. However, in case of injury to a nerve (LMN lesion), the sensory loss is restricted only to the dermatome of the affected nerve.

The myotomes behave differently. In case of cord lesion, the muscles at the level of cord injury end up in flaccid paralysis while those below the level of the injury show spastic paralysis due to cessation of inhibitory impulses from higher centers. But in nerve lesions, the muscles supplied by the nerve only are paralyzed and demonstrate flaccid paralysis. The distal muscles remain normal.

The levels of some important dermatomes (Fig. 3.6) and myotomes (Table 3.3) are shown below.

Deciding the Level of Spinal and Vertebral Lesion

After knowledge of the above discussed concepts localization of spinal cord lesion becomes very simple. If a patient

Table 3.2: Levels of some important reflexes
C5: Biceps
C6: Supinator (Brachioradialis)*
C7: Triceps
L3, L4: Knee reflex (Quadriceps)
L5, S1: Plantar reflex**
S1, S2: Ankle reflex (Gastro-soleus)

* The term “supinator reflex” is a misnomer. It is actually brachioradialis reflex as we strike the tendon of brachioradialis muscle at the radial styloid process. The older name for brachioradialis was supinator longus and hence the term.

**Plantar reflex is elicited by striking the lateral border of the sole of foot. In normal reflex there is plantar flexion of great toe and all toes come together. When the reflex is exaggerated, there is great toe dorsiflexion and fanning of all toes. This is called as Babinski sign. When the reflex is absent, there is no toe movement and the reflex is said to be mute.

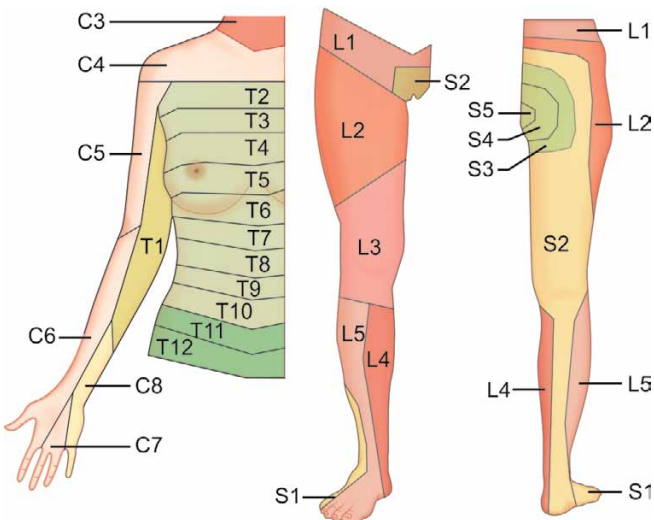


Fig. 3.6: Dermatomes of upper and lower limbs.

Table 3.3: Important myotomes of upper and lower limbs

C5: Deltoid
C6: Wrist extensors
C7: Wrist flexors/Elbow extensors
C8: Finger flexors
T1: Finger abductors
L1, L2: Hip flexor (Ilio-psoas)
L3: Knee extensor (Quadriceps)
L4: Ankle dorsiflexor (Tibialis anterior)
L5: Long toe extensor (Extensor hallucis longus)
S1: Ankle plantar flexor (Gastro soleus)

has exaggerated reflexes and hypertonia, there is an injury to spinal cord. One should look for the absent reflex to locate the upper most level of injury to the cord and would find all reflexes distal to that level to be exaggerated as would be the tone. An injury to a nerve root should be suspected when there is an isolated absent reflex or flaccid paralysis of a single level myotome with distal functions preserved.

Once the level of cord lesion is deduced, one can take out the vertebra that is involved as well by a simple formula mentioned below (Table 3.4).

Caution: Do remember that spinal cord finishes at the lower border of L1, so there is no cord below that level and hence, if there is a lesion in vertebral column below that level (for example, disk prolapse L4–L5), one can never have exaggerated reflexes or UMN lesion. It would present as a LMN picture which means that the involved reflex will be absent, muscle flaccidly paralyzed and sensation in affected dermatome gone. However, everything below that level would be unaffected. Upper motor lesion is generally common with vertebral injuries above L1 because most of the canal in this region is occupied by spinal cord.

Identifying the Affected Vertebra

Once the diagnosis has been reached and the affected vertebra elucidated, one can cross confirm the diagnosis by identifying and palpating the vertebra (Table 3.5). Following landmarks may guide in this identification process.

NEUROLOGICAL DEFICITS AT VARIOUS SPINAL LEVELS

Cervical spine: Here injury to vertebral column generally causes injury to the spinal cord that occupies the greater part of the canal, thereby leading to a UMN lesion. The segmental level of the cord generally corresponds to the level of vertebral fracture. A transection above C5 level is mostly fatal as the respiratory muscles (intercostal muscles) including the diaphragm are paralyzed while transactions below C5, different muscles of the upper limb get spared depending upon the level of involvement.

Thoracic spine (Till D10): In these patients there is paraplegia along with varied paralysis of the trunk muscles.

Table 3.4: Relationship between vertebral level and cord level

Spinal level	Cord level
Cervical vertebrae	Add 1 to vertebral level
Upper dorsal (D1 to D6)	Add 2 to vertebral level
Lower dorsal (D7 to D9)	Add 3 to vertebral level
D10	All dorsal segments over
D12	All lumbar segments over
L1	All sacral segments over
Below L1	Cauda Equina

Table 3.5: Landmarks for some important vertebral levels

C2: First palpable spinous process
C3: Hyoid bone
C4, 5: Thyroid cartilage
C6: Cricoid
C7: Vertebra prominens (Longest spinous process)
T3, 4: Sternal notch
L3, 4: Umbilicus
L4, 5 disk: Highest point of iliac crest
S2: Posterior superior iliac spine.

**Fig. 3.7:** Eliciting Beevor's sign.

Behind D10 vertebrae the cord level is L1, so any injury at and below this level spares the trunk muscles and the only the lower limbs get involved. Localizing an injury in the thoracic segments needs knowledge of Beevor's sign and the trunk dermatomes.

Beevor's sign (Fig. 3.7): Patient raises the head from a recumbent position. The umbilicus is displaced toward the head. This is the result of paralysis of the inferior portion of the rectus abdominal muscle, so that the upper fibers predominate pulling upwards the umbilicus, signifying injury distal to D10 cord level (Remember, umbilicus lies at D10 spinal level).

D11–L1 lesions: Behind these vertebral segments lie the lumbar and sacral cord segments. Injuries at these levels can involve both the cord as well as the nerve roots and mixed pictures often result.

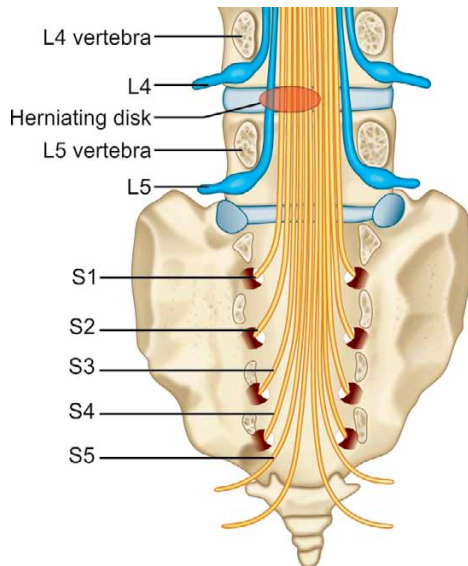


Fig. 3.8: Relation of nerve root and corresponding disk.

Lesions below L1 vertebrae: Below L1, there is no spinal cord and the canal is occupied only by nerve roots the so called “Cauda Equina”. Thus, injury in this area can only damage nerve roots and hence an upper motor picture is never possible. There is a lower motor lesion as per the number of nerve roots involved.

Nerve Root Involved in a Prolapsing Disk

Disk prolapse is generally seen in lower lumbar spine with most common site being L4–L5 greater than L5–S1. We already know that every spinal nerve exits the canal by passing through the intervertebral foramen present on the sides of the corresponding vertebrae, e.g. L4 nerve root will pass out of the canal by exiting through the intervertebral foramen on the side of the L4 vertebrae. Now, consider the situation when there is a disk prolapse L4–L5. The disk is present below the L4 vertebrae and if this disk goes back, it cannot compress the L4 nerve root as the same has already exited (Fig. 3.8), viz. the foramen present on the sides of the vertebrae. However, the L5 nerve root is coming from L1 level where the cord has already ended and thus L5 is the traversing nerve root in the canal which is traveling down to exit on the side of the L5 vertebrae. Henceforth, if the disk between L4 and L5 prolapses, it would be the L5 nerve root that would be affected (Fig. 3.8). The same applies to all lumbar nerve roots and it is always the lower level nerve root that is involved.

Caution: Even in cervical disk prolapse where the nerves actually exit from top of the corresponding vertebrae rather than below it, the lower nerve root is involved. This is because while in lumbar spine the disk involves traversing nerve root, in cervical spine the disk involves exiting nerve root due to a varied anatomy. However, in cervical disk prolapse isolated disk involvement occurs only if the disk prolapse is far lateral, as most other disks tend to indent

cord that is present in cervical area but already ended in lumbar area.

Cauda Equina and Conus Medullaris

We already know that if L4–L5 disk will prolapse, it will compress the L5 nerve root as the latter is the traversing nerve root in the canal. But one can well imagine that all distal nerve roots, viz. S1–S5 will also be the traversing roots at this level (Fig. 3.8), although more central in location. When a single nerve root is compressed by any lesion (most often a disk), the condition is called as “radiculopathy”. But many a times a compressing lesion (like a large sized disk) involves compression of multiple nerve roots that are hanging in the canal. This condition is referred to as “Cauda Equina syndrome” (c.f. Cauda Equina—Hanging nerve roots). This multilevel radiculopathy is manifested clinically as a LMN lesion as it is a nerve root compression and presents as a triad that includes asymmetric (since disks generally herniate posterolaterally to one side), areflexic (lower motor lesion) motor paralysis, bladder bowel involvement (S2–S4 involvement) and saddle anesthesia (anesthesia in distribution of S3 and S4 roots that involves the periphery of buttocks but initially spares the peri-anal area as peri-anal dermatome S5 is involved the last). One must remember that “Cauda Equina” is an orthopedic emergency and must be treated urgently.

An important differential of Cauda Equina syndrome is the Conus Medullaris syndrome. The latter results due to compression of the conus (sacral part of spinal cord). When the sacral part would be compressed, at the level of the lesion, there would be lower motor picture and below exaggerated picture. But this is an exception, because there is nothing below sacral level for exaggeration, the lesion turns out to be LMN type, thereby closely resembling Cauda Equina syndrome. However, the two can be differentiated on the following basis (Table 3.6).

Grading of motor weakness is done according to standardized motor examination rating scale (Table 3.7). Sensory examination should include pin prick, light touch and compared with other side.

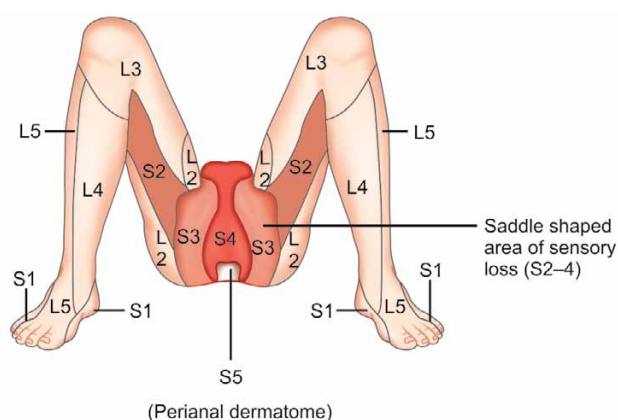
ACUTE SPINAL CORD INJURY

The behavior discussed above is the behavior shown by the spinal cord in chronic long-term cases. In case there is an acute traumatic injury to the cord, the initial behavior is slightly different till the classic patterns discussed above become evident.

Just after an acute cord injury there is cessation of all activity at and below the level of lesion. This stage of physiological disruption is referred to as “spinal shock”. The stage persists for 24–48 hours after which recovery starts and the classical UMN pattern starts evolving. The first reflex to return once the spinal shock is over is “the Bulbocavernosus reflex (Fig. 3.10)”, hence the presence of this reflex heralds the end of the stage of spinal shock and onset of recovery.

Table 3.6: Differentiating features of Cauda Equina and Conus medullaris syndrome

Features	Cauda Equina syndrome	Conus medullaris syndrome
Presentation	Asymmetric	Symmetric
Radicular pain	Severe	Usually not present
Sensory involvement (Fig. 3.9)	Saddle anesthesia (S2–S4) with perianal sparing initially (S5 sparing)	Perianal anesthesia (S5) as sacral cord compression involves loss of S5 cord segment
Motor involvement	Asymmetric flaccid paralysis	Symmetric usually flaccid sometimes hyper-reflexive paralysis
Reflexes	Areflexia is classical Knee reflex is lost if L3 and L4 roots involved	Knee reflex is always preserved
Bladder bowel involvement	Late feature	Early feature
Level of causative lesion	Compression of nerve roots usually by vertebral lesion L1 vertebra	Compression of conus (sacral part) by D12–L1 vertebral lesions
Sensory dissociation	Not found	Sensory dissociation can occur

**Fig. 3.9:** Diagrammatic depiction of saddle and perianal anesthesia.

COMPLETE VERSUS INCOMPLETE SPINAL CORD INJURY

Once the bulbocavernosus reflex returns, it signifies that spinal shock is over and recovery has started. Complete spinal cord transection is characterized by complete absence of sensations as well as voluntary motor activity caudal to the level of spinal injury after the spinal shock is over, i.e. an elicitable bulbocavernosus reflex.

If any evidence of neurological function (motor or sensory) can be demonstrated distal to the level of lesion, the injury is termed incomplete. Incomplete injury means that at least sacral nerve root function is preserved since it is the central most part of the spine. This “sacral sparing” is represented by intact perianal sensations, voluntary rectal motor function and great toe flexor activity. It indicates at least partial continuity of white matter long tracts thereby signifying incomplete injury and potential for a greater return of cord function.

Incomplete Spinal Cord Injury (SCI) Syndromes (Fig. 3.11)

Incomplete injury to the spinal cord may present in either of the following commonly encountered patterns:

Table 3.7: Grading of motor weakness according to standardized motor examination rating scale

- Grade 0: Total paralysis
- Grade 1: Palpable or visible contraction
- Grade 2: Active movement through full range of motion, gravity eliminated
- Grade 3: Active movement through full range of motion, against gravity
- Grade 4: Active movement through full range of motion, against gravity and provides some resistance
- Grade 5: Active movement through full range of motion, against gravity and provides normal resistance

Central Cord Syndrome

This is the most common incomplete spinal cord injury (SCI) syndrome. It results from hyperextension injury in older person with preexisting osteoarthritis of spine. The spinal cord is pinched between the vertebral body anteriorly and the buckled ligamentum flavum posteriorly with pressure getting concentrated around the cord area lying in vicinity of central canal. Due to typical arrangement of spinal tracts (the arm fibers medially, and the leg fibers laterally, Figures 3.12A and B) the arms are more severely affected than the legs, resulting in a disproportionate motor impairment. Clinical presentation depends on the site of involvement. In cervical spine involvement (most commonly affected area) patients present with quadriparesis with weakness involving the upper limbs (flaccid paralysis, due to LMN type lesion at the level of spinal injury) more than lower limbs (spastic paralysis due to UMN type lesion below the level of injury), varying degree of sensory loss below the level of spinal injury with or without bladder involvement. Prognosis is good with more than 50% patients recovering bladder bowel function and ambulation.

Brown-Séquard Syndrome

It refers to hemi-transection of spinal cord characterized by ipsilateral loss of muscle power, proprioception and

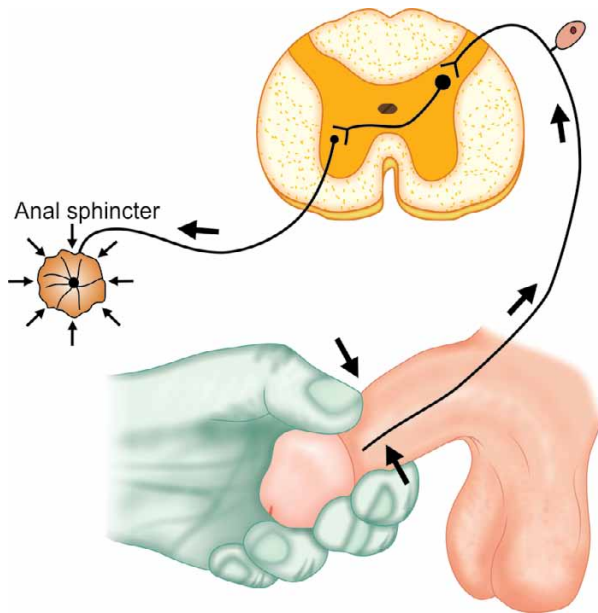


Fig. 3.10: Bulbocavernosus reflex refers to contraction of the anal sphincter in response to stimulation of trigone of bladder with either a squeeze on the glans penis, a tap on the mons pubis or a pull on the urethral catheter.

sense of vibration and contralateral loss of pain and temperature sensation. Prognosis for recovery is very good.

Anterior Cord Syndrome

Anterior cord syndrome typically results after hyperflexion injuries to the cord. It is characterized by predominantly motor loss and loss of pain and temperature. Dorsal column (sensations) function is preserved. Recovery rate is the poorest.

Posterior Cord Syndrome

It is caused by extension injury and involves the dorsal column. There is loss of dorsal column function (proprioception and vibration). Motor and other sensory functions (pain and temperature) are generally spared. Recovery rate is poor.

COMPLICATIONS OF ACUTE SPINAL CORD INJURY

Two notable complications that may arise when the patient is in the stage of spinal shock are: (1) neurogenic shock and (2) autonomic dysreflexia.

Neurogenic Shock

Neurogenic shock is seen in cases with SCI above T6 level. It results from impairment of the descending sympathetic pathways in the spinal cord resulting in loss of vasomotor tone and loss of sympathetic innervations to the heart.

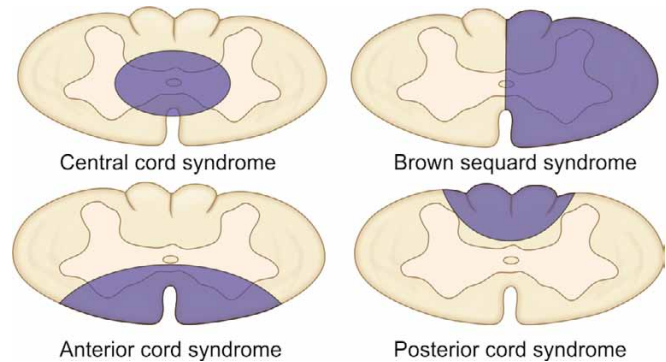


Fig. 3.11: Incomplete spinal cord injury syndromes.

The result is the classic hemodynamic triad consisting of hypotension (due to loss of vasopressor tone causing peripheral vasodilatation), bradycardia and hypothermia. An important differential is hypovolemic shock but the latter is characterized by hypotension with tachycardia.

Management: Unlike hypovolemic shock where the prime treatment is fluid replacement, in neurogenic shock vasopressors have to be given to counteract hypotension and atropine to counteract bradycardia. The condition almost always resolves within 24–48 hours.

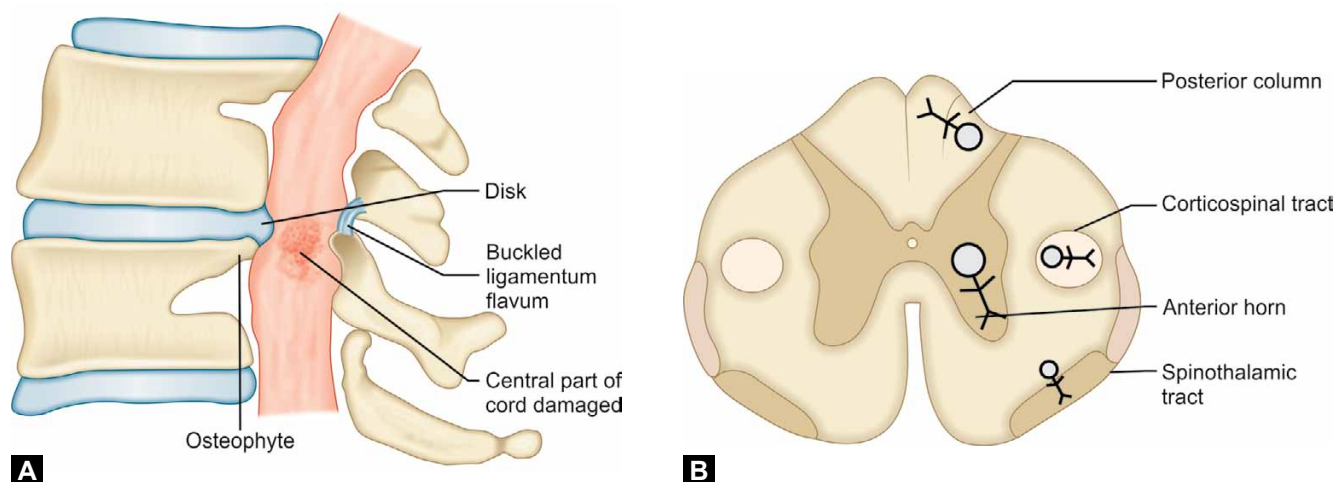
Autonomic Dysreflexia

Autonomic dysreflexia also occurs in people with a SCI at or above T6 level but results in severe hypertension, bradycardia and symptoms such as profuse sweating and headache. The exact mechanism is unclear but seems to be related to a large sympathetic outflow from the injured cord or increased responsiveness of organs to catecholamines after SCI.

Management: Management involves removing a potential trigger like a blocked catheter or administering drugs like antihypertensives (nitroglycerine), lidocaine to block afferent signal or spinal anesthetics.

HIGH-YIELD POINTS

- **Inverted reflex:** Here contraction of opposite muscle occurs than expected on performing the reflex. This is usually seen when there is radiculomyelopathy as when a degenerative disk presses both nerve root and cord. Nerve root compression leads to absent segmental reflex while cord compression leads to hyperreflexia that causes antagonist muscle contraction. For example in Inverted radial reflex (C5 > C6) tapping distal Brachioradialis tendon produces diminished Brachioradialis contraction but hyperactive finger flexion.
- **Hoffman reflex:** Upper extremity variant of Babinski. Flickering terminal phalanx of 3rd-4th finger produces flexion of terminal phalanx of thumb.



Figs. 3.12A and B: Mechanism of central cord syndrome.

SPINAL INJURIES

Spinal cord injury remains the most devastating injury for patients and spine surgeons alike. Despite several basic science and clinical advances in the study of cord injury, there is still no effective cure. Hence research continues and treatment principles continue to evolve as our understanding of the biomechanics is increasing.

INTRODUCTION

Vertebral fractures span through all age groups and affect four times more commonly the males than the females. Almost one out of every five patients lands up with a neurological deficit, in the form of either paraparesis or quadriplegia. The most common mode of injury leading to spine fractures in the developing world remains fall from height while in the developed world the road traffic accidents have taken the precedence. Cases are also being increasingly reported in athletes and sportsmen (15%). The overall mortality from spinal fractures has been reported to be as high as 20% at initial hospitalization which signifies the catastrophic potential of SCI.

RELEVANT ANATOMY

The vertebral column is composed of 33 vertebrae (7 cervical, 12 dorsal, 5 lumbar, 5 sacral and 4 coccygeal; the last five segments being generally fused together). Each vertebra has a similar structure being composed of a vertebral body anteriorly and a vertebral arch posteriorly. The arch is composed of pedicles, laminae, spinous processes and the facet joints. The cord lies in the spinal canal being surrounded anteriorly by the vertebral body's posterior margin and posteriorly by the elements of the vertebral arch (Fig. 3.13).

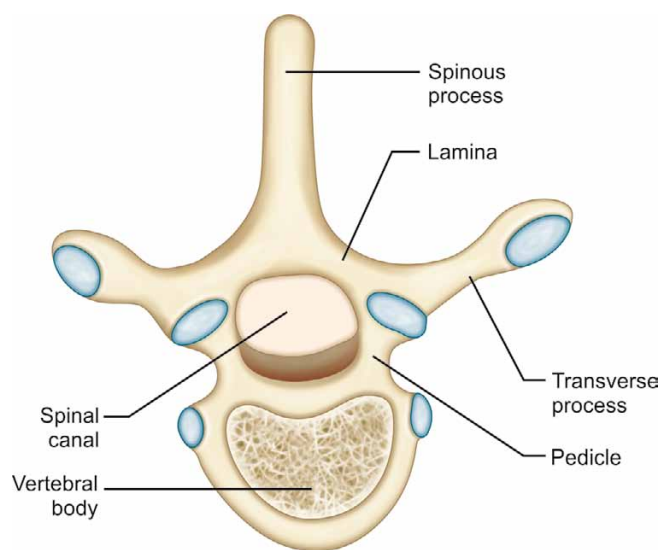


Fig. 3.13: Parts of a vertebral body.

The vertebral bodies articulate with each other via the intervening intervertebral disks between them while the vertebral arches articulate via synovial joints—the facet joints. The direction and size of these articular facets is different in different regions of the column. In the cervical spine, the facet joints are more horizontally oriented and shorter while in the dorsolumbar spine their orientation is more vertical and they are stouter (Fig. 3.14). Hence dislocations are more common in cervical spine while in the lower spine, pure dislocations without concomitant fractures are rare.

Apart from these bony articulations, a number of ligaments play vital role in providing stability to the spine (Fig. 3.15). The anterior and posterior longitudinal

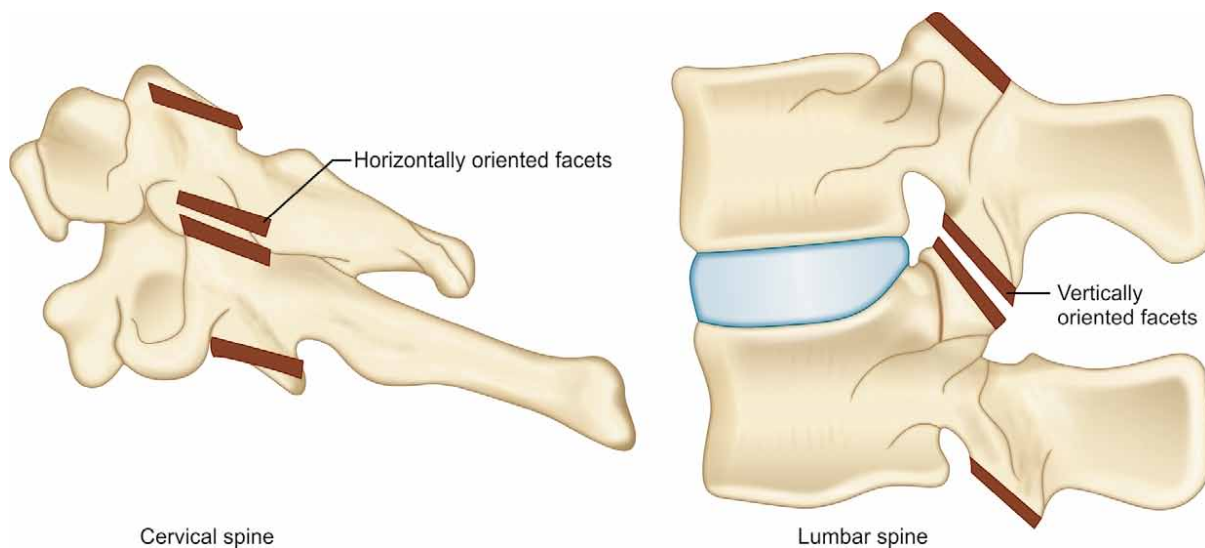


Fig. 3.14: Diagram showing orientation of the facet joints.

ligaments run longitudinally along the anterior and posterior margins of the vertebral body respectively. The vertebral arches are connected together via the posterior ligamentous complex (PLC) which includes the thick but elastic ligamentum flavum connecting the adjacent laminae, the inter-transverse ligaments connecting the adjacent transverse processes, the interspinous ligaments between adjacent spinous processes and the supraspinous ligaments connecting the tips of adjacent spinous processes.

BIOMECHANICS OF SPINAL CORD INJURY

The key fundamental concepts pivotal to the understanding of the SCI are its pathophysiology, the common injury mechanisms and the concept of spinal stability.

Pathophysiology

Pathophysiology: In injury the cord can be damaged by primary and secondary mechanisms. Primary damage to the spine refers to the direct compression of the cord by bony fragments or disk material leading to hypoxia of both white and gray matter. This acute primary damage initiates a cascade of vascular and metabolic events consisting of oxidative free radical damage and reperfusion injury to cord. This post-traumatic cord ischemia (secondary damage) is directly proportional to severity of injury.

Mechanisms of Spinal Cord Injury

Many types of forces act either in isolation or more commonly in combination to cause spinal injury. Basically there are four categories of forces relevant to spinal injuries:

1. Axial compression or distraction
2. Hyperflexion (most common) or hyperextension
3. Rotation and
4. Shear/translation

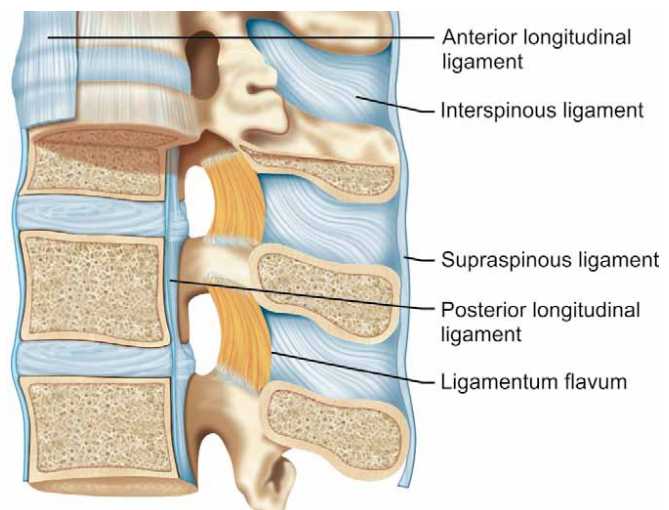


Fig. 3.15: Diagrammatic depiction of the spinal ligaments.

These forces mostly act in varied combinations to produce bony and ligamentous injury of spine. Due to different shape and orientation of vertebrae in different parts of spine same forces may produce different patterns of injury in different parts of spine (*see below*).

CONCEPT OF SPINAL STABILITY

A stable injury is one where the vertebral fracture would not displace further by normal movements of the spinal column. So if the neurological structures are not damaged, there is little risk of any damage occurring further. An unstable injury is one where there is a risk of further displacement of the fracture during the normal spine movements, thereby posing significant risk of further neurological deterioration.

To define spinal instability, Denis gave the three column concept of spinal stability (Fig 3.16). He divided spine into three columns, anterior, middle and posterior.

Injuries that involve two or more than two columns are considered unstable. Also injuries that do not involve the middle column are termed “minor injuries” and are considered stable.

A recently proposed concept is by Punjabi and White for quantifying the spinal stability for thoraco-lumbar region. It is a complex scoring based on the amount of displacement in spinal fracture, presence of neurological damage and the response of spine on physiological loading.

DIAGNOSTIC ASPECTS

Clinical Assessment

A meticulous clinical examination is must to rule out presence of a neurological involvement. A thorough neurological assessment (as described above in behavior of spine) should answer the three important questions.

1. What is the level of vertebral and cord involvement (if any)?
2. Whether the spinal cord injury is complete or incomplete?
3. If there is any associated injury (e.g. head injury).

The examination is particularly difficult in an unconscious patient in whom a spinal injury must be assumed

unless proven otherwise. Alarming signs include absence of a painful stimulus, a flaccid anal sphincter, diaphragmatic breathing, concomitant head injury and hypotension with bradycardia (neurogenic shock).

Imaging

It is mandatory to get both AP and lateral radiographs of spine in every polytrauma patient who complains of pain or stiffness around neck or back. A lateral X-ray can identify lesion in 85% cases of cervical spine fractures. Open mouthed views may be required for visualizing the upper two cervical vertebrae. Swimmer's view (Figs. 3.17A and B) is useful to obtain visualization of all cervical vertebrae and sometimes it may also show the upper half of T1 vertebrae.

For imaging difficult areas like the upper cervical spine or the cervico-thoracic junction, CT scan is the preferred modality. CT is ideal for identifying any structural damage to the vertebra or displaced vertebral fragments into the spinal canal.

Magnetic resonance imaging (MRI) is the investigation of choice for displaying the intervertebral disks, ligamentum flavum and the neural structures. It can best identify compression of the cord or nerves and is a prerequisite prior to undertaking a patient for surgical decompression.

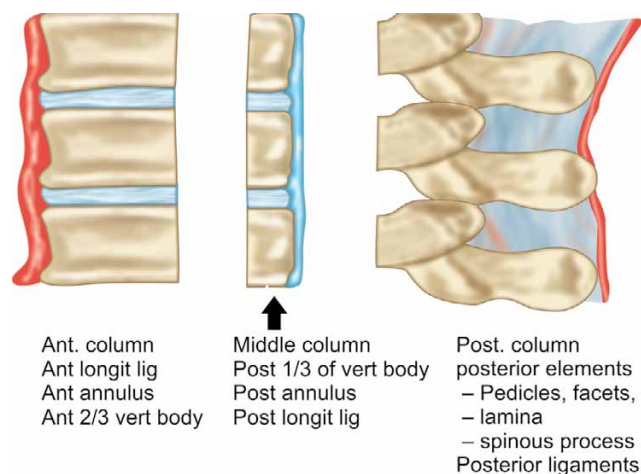
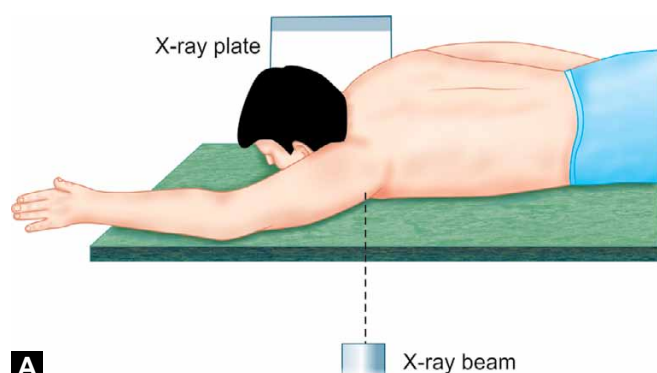


Fig. 3.16: Denis three column concept of spinal stability.



Figs. 3.17A and B: Swimmer's view.

MANAGEMENT OF SPINE INJURY PATIENTS

Emergency Management

The focus initially is to start the resuscitation protocol (ABCDE) as the patient is received in the emergency. The essential principle is that if there is even a slight possibility that the patient might have a spine injury, the spine must be immobilized appropriately while the doctor starts the resuscitation protocol by securing the airway (airway with cervical spine control). In case intubation is required, manual in line stabilization (MILS) (Fig. 3.18) of the cervical spine must be maintained. In case one needs to examine the back, the log rolling technique (Fig. 3.19)





Fig. 3.18: Manual in-line stabilization.

should be used to turn the patient. Thereafter, other serious injuries should be identified and appropriately treated. Immobilization of the spine should be discontinued only after spine has been cleared after thorough clinical and radiological assessment.

The most commonly used treatment strategy during emergency management to prevent the secondary injury to the spinal cord is “methylprednisolone”. Although as per current literature the benefit is dubious, some surgeons prefer to give this steroid in a dose of 30 mg/kg IV bolus followed by a maintenance infusion of 5.4 mg/kg/hour over next 23 hours, preferably in patients who present within 8 hours of injury.

Definite Management

Definitive management of these lesions is guided by two important factors—the stability of the spine and the presence of a neurological deficit.

No Neurological Deficit and Stable Fractures

The management in such cases largely is conservative. A period of spinal immobilization (with collars or braces) is all that is needed to give rest to the healing tissues and ligaments. Neurological deficit in stable fractures develops only occasionally, which could be an indication for decompression of the cord and fusion of the unstable spine.

Presence of Neurological Deficit or Unstable Lesion

In case of unstable fractures with no neurological deficit, one can opt for conservative management but it is practically very difficult. A substantial period of cervical traction is required for patients with cervical spine fractures. A specialized team is needed to turn the patient every 2 hourly, care for bladder and bowel and provide appropriate physiotherapy. Over time the fracture stabilizes spontaneously and the patient can then be mobilized. In most other cases, the doctors generally prefer to go ahead with fusion of the unstable spine. However, when a patient presents with a progressive neurological deterioration, with evidence of further



Fig. 3.19: Log rolling technique.

neural compression on MRI, it signifies a positive indication for a surgical intervention. The surgery involves decompressing the involved neural elements by removal of fracture pieces that have retro pulsed followed by fusion of the spine.

TREATMENT METHODS

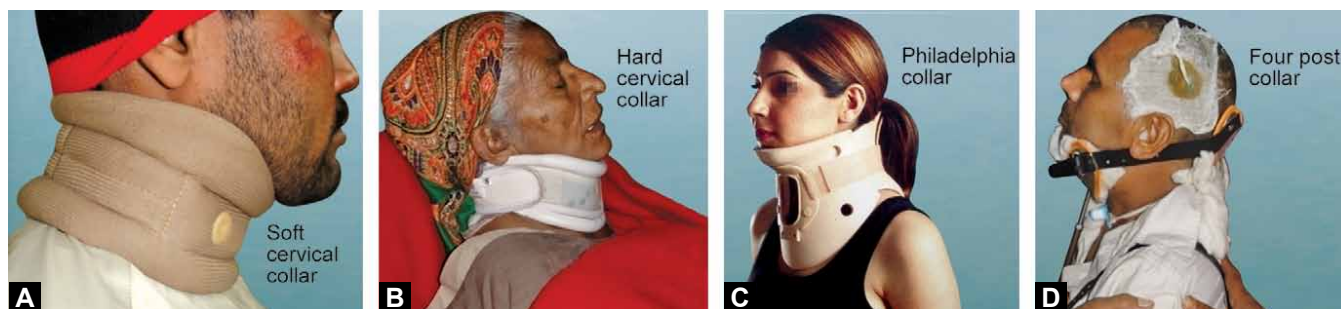
Cervical Spine

Cervical collars (Figs. 3.20A to D): A wide variety of cervical collars are available for providing immediate spinal support in patients suspected of having cervical spine injury. Soft collars provide only minimal support and hard/rigid collars are thus preferred. A still better option is the Philadelphia collar.

Crutchfield tongs and cervical traction: Cervical traction is a conservative method of achieving reduction and maintaining it in unstable cervical spine fractures. Crutchfield tongs (Fig. 3.21) are fixed to the skull and a weight of minimum 10 kg is applied. Check X-rays are performed every 12 hours and weight adjusted as per needed. Once acceptable reduction is achieved, light traction is continued for 6 weeks and then a halo vest (see below) or a four post collar is applied for another 6 weeks. A close watch must be kept on the neurological status during traction as at times there may even be deterioration, in which case a surgical intervention is generally warranted.

Halo vest (Figs. 3.22A and B): The halo ring is fixed to the forehead and connected to a vest applied to the chest to achieve immobilization of the neck. The stability of the system is very good. Proper positioning and checking torque pressure in the pins used for fixation of the halo ring regularly is essential.

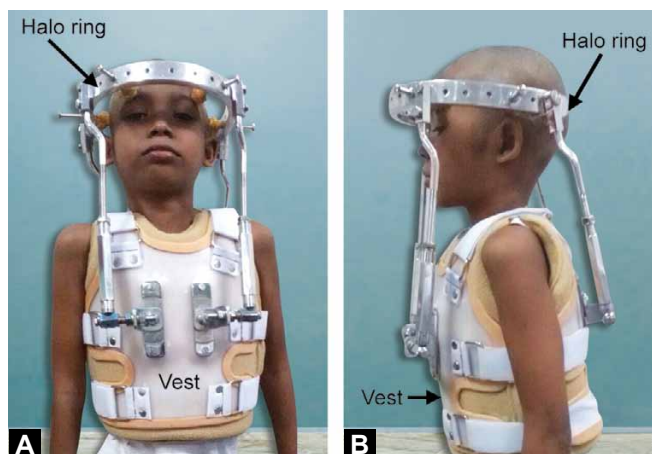
Decompression and fixation: Unstable fractures with neurological deficit need decompression in the form of removal of the fractured vertebral body (anterior cervical corpectomy) followed by spinal fusion with grafting and instrumentation. Surgical fusion of the unstable cervical spine fractures allows early mobilization and is widely gaining popularity. The cervical spine is generally approached via the anterior approach.



Figs. 3.20A to D: Cervical spine immobilization with cervical collars.



Fig. 3.21: Cervical traction via the crutchfield tongs.



Figs. 3.22A and B: Halo vest (A) front view (B) side view.



Fig. 3.23: Patient with suspected injury being fixed to spine board.

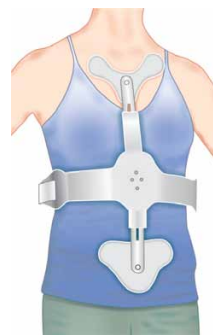


Fig. 3.24: ASHE brace.

Thoracolumbar Spine

Spine board (Fig. 3.23): All patients suspected of having spine injury must be transported on a spine board. The same should essentially be available at the emergency department of the hospital.

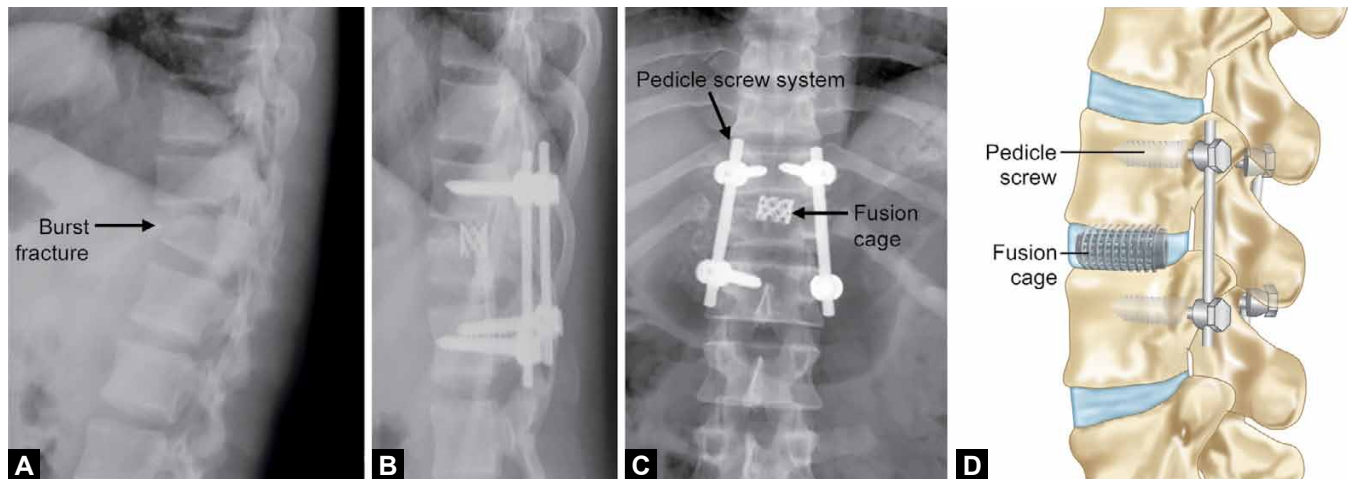
Braces: Many types of thoracolumbar braces are available. Anterior spinal hyperextension brace (ASHE brace) (Fig. 3.24) provides three-point fixation and avoids inadvertent flexion that can be damaging. It is particularly used in some burst fracture and compression fracture cases where the patterns are stable and patient has no neurological deficit.

Decompression and fixation: For patients presenting with neurological deficit and unstable fractures surgery in the form of decompression of cord and spinal fusion is the

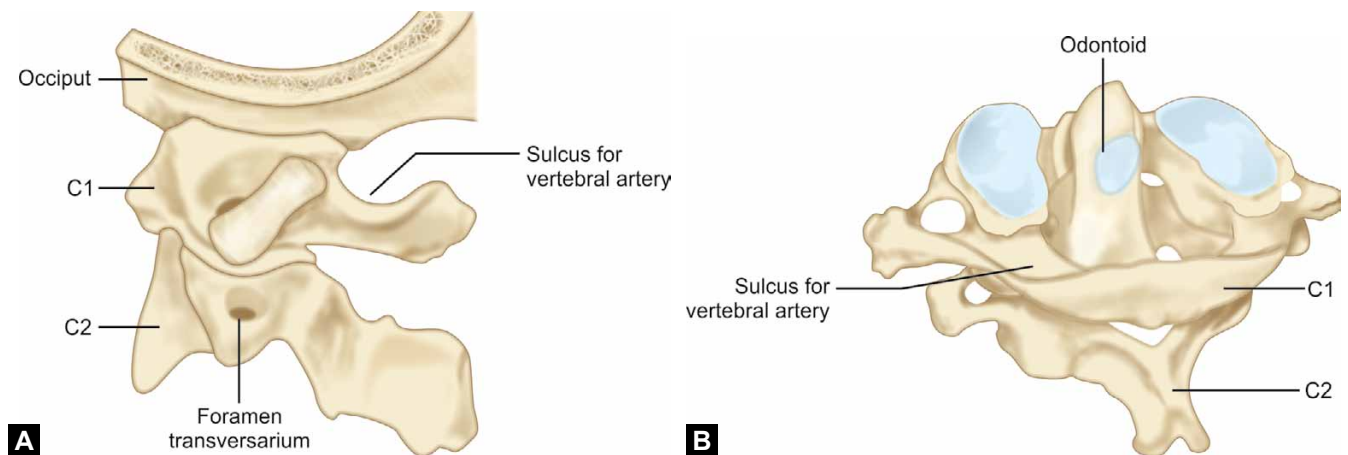
preferred treatment. For fusion, graft is placed enclosed in a cage followed by fixation performed mostly by the use of special pedicle screw system (Figs. 3.25A to D) and the spine can be approached both by anterior and posterior approaches. Anterior approach is preferred for burst fractures where body fragments have retro-pulsed into the canal while posterior approach being more surgeon friendly is preferred in most other situations.

CERVICAL SPINE INJURIES

Distribution: The prevalence of injuries to the cervical spine has a bimodal distribution; they are most often encountered in adolescents and young adults (15-25 years) and in those older than 60 years of age. Upper cervical



Figs. 3.25A to D: (A) X-ray of thoracic spine lateral view showing burst fracture (B) AP and (C) Lateral views of thoracic spine of same patient after pedicle screw fixation. (D) Diagrammatic representation of pedicle screw fixation.



Figs. 3.26A and B: Craniocervical junction (A) Lateral view (B) posterior view.

spine injuries are responsible for the majority of these, with C2 being the most common site of injury. Head injury is the most common associated injury which occurs in conjunction with cervical spine injuries in up to 53% of these cases.

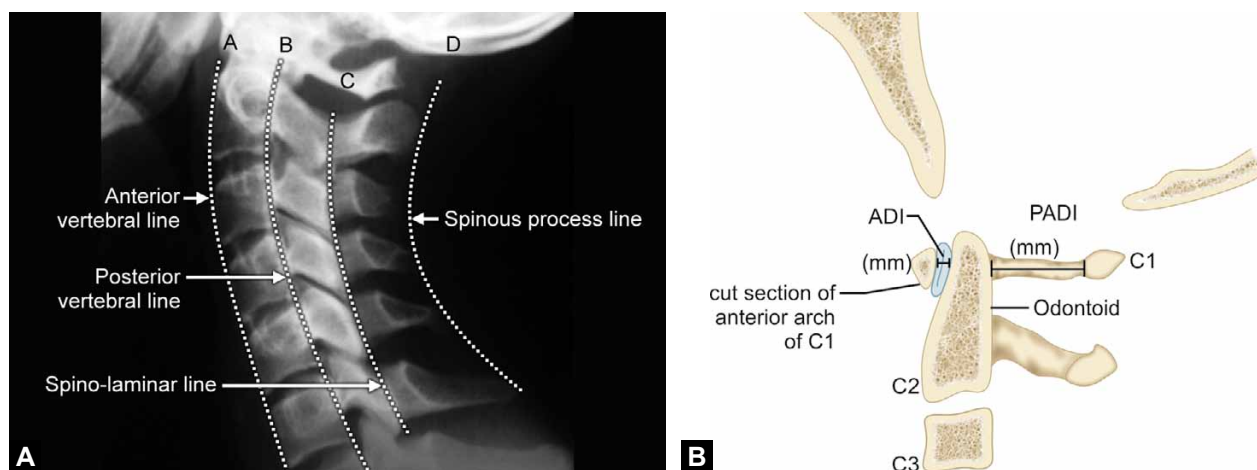
Injuries of the Upper Cervical Spine

Relevant anatomy: The upper cervical spine consists of the occiput, atlas and axis. These three structures along with their strong ligamentous attachments are often referred to as the “craniocervical junction (CCJ) (Figs. 3.26A and B)”. The occiput-C1 articulation supplies approximately 50% of total cervical flexion and extension, and the C1-C2 articulations supply 50% of total cervical rotation. Corresponding to this, the majority of the mechanical stability at the CCJ is provided by the investing ligamentous structures.

Clinical presentation: Patients with upper cervical spine injuries can present with complete ventilator dependent

quadriplegia to incomplete lesions including central cord syndrome (page 159) or as bell’s cruciate paralysis (due to compression of crossed upper limb and uncrossed lower limb tracts). In these injuries there is high chance of a vertebral artery rupture which can cause fatal ischemic damage to the brainstem. So, patients with upper cervical injury can also present with features of cranial nerve injury (CN VI, VII, IX, X, XI and XII). A classical example is Wallenberg’s syndrome which is lateral medullary infarction resulting from occlusion of vertebral artery (more common) or posterior inferior cerebellar artery. Delayed cortical blindness and recurrent quadriplegia can also occur from occult vertebral artery injury after cervical trauma.

Imaging: Plain radiographs are the first modality with antero-posterior, lateral and open mouth view as the standard series of X-rays. The sagittal alignment of the spine should be evaluated by four imaginary lines: (1) anterior vertebral line, (2) posterior vertebral line, (3) spino-laminar line and (4) the spinous process line and



Figs. 3.27A and B: (A) Cervical spine lateral X-ray showing important radiological indices; (B) Atlanto-dens interval and posterior atlanto-dens interval.

the atlanto-dens interval (ADI) and posterior atlanto-dens interval (PADI) (Figs. 3.27A and B). In a perfect lateral view these lines should be unbroken. The atlanto-dens interval (ADI) is distance between posterior surface of anterior C1 ring and anterior surface of odontoid. The posterior atlanto-dens interval is distance between posterior surface of odontoid surface and anterior surface of posterior C1 ring. ADI should be less than 3 mm in adults. PADI less than 13 mm indicates critical canal compromise. Computed tomography (CT) remains the most sensitive imaging modality to evaluate fractures of the upper cervical spine, subaxial spine and cervicothoracic junction. A clue to the presence of a cervical spine injury is given by the detection of abnormal thickness of prevertebral space. If it is more than 7 mm at C2-C3 level and 21 mm at the C6-C7 level, it is indicative of cervical spine injury.

HIGH-YIELD POINTS

- Spinal canal is widest at C2 level.
- Vertebra with most constant number are cervical and with most variable number are coccygeal.
- Non-traumatic conditions associated with increase in atlanto-dens interval are— Down syndrome, rheumatoid arthritis, osteogenesis imperfecta, Morquio syndrome, Grisel syndrome, neurofibromatosis, etc.

Specific Injuries

Jefferson fracture: This is a burst fracture of C1 vertebra (Atlas) caused by an axial loading force. There is fracture involving both anterior and posterior ring of the atlas (Figs. 3.28A and B). It has an extremely high association (up to 50%) with other cervical spine fractures. Patients will often complain of severe suboccipital discomfort and a sense of instability. At C1 level only 35% of the canal is occupied by cord with plenty of space as opposed to 50% occupancy in lower spine, hence, neurologic injury is uncommon.

However, when it occurs, the greater occipital nerve is most frequently injured, followed by the lower cranial nerves. Undisplaced fractures can be managed on collar while displaced ones are managed by application of halo vest.

Odontoid fractures: Fractures of the dens constitute approximately 10% of all cervical spine injuries. However, odontoid/dens fractures are the most common types of Axis fractures (more common than Hangman's fracture). Hyperflexion results in anterior displacement of the dens fracture and hyperextension results in posterior displacement of the dens fracture. A displaced fracture is actually a fracture dislocation of the atlanto-axial joint.

An open mouth odontoid view aids in diagnosis. However, MRI is the preferred modality as it can also identify tear of the transverse atlantal ligament that can contribute to instability.

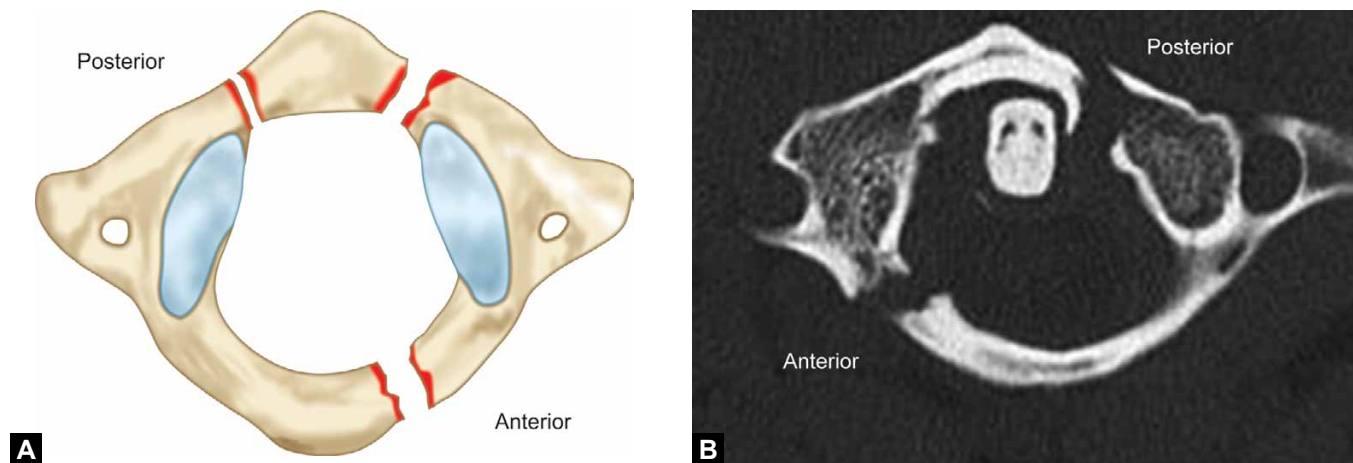
These fractures are classified by Anderson and D'Alonzo classification (Figs. 3.29A to C) into three types:

1. Avulsion of apex of odontoid
2. Fracture at junction of body and neck (high non-union rate)
3. Fracture extends into the vertebral body of C2.

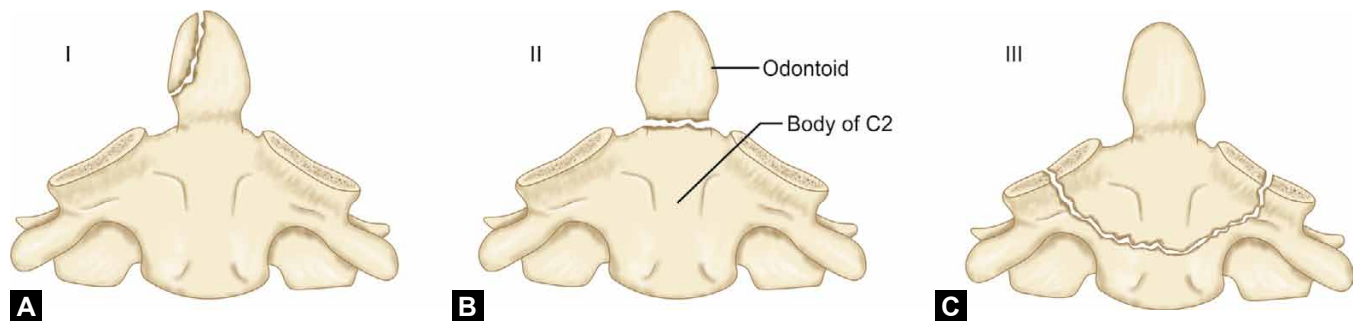
Treatment: Type 1, type 3 and minimally displaced type 2 fractures are treated by halo vest immobilization. Displaced type 2 fractures which are not adequately reduced by traction or not maintained in immobilization require surgery (screw fixation and/or fusion).

Hangman's Fracture (Traumatic Spondylolisthesis of Axis) (Figs. 3.30A and B)

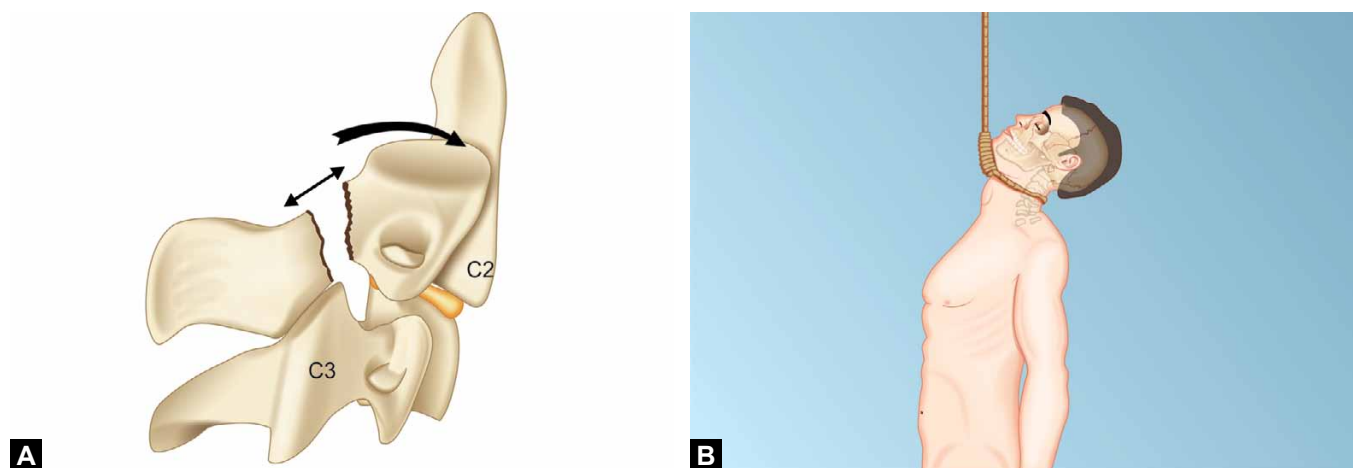
This is a fracture of the isthmus part of axis (pars interarticularis) characterized by forward slipping of C2 over C3 (spondylolisthesis), originally described in patients subjected to judicial hanging. The mechanism in judicial hanging is extension of the spine with distraction.



Figs. 3.28A and B: Jefferson fracture (A) Diagrammatic representation (B) CT scan.



Figs. 3.29A to C: Odontoid fractures classified by Anderson and D'Alonzo.



Figs. 3.30A and B: (A) Hangman's fracture (B) Injury mechanism in judicial hanging.

Hangman's fracture is more commonly seen in road traffic accidents where it is caused by extension of the spine with axial loading (when head strikes to dash board). Mostly there is no neurological deficit as the fracture of the posterior arch tends to decompress the spinal cord and acute postadmission mortality is low (2–3%).

It is classified by modified Levine and Edward's classification:

- **Type I:** These are stable fractures that have less than 3 mm translation and no angulation. These fractures are treated in a rigid collar.
- **Type II (most common subtype):** These fractures have greater than 3 mm of displacement and angulation of C2 on C3. A variant of type II fractures has been described. This type IIA fracture shows significant angulation but has minimal translation. It results from a flexion-distraction injury. Traction is contraindicated in such fractures as the mechanism is distraction. Type 2 fractures are reduced by traction and immobilized in a halo vest for 3 months. Type 2a fractures are reduced manually by extension and slight compression and immobilized in halo vest.

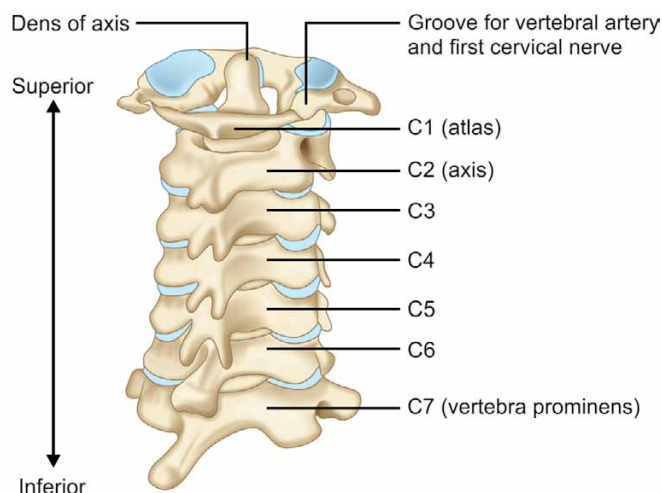


Fig. 3.31: Cervical spine anatomy.

- **Type III:** These are unstable injuries associated with unilateral or bilateral facet dislocations of C2 on C3 and are usually the result of flexion-distraction followed by hyperextension. All type III fractures should be treated with surgical reduction and posterior C2–C3 fusion. Most of these fractures heal rapidly and union is almost never a problem.

Injuries of the Lower Cervical Spine

The osseous-ligamentous complex that surrounds and protects the upper cervical spinal cord, the brainstem, and lower cranial nerves is anatomically and functionally distinct from the motion segments in the subaxial cervical spine (C3–C7).

Relevant anatomy (Fig. 3.31): The spinous processes project posteriorly, angling downward, and are progressively larger from cranial to caudal direction. The spinous process of C3–C5 is always bifid, whereas C6 may be and C7 is never bifid. The vertebral body is short and is connected to the next vertebra by a disk, uncovertebral and facet joints. The facets are oriented horizontally and hence the chances of pure dislocations in the subaxial cervical spine are more (see Fig. 3.14).

The vertebral artery ascends from the subclavian artery to pass within the foramen transversarium at C6. It exits the foramen transversarium of C2 turning anteriorly and medially in C2 and then again laterally into C1.

Classification of Sub-Axial (C2–C7) Cervical Spine Injuries

These injuries are classified by Allen and Ferguson Classification (Table 3.8). This is based on the mechanism of injury. Each of these has a sub-classification of injury types based upon their characteristic patterns. The important fractures caused by these mechanisms in isolation or in combination have been discussed below.

Table 3.8: Allen and Ferguson Classification

1. Compressive flexion
2. Vertical compression
3. Distractive flexion
4. Compressive extension
5. Distractive extension
6. Lateral flexion

Specific Fractures

Wedge Compression and Tear Drop Fractures (Flexion Compression Injuries)

Flexion-compression injuries are common cervical spine injuries which range from mild wedge compression fracture to severe tear drop fractures. The most severe pattern results in posterior subluxation of the posterior vertebral body into the canal and disruption of posterior ligaments.

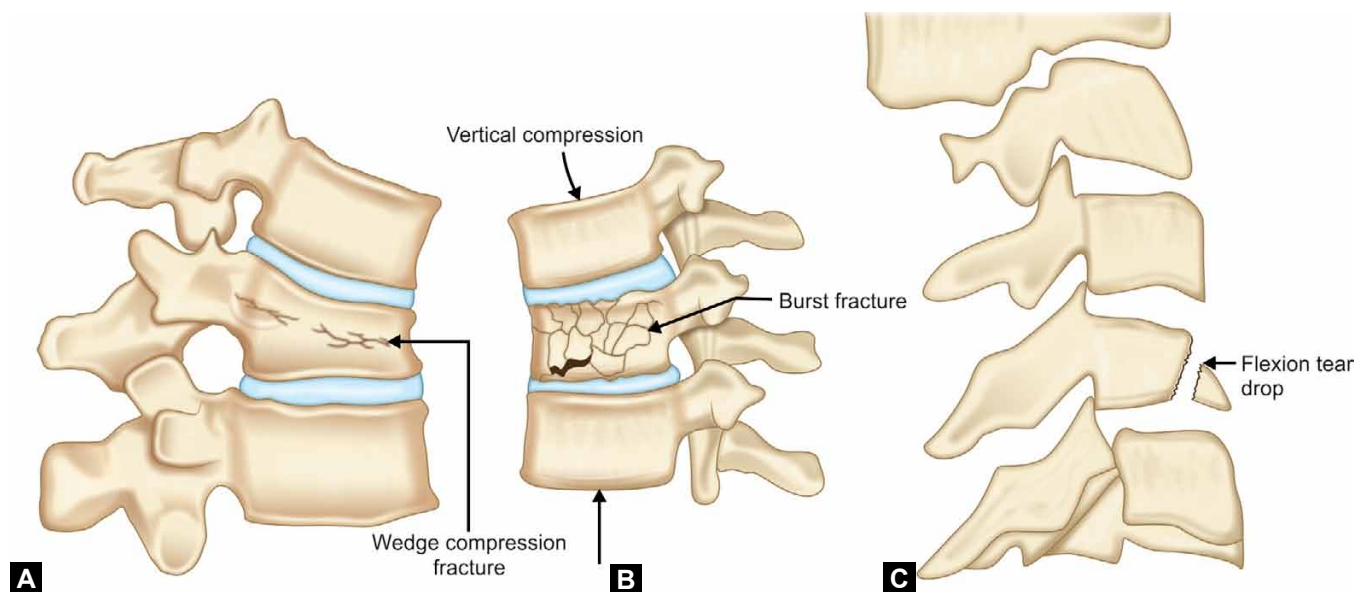
Wedge compression fractures (Fig. 3.32A) involve the anterior column and usually are stable injuries with no neurological involvement. Tear drop fractures are hyperflexion compression injuries, involving middle and anterior column. Tear drop dislocation fractures (Fig. 3.32 C) are characterized by shearing of a tear drop bone fragment from the anteroinferior edge of the vertebral body and the protrusion of the posteroinferior edge into the spinal canal.

Treatment: Mild wedge compression injury without neurological involvement requires nothing more than collar immobilization. Severe injuries require corpectomy (removal of vertebral body) and anterior column reconstruction using bone graft or a metal cage and plating.

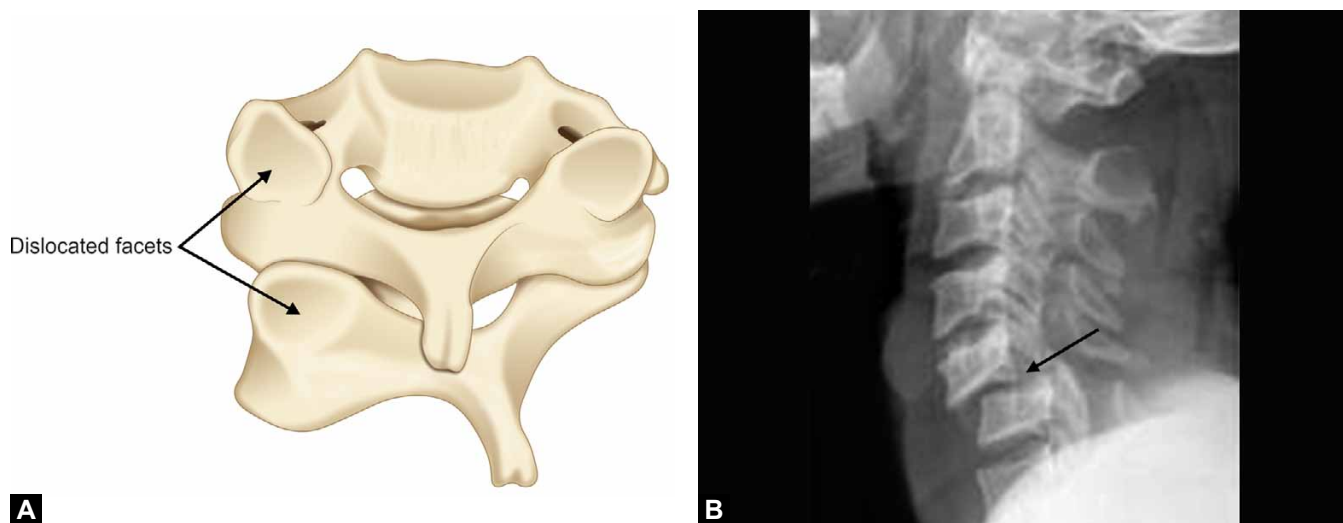
Facet Dislocations (Flexion Distraction Injuries, Figs. 3.33A and B)

Flexion distraction injuries (flexion rotation is a part of this mechanism only) are the most common pattern of sub-axial cervical spine injury. C5–C6 is the most common site. Spectrum of flexion distraction injuries ranges from posterior ligamentous sprain to unilateral or a bilateral facet dislocation.

In unilateral facet dislocations, flexion and simultaneous rotation of vertebra around a facet joint causes superior facet on contralateral side to slip forwards over the tip of inferior facet of the joint leading to dislocation of single facet joint (locked facet). A fracture of the facet joint may be associated. Only the posterior ligaments are disrupted while the anterior ones remain intact. There can be up to 25% anterior subluxation at the involved level. In bilateral facet dislocations there is flexion injury anteriorly and severe distraction posteriorly causing bilaterally locked facets. There is tear of all spinal ligamentous structures. Typically there are no associated facet fractures as the posterior column is distracted. The anterior subluxation at the involved level can be up to 50%.



Figs. 3.32A to C: Common fracture pattern of lower cervical spine injury: (A) Wedge compression fracture (B) Burst fracture and (C) Tear drop fracture.



Figs. 3.33A and B: Flexion distraction injury: (A) Facet dislocation (B) X-ray cervical spine lateral view showing facet dislocation (arrow).

The diagnosis in unilateral facet dislocations can be difficult and caution should be high. Infact, a unilateral facet subluxation is one of the most frequently missed injury after an initial evaluation. Unilateral facet dislocations and facet fracture dislocations present typically with bow tie or sail sign on lateral view of cervical spine. Disk herniation can occur in up to 10% of patients with facet dislocations and should be evaluated by MRI.

Treatment: If MRI shows significant disk herniation anterior cervical discectomy with fusion with bone grafting is done. Reduction can be achieved preoperatively (with skeletal traction) or at the time of anterior cervical discectomy. If MRI demonstrates no significant disk herniation, a closed reduction via crutchfield traction may be achieved. In case closed reduction fails, then open posterior reduction with stabilization (fixation with instruments) is

the treatment of choice. A bilateral facet dislocation has increased chances of re-dislocation following reduction.

Burst Fractures (Vertical Compression Injuries)

A burst fracture is a typical example of vertical compression injury. Burst fracture (Fig. 3.32B) is characterized by involvement of anterior and middle column and shortening of vertebral height. Status of posterior column decides the stability of burst fracture. In unstable burst fracture vertical compression or axial loading of cervical spine causes comminution of vertebral body and retropulsion of the vertebral body fragments into the spinal canal.

Treatment: These injuries are treated by corpectomy (removal of vertebral body fragments) and anterior column reconstruction using bone graft or metal cage with plating.



Fig. 3.34: Diagrammatic depiction of mechanism of whiplash injury after rear end collision of a vehicle.

Extension Injuries

Hyperextension injuries of the cervical spine are common in old patients with stiff neck. Loss of neck movement causes failure of dissipation of energy of trauma thus patients with ankylosing spondylitis and disseminated idiopathic skeletal hyperostosis (DISH) are at particular risk of hyperextension injury. These injuries are characterized by anterior widening of disk space and/or disruption of posterior ligaments and posterior displacement of vertebra. Central cord syndrome (page 159) is also an example of extension cervical spine injury which is common in elderly with osteoarthritic changes in cervical spine.

For treatment, cervical immobilization in a collar is usually all that is required. If MRI shows significant disk disruption then anterior discectomy, fusion with bone graft and plating is done.

Whiplash Injury (Sprained Neck)

Whiplash describes a range of injuries in the neck seen after rear end collision of vehicles. Before the invention of the car, whiplash injuries were called “railroad spine/Erichsen’s disease” as they were noted mostly in connection with train collisions and had been described by John Erichsen.

Although the exact mechanism in these injuries is debatable, the acceptable theory is that patient’s body is thrown forwards by the car seat while his head flips backwards and then recoils in flexion (hyperextension followed by flexion) (Fig. 3.34). Nevertheless the hyperextension force causes the prime damage. Mostly there is sprain of the capsular ligaments of the facet joints and the neck muscles, in rare instances there could be an unstable fracture.

Women more commonly land up with whiplash owing to their weaker muscles. Patients mostly present with pain and stiffness in the neck. There could be paresthesias in the ulnar nerve distribution due to nerve root compression by a spasmodic scalenus muscle. On examination, neck muscles are usually tender and movements often restricted. Neurological deficit is uncommon. The Quebec



Fig. 3.35: Clay-shoveler’s fracture (arrow).

Table 3.9: Quebec task force grading of whiplash injury

Grade 1: No neck symptoms or signs
Grade 2: Neck pains and stiffness but no physical signs
Grade 3: Musculoskeletal signs
Grade 4: Neurological signs
Grade 5: Fracture dislocation present.

Task Force grading of the severity of whiplash injury lesion has been depicted in Table 3.9.

X-rays may be normal or show straightening of the normal cervical curvature, a sign of muscle spasm.

Treatment is largely symptomatic. Collars are avoided as they hinder recovery more than helping. Isometric exercises are encouraged and most patients fair well.

Clay-Shoveler’s Fracture

Clay-shoveler’s fracture (Fig. 3.35) usually occurs in laborers who perform activities involving lifting weights rapidly with the arms extended. Violent muscle forces in these persons often leads to avulsion fractures of the spinous process of vertebra (C7 > D1). The fracture is absolutely stable and treatment is mainly symptomatic; neck exercises are encouraged as symptoms permit.

HIGH-YIELD POINTS

- Most common mode of cervical spine injury is fall from height.
- Most common site of cervical spine injury is atlanto-axial junction (or C2 vertebra).
- Cervical spine is the most common site of spinal cord injury.
- Clinical protocols for deciding the need for radiographic examination in cervical spine injury include NEXUS low risk criteria and Canadian C spine rule.
- Flexion distraction is the most common type of injury mechanism in cervical spine injury.
- Commonly missed fractures in cervical spine injury on plain X-ray include odontoid fracture, tear drop fracture, facet injury and Hangman’s fracture.

THORACOLUMBAR FRACTURES

Relevant anatomy: In the thoracic spine the vertebrae are linked to each other via disks and facet joints and also linked to the ribs via costo-transverse joints and costovertebral joints. The thoracic spine, protected by the rib cage, is thus the least mobile spine. A transition comes at transitional area D12–L2, where a rigid thoracic spine meets the relatively flexible lumbar spine. Majority of the fractures in this area thus tend to involve this transitional segment D12–L2 (D12 > L1). The spinal canal in this area is relatively narrow and therefore cord damage is not uncommon in these fractures. The cord ends at the lower border of L1 and injuries distal to this level involve the nerve roots. Very commonly these fractures are also associated with injuries in the chest and abdomen.

The treatment of unstable fractures and fracture dislocations of the thoracic and lumbar spine has long been controversial. The classifications of thoracolumbar injuries have evolved over many years. McAfee classification divides these injuries in 6 types: (1) *Wedge compression fracture*: There is isolated failure of anterior column due to compression. Usually it is not associated with neurological impairment. (2) *Stable burst fracture*: It is characterized by failure of anterior and middle column and intact posterior column. (3) *Unstable burst fracture*: It is characterized by failure of the anterior and middle columns in compression and also the failure of posterior column in distraction. It is an unstable injury with high chances of kyphotic deformity and neural compression due to retropulsion of bony fragments into the canal. (4) *Chance fractures*: These are flexion distraction injuries characterized by horizontal avulsion of the vertebral bodies caused by flexion around

Table 3.10: Thoracolumbar injury classification and severity score. (From Vaccaro AR, Zeiller SC, Hulbert RJ, et al: The thoracolumbar injury severity score: a proposed treatment algorithm, J Spinal Disord Tech 2005;18:209.)

Features	Points
<i>Fracture mechanism</i>	
Compression fracture	1
Burst fracture	1
Translation	3
Distraction	4
<i>Neurological involvement</i>	
Intact	0
Nerve root	2
Cord, conus medullaris, incomplete	3
Cord, conus medullaris, complete	2
Cauda equina	3
<i>Posterior ligamentous complex</i>	
Intact	0
Indeterminate	2
Injured	3

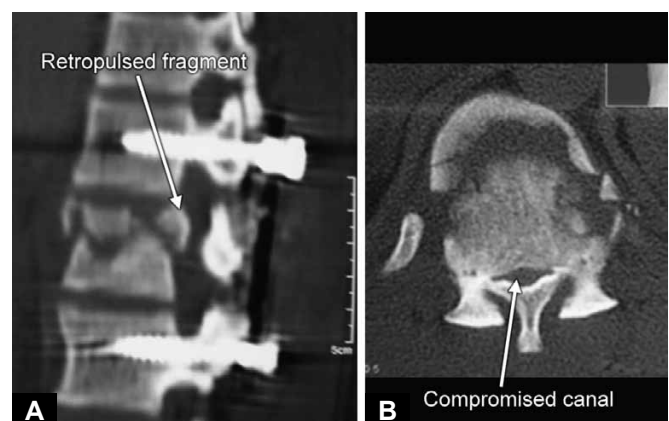
an axis anterior to the anterior longitudinal ligament. (5) *Flexion compression injuries*: In these injuries the flexion axis is posterior to the anterior longitudinal ligament. The anterior column fails in compression, whereas the middle and posterior columns fail in tension. This is an unstable due to disruption of posterior ligamentous complex. (6) *Translational injury*: These are characterized by failure of all three columns in shear. These are unstable injuries with complete displacement of neural canal in transverse plane. Although this is one of commonly used classification of these injuries, this does not explain mechanism of injury of all fractures of thoracolumbar spine.

Vaccaro et al. recently proposed the thoracolumbar injury classification and severity score (TLICS) to simplify injury classification and facilitate decision making in thoracolumbar fractures (Table 3.10). It evaluates fracture morphology, the posteroligamentous complex and neurologic function to aid decision making. A maximum score of 10 is possible. Surgery is indicated if the score is 5 or more and non-operative treatment is indicated for score 3 or less. Treatment is individualized (operative and non-operative) for a score of 4.

Specific Fractures

Wedge compression fractures: These are the most common fracture type and result due to combination of flexion and compression forces resulting in failure through the anterior column. The posterior column is usually not involved. Being mostly stable, these fractures are often managed on a hyperextension brace (ASHE brace). Surgical stabilization may be considered when there is significant traumatic kyphosis (> 30°) or when vertebral body height loss is larger than 40%, which indicates setting in of posterior ligamentous complex compromise due to distraction posteriorly.

Burst fractures: Burst fractures are caused by pure axial compression through the vertebral body. In severe injuries, retropulsion of the fractured middle column fragments into the spinal canal is the hallmark of a burst fracture (Figs. 3.36A and B). The generally accepted differentiation



Figs. 3.36A and B: Intraoperative images of burst fracture being fixed with pedicular screws showing a retropulsed fragment (A) Sagittal view (B) Axial view.

between wedge compression fractures and burst fractures occurs at the middle column, which is spared in compression fractures and involved with burst fractures. The identification is relatively simple on radiographs. Loss of vertebral body height with splaying of pedicles (increased inter-pedicular distance) is characteristic of burst fractures.

Stable burst fractures can be treated with bracing while unstable burst fractures (loss of vertebral height > 50%, posterior column disrupted or neurological deficit present) should be managed with surgery. Direct decompression (corpectomy) via an anterior approach is preferred, but it can also be performed via a posterior transpedicular approach, followed by instrumented fusion of spine (with pedicle screws). Posterior pedicle screw fixation and fusion restores the posterior ligament tension-band effect and is the instrumentation of choice (see Figs. 3.25A to D).

Chance Fractures (Seat Belt Injury/Jack Knife Injury)

These are typically seen in head on collision of vehicles when the passengers are wearing seat belts. The mechanism involved is Flexion distraction (Figs. 3.37A to C). When the collision occurs the body is thrown forward and the seat belt restrains the lap. The combined flexion and posterior distraction causes the lumbar spine to jack knife around an axis placed anterior to vertebral column. Although there is no crushing of the vertebral body but the posterior and middle column fail in distraction. The classical injury described by Chance (Chance fracture, GQ chance, 1948) was purely an osseous lesion with fracture line traversing the vertebral body as well as the posterior elements from front to back. However, the injury may be entirely discoligamentous in nature (Chance variant-transaction being thorough the disk and ligaments only with no bony involvement) or a combination of osseous and ligamentous disruption. D12-L2 is the segment mostly

involved. In almost 50% cases these fractures are associated with a concomitant intraabdominal injury.

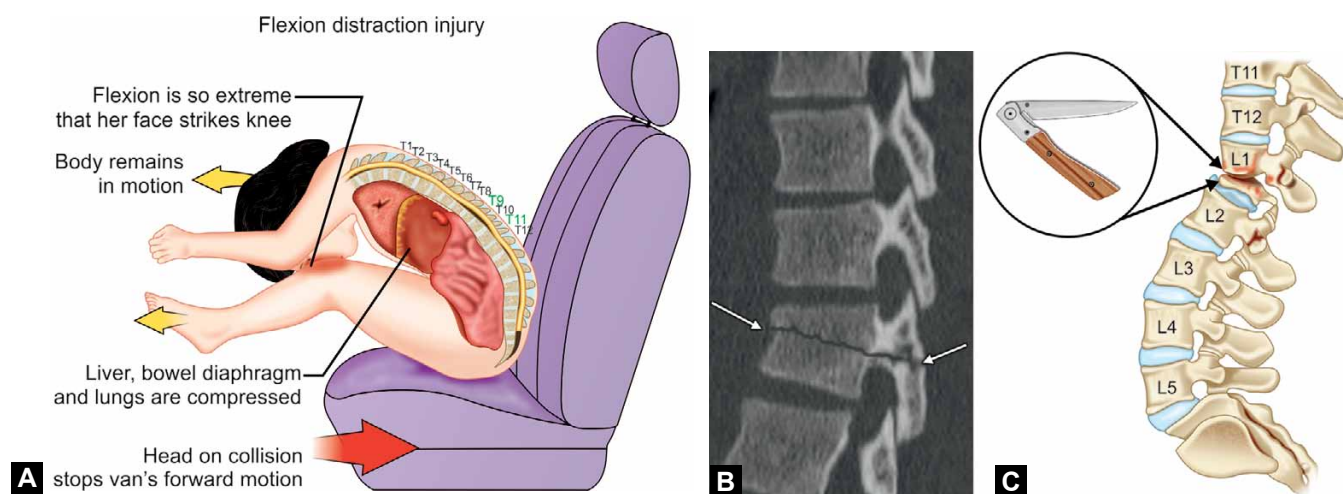
The incidence of neurologic deficit in flexion-distraction injuries is relatively low. Brace treatment (hyperextension braces) therefore is more likely to be successful in stable bony injuries. Unstable injuries of both the bony and ligamentous types are best treated surgically.

Fracture dislocations: Fracture-dislocations are highly unstable injuries with high chances of neural compression owing to translation of one vertebral body over another. All three columns fail under compression, tension, rotation or shear. Three combinations are mostly involved- shear, flexion rotation and flexion distraction. Most dangerous mechanism is shear force which causes translational injuries with complete neurological deficit in all cases. Next most dangerous mechanism is flexion rotation followed by flexion distraction. The hallmark is anterior, posterior, or lateral translation of the cephalad vertebral body on the adjacent caudal vertebral body (Figs. 3.38A and B). There is no role for bracing. Surgical treatment should proceed as soon as possible. Posterior pedicle screw instrumentation and fusion can usually be limited to two levels above and below the injury, though longer constructs may be required. Anterior procedures are usually not necessary.

MANAGEMENT OF TRAUMATIC PARAPLEGIA AND QUADRIPLEGIA

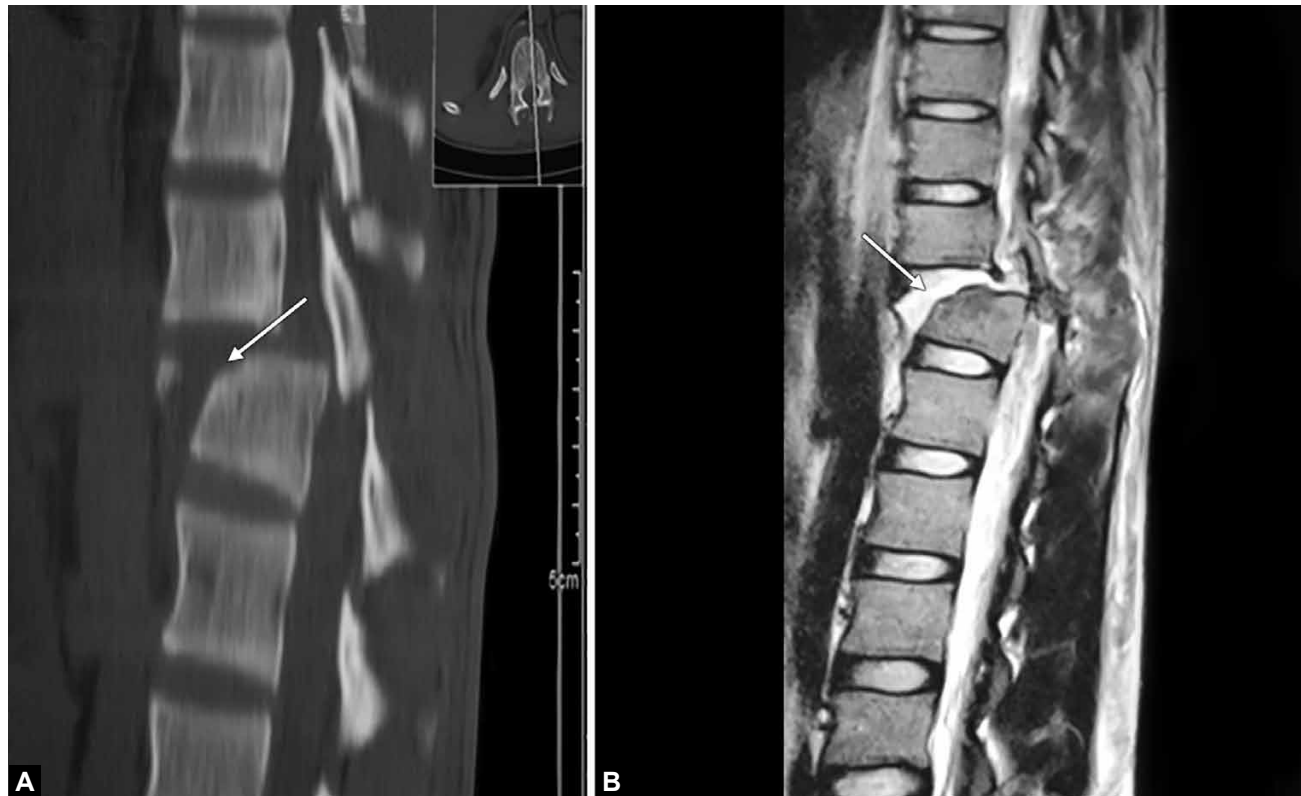
Paraplegia is a devastating complication of SCI and needs a team effort to rehabilitate the patient to nearly normal life. Care of a paraplegic can be divided into following parts.

Care of skin: Anesthetic skin is extremely prone to develop pressure sores (Table 3.11 for classification) and needs meticulous care. Crumples in the bed sheets must be avoided. Postural turning is advised every 2 hours. Use of air beds/water beds may assist in preventing sores. If sores



Figs. 3.37A to C: (A) Flexion distraction injury mechanism; (B) CT scan showing chance fracture (arrow) and (C) Injury pattern of chance fracture simulating opening of jack knife.

Courtesy: LearningRadiology.com for Figure 3.37B.



Figs. 3.38A and B: CT and MRI showing a fracture dislocation (arrow) of thoracic spine.

Table 3.11: Grading of bed sores

Grade 1: Intact skin but nonblanchable erythema present
Grade 2: Loss of tissue till dermis
Grade 3: Penetration through whole of dermis, going into subcutaneous tissue
Grade 4: Full thickness tissue loss with exposed bone, tendon or muscle.

have developed they need periodic debridement and if needed a surgical closure, else they never heal on their own.

Care of muscles and joints: Paraplegics are prone to land up with joint contractures which may limit their functional capability further. Moreover, it restricts the possibility of undertaking them for some suitable tendon transfers to upgrade their functional capability. A good physiotherapy is must to ensure supple joints. Heterotopic ossification is common in this setting and if it occurs, excision must be performed to prevent its hazards.

Care of bladder and bowel: Bowel paralysis leads to fecal retention. Measures are directed to achieve fecal softening by modification is diet, use of laxatives, suppositories or enemas. Digital evacuation may be performed as and when needed.

Bladder care depends on the stage of injury the patient is in. Initially in the stage of spinal shock, the paralyzed bladder is distended and unable to empty. Catheterization should be performed in this stage. The further behavior of the bladder depends on the disruption of the pathways.

Autonomous bladder (LMN bladder) occurs when the injury involves S2 level or below. The detrusor tone is flaccid and large residual urine collects and patients tend to have stress incontinence. Periodic emptying in these patients should be assisted by manual pressure to prevent bed wetting or the patient can be taught to apply suprapubic compression. Automatic bladder (UMN bladder) occurs when there is transaction of the cord above S2 level. The detrusor is spastic and patient tends to have urge incontinence with involuntary dribbling of urine with reflex activity. Such patients can be managed with a condom catheter until recovery occurs.

Retraining of bladder function: Recovery of bladder function may take a few weeks. When the signs of sensory/motor recovery appear, retraining of the bladder function should also be taken by clamping the catheter and encouraging reflex emptying. Once an autonomous/automatic bladder is established, measures can be directed as per the case.

Psychological care: Depression is a major and hidden ailment in these patients. Appropriate occupational, vocational and sexual rehabilitation must be ensured to deal with the same.

HIGH-YIELD POINTS

- Most common site of spinal fracture: D12 > L1
- Most common site for compression fractures: D12 > L1
- Most common site of fracture after fall from height: D12 vertebra

- Vertebral fractures are the most common fractures in elderly and their most common cause is “osteoporosis”.
- Most common spinal injury mechanism is flexion (flexion distraction specifically).
- Most dangerous spinal injury mechanism is translation injury > flexion rotation > flexion distraction all causing fracture dislocations.
- *Chalk stick fractures*: In these fractures, the fracture line is transverse to the long axis of the bone, like a broken stick of chalk. They are seen mostly in long bones in Paget’s disease and osteopetrosis. Similar transverse fractures may be seen in the spine in patients with ankylosing spondylitis and are highly unstable lesions.
- *Spinal cord injury without radiological abnormality (SCIWORA)*: This is a special pattern of injury seen in pediatric patients (mostly less than 8 years of age) where the patients present with a neurological deficit but a normal X-ray. The reason is that children tend to have lax ligaments and injury often causes

displacement of vertebral column and traction injury to cord. Elasticity of the ligaments pulls the displaced vertebrae back and thereby X-rays appear normal. The characteristic age group affected is the infant population. Pediatric cervical spine is the most common site for SCIWORA.

- If a patient of head injury presents with hypotension and bradycardia, he is likely to be in neurogenic shock due to associated lower cervical spine injury.
- *Motorcyclist’s fracture (see Skull fractures, page 151)*: It is a transverse fracture across the base of the skull leading to separation of skull into anterior and posterior halves. Since each part of skull can move independent of each other as if connected by a hinge, it is also called “Hinged fracture”.
- *Undertaker’s fracture*: It is basically a postmortem fracture which occurs due to careless handling of the dead body by undertakers. It is caused by falling of head backwards forcibly causing tearing of intervertebral disk and subluxation of cervical spine most commonly at C6-C7 level.

SPONDYLOLISTHESIS

INTRODUCTION

Forward slip of upper vertebra over the adjoining lower vertebra is called as “Spondylolisthesis”. The most common site of affection is L5 over S1 followed by L4 over L5 and the most common root irritated is L5.

Based upon the cause of slip, there are five varieties described:

1. *Isthmic/Lytic*: This is the most common subtype. The basic lesion in this category is a defect/fracture in the pars interarticularis of the neural arch. Pars interarticularis (Fig. 3.39) is the part of vertebrae that lies between the facets and lamina. A fracture in the pars on both sides causes the upper vertebrae (along with the whole spinal column above) to slide forward on the lower vertebrae.
This lesion likely occurs in a congenitally weak pars that sustains a fatigue fracture in people involved in sports activities like weightlifting or those who sustain extension stresses of gymnastics or wrestling. The neural arch defect appears mostly between the ages of 5 years and 7 years. Forward slipping of the vertebral body occurs most frequently between the ages of 10 years and 15 years and rarely increases after age of 20 years.
2. *Dysplastic*: This is the rare congenital variety due to either a defect in the formation of first sacral arch and superior facets of S1 or due to attenuation and elongation of pars. There is no defect/fracture in

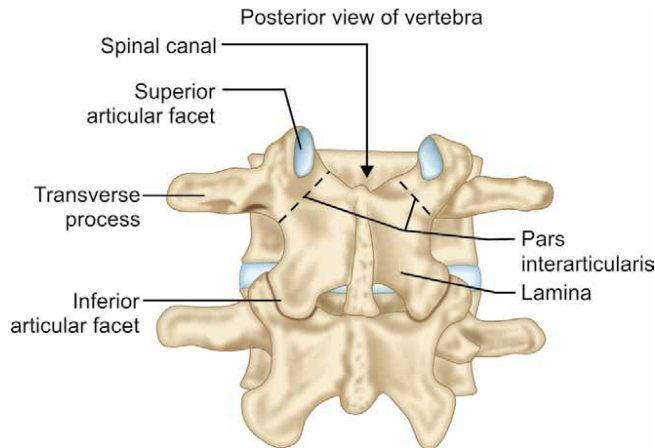


Fig. 3.39: Diagram showing pars interarticularis.

the pars. In this variety the chances of developing a neurologic deficit are more than in the isthmic variety.

The average age of symptom onset is usually near the final growth spurt age (14 years in girls and 16 years in boys). The onset may be quite sudden and dramatic and is aptly termed as “lithetic crisis”. The patient experiences a sudden onset of backache and, on examination, characteristically presents with a rigid lumbar spine that is commonly associated with a spastic or functional scoliosis (list).

3. *Degenerative*: This is the second most common variety. The only variety which is more common at L4-L5 level

and more common in females especially with age more than 50 years. The L4–L5 segment of the lumbar spine is normally the site of the greatest mobility. The primary pathology is degeneration of the disk followed by facet joint degeneration and secondary osteoarthritis of these joints. This makes them unstable and the vertebrae slips. The neural arch however is intact. Usually, the slip is of low grade.

4. *Traumatic*: This is a rare variety where there is a fracture in an area other than pars causes the slip.
5. *Pathologic*: In this subtype the pars is broken secondary to a localized or a generalized bone disease.

Spondylolysis: This is a condition in which there is a defect/fracture in the pars but no obvious slipping of the vertebrae. The majority of spondylolytic lesions occur at L5, but a few will be present at higher lumbar levels. Remember that 5% of the general population walks around with a spondylolysis that is completely asymptomatic. Spondylolysis may be unilateral in up to one-third of these patients.

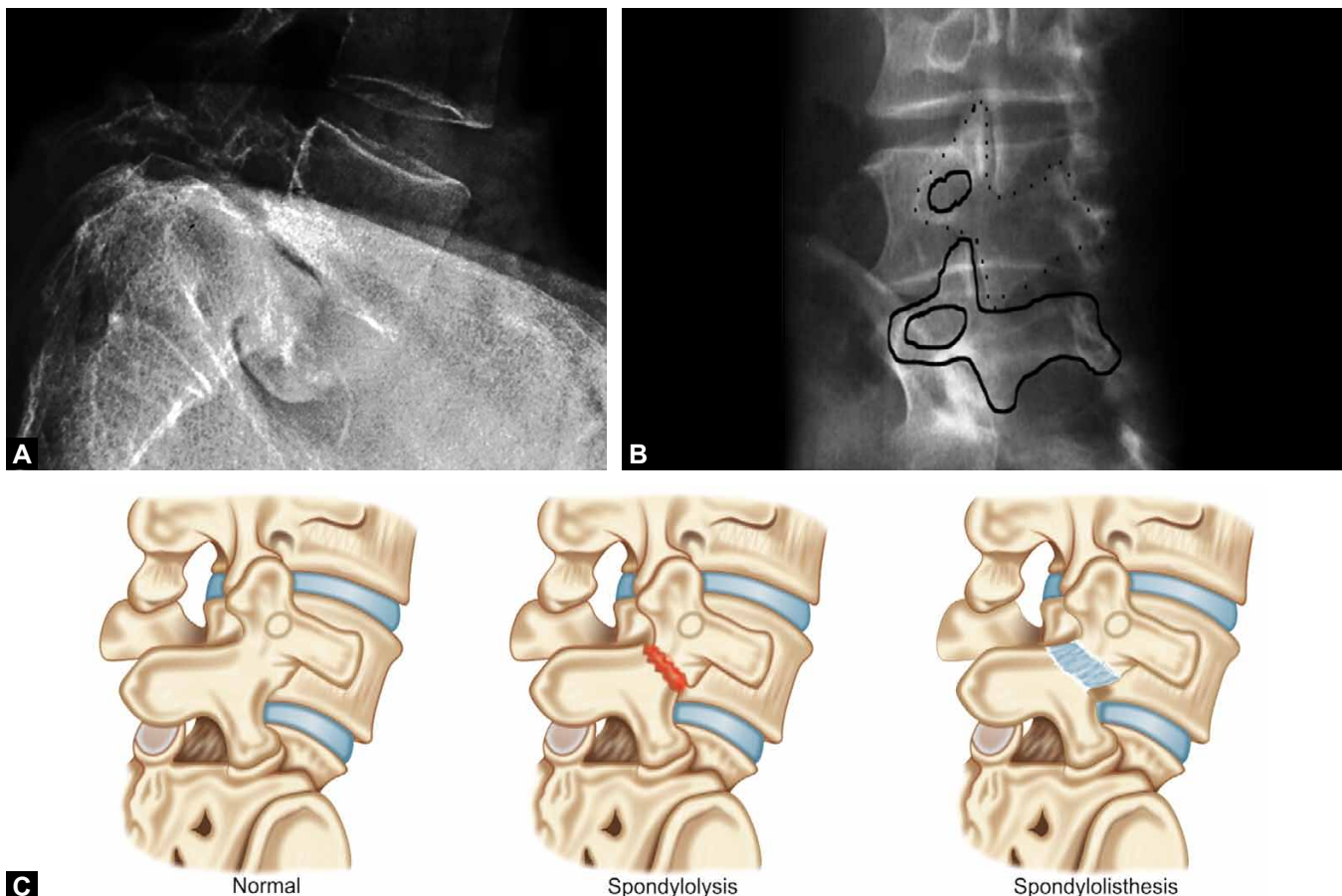
Retrolisthesis: A condition in which the cephalad vertebra goes posterior to the caudal vertebra. It is a sign of stability and happens in patients with degeneration who have crossed the stage of instability to enter into the stage of stability.

CLINICAL PRESENTATION

- Most of the patients are asymptomatic and the finding is incidental.
- Back pain is the presenting symptom in others and varies from severe acute low back pain to low back discomfort only on doing certain activities.
- There is hamstring stretch on raising the leg passively.
- In rare situations where the degree of slip increases, the disk may retro pulse and the canal may become stenotic producing symptoms of neurological claudication, i.e. radicular pain (*see Spinal Canal stenosis*). Further compression may produce a neurological deficit.

RADIOGRAPHY

- **Plain radiographs**: Oblique radiographs of lumbosacral spine may show a break in the pars interarticularis which represents the break in the neck of the “Scottish Terrier Dog (or Scottish terrier dog with collar)” visible on the radiographs as shown in Figures 3.40A to C (Scottish terrier dog is the normal appearance on the oblique view of lumbosacral spine). An AP X-ray shows “Inverted Napoleon Hat sign” which indicates the marked anterolisthesis of L5 over S1 (Fig. 3.41).



Figs. 3.40A to C: (A) X-ray lateral view of LS spine showing spondylolisthesis and (B) Scottish terrier sign in normal oblique view of LS spine and (C) broken neck of scottish terrier in spondylolysis and spondylolisthesis.

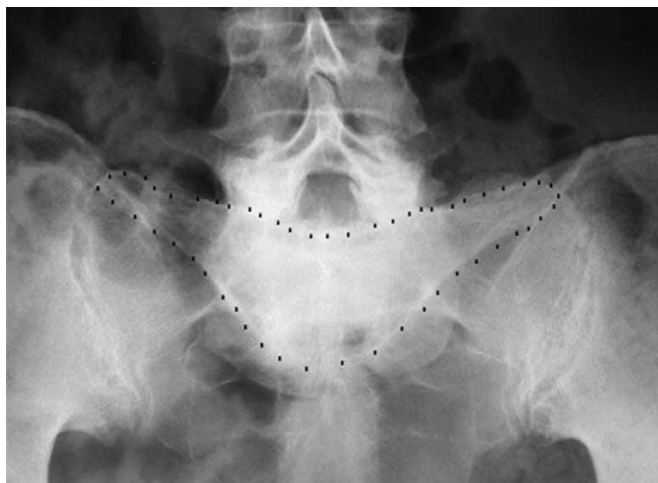


Fig. 3.41: Inverted Napoleon hat sign.

- *Dynamic X-rays (Flexion and extension views)*: May be done to assess the instability in spine.
- *CT scan and single photon emission computed tomography (SPECT)*: They are useful in detecting “spondylolysis”.

Grading of Spondylolisthesis

In Myerding’s method the anteroposterior (AP) diameter of the superior surface of the lower vertebral body is divided into quarters and a grade of I–IV is assigned to slips of one, two, three or four quarters of the superior vertebra, respectively. Taillard method expresses the degree of slip as a percentage of the AP diameter of the top of the lower vertebra. A complete dislocation of L5 on S1 is called a “spondyloptosis”.

TREATMENT

Spondylolysis

Rule of thumb: If the patient is asymptomatic, let them play regardless of the investigation results. If the patient is symptomatic, restrict strenuous activities until lesion heals.

Spondylolisthesis

Low-grade slips (I and II) behave as degenerative disk disease and can mostly be managed conservatively while

high-grade slips (III and IV) behave as adult deformity and when causing canal stenosis, mostly need surgery.

Conservative treatment: Conservative treatment is the initial treatment of choice for most cases of spondylolisthesis, with or without neurologic symptoms. Mostly treatment consists of 1 to 2 day period of rest and anti-inflammatory medications. Physical therapy is also often prescribed in addition and include bracing, exercise, ultrasound, electrical stimulation, and therapeutic exercise (core strengthening exercises, postural instruction, lumbopelvic mobilization exercises, and a flexion-based exercise program). Stationary bicycling is an excellent exercise as it promotes spine flexion and deconstriction of the thecal sac.

Surgical treatment: In cases with features of canal stenosis not responding to conservative treatment, decompression of the neural structures by removal of the protruding disk and lamina (discectomy and laminectomy) and fusion of the adjacent vertebrae (transforaminal lumbar interbody fusion) with or without instrumentation (i.e. fixation with instruments like pedicle screws), to achieve spinal stability is the preferred procedure.

Treatment principles should actually be individualized to specific types:

Isthmic: Unlike dysplastic spondylolisthesis, further slipping is unlikely to occur in the older age group, and surgery, therefore, is not indicated to prevent further forward displacement. Continuing disabling pain constitutes the sole indication for surgery in this group of patients. A progressive neurological deficit that might end up with “Cauda Equina syndrome” constitute other indications for a surgical intervention.

Dysplastic: The management here is usually surgical if the lesion is symptomatic before the age of 21 years.

Degenerative: Depending on the symptoms, decompression alone or decompression with spinal fusion may be offered to the patients.

Pathologic: The management depends on the nature of the pathology. The instance is, however, very rare.

HIGH-YIELD POINT

An oblique X-ray gives the maximum information in spondylolisthesis while AP view gives least.

PIVD AND CANAL STENOSIS

RELEVANT ANATOMY

A motion segment in the vertebral column can best be understood by the “three joint complex” model (Fig. 3.42)—one intervertebral disk between the vertebrae and two articulating zygapophyseal (facet) joints.

Structure of the Intervertebral Disk

An intervertebral disk comprises of two cartilaginous end plates (made of hyaline cartilage) on either side—caudad and cephalad, a nucleus pulposus in the center and an annulus fibrosus encircling the nucleus (Fig. 3.43).

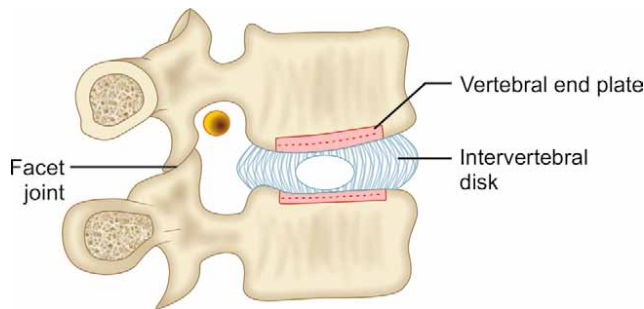


Fig. 3.42: Vertebral motion segment.

Nucleus pulposus, a remnant of notochord, is a gelatinous material, lying slightly posterior to central axis of vertebrae that comprises almost two-thirds of the surface area of the disk. Since the nucleus is continuously under considerable pressure, to restrain it in place there is a lamellar structure the annulus, composed of concentric fibrocartilage rings, that encircles it all around. Collagen fibers continue from the annulus to the surrounding tissues, tying it to the anterior and posterior longitudinal ligaments and the hyaline cartilage endplates superiorly and inferiorly.

The disk primarily receives its nutrition from the vascular vertebral bodies by diffusion via the end plates, although the outer third of the annulus receives blood supply from the epidural space.

DISK PROLAPSE (SLIPPED DISK)

A disk prolapse is a condition in which there is a tear in the annulus fibrosus (usually an end plate rupture) through which the gelatinous nucleus herniates out, thereby compressing the neural elements in the spinal canal. From youth into the 3rd decade the nucleus comprises of approximately 90% water by weight. Gradually over the next 4 decades the water content decreases to approximately 60%. The resultant desiccated disks are not that flexible and strong and tend to give way and herniate. Failure generally tends to begin at the cartilaginous end plates.

The most common site for a disk prolapse is the lumbar spine (L4–L5 > L5–S1). Next in frequency comes the cervical spine (C5–C6 > C6–C7). Thoracic disks seldom prolapse due to the extra stability provided by the presence of strong rib cage in the region.

A number of predisposing factors have been identified which include smoking, sedentary lifestyle, history of lifting of a heavy weight, squatting, too much of bending forward, involvement in contact sports and driving on bumpy roads.

The process of disk prolapse is divided into the following stages (Fig. 3.44) for understanding of the pathological process:

Nuclear degeneration: Desiccation causes degeneration and fragmentation of the nuclear material which herniates through the end plates into the vertebral body producing the characteristic “schmorl’s nodes”.

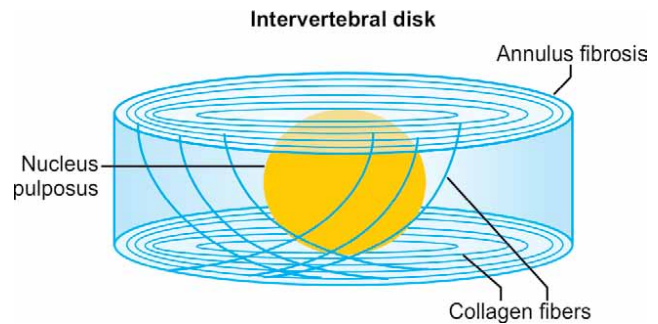


Fig. 3.43: Structure of intervertebral disk.

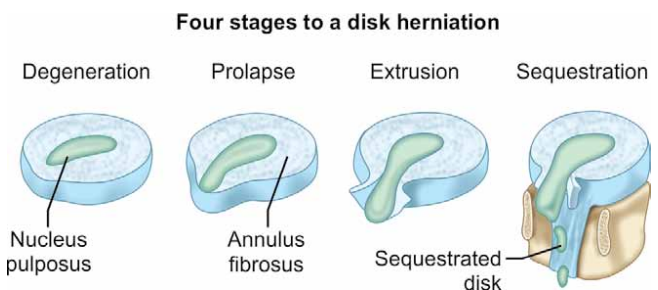


Fig. 3.44: Stages of disk degeneration.

Stage of protrusion: The annulus becomes weak due to constant pressure by the degenerated nucleus and gives way in its weakest part, i.e. the posterolateral area thereby allowing the nuclear fragments to bulge through annulus. This is called “disk protrusion”.

Stage of extrusion: More bulging in the nucleus causes it to herniate through the annulus and lies underneath the posterior longitudinal ligament while still maintaining contact with the parent disk. This is called as “disk extrusion”.

Stage of sequestration: Once the extruded disk loses contact with the parent disk, it is called a “Sequestered disk”. Now, it lies as a free fragment in the canal.

Stage of fibrosis and repair: The sequestered disk eventually becomes fibrosed and undergoes calcification. New bone forms at areas where posterior longitudinal ligament has been stripped from vertebral margins leading to osteophyte formation that adds to neural compression.

Types of Disk Herniations

Degenerated disk is extruded posteriorly in three patterns (Fig. 3.45):

1. Central herniation
2. Paracentral/paramedian type
3. Far lateral disk herniation.

Presentations in Disk Prolapse (Fig. 3.46)

When the disk herniates back, the herniated material may come to lie either superolateral to the affected nerve root (Shoulder presentation) or inferomedial to the affected nerve root (Axillary presentation).

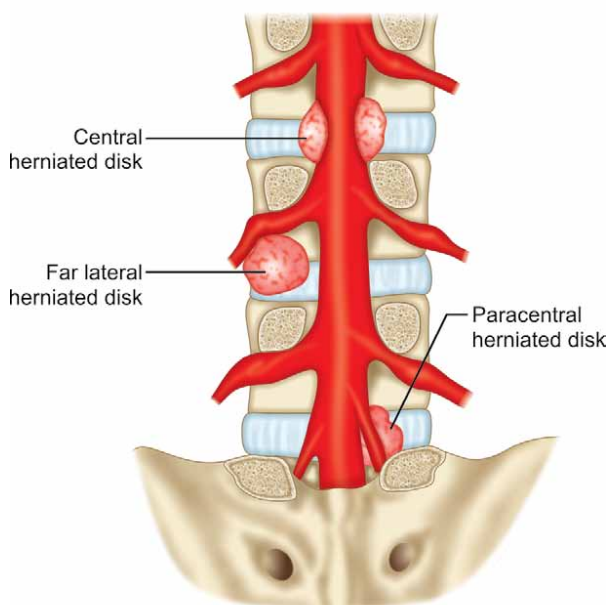


Fig. 3.45: Types of disk herniations.

Secondary effects of disk prolapse: As the disk degenerates, there is increased motion between adjacent vertebral segments which produces vertebral instability. Instability leads to more motion at facet joints which causes thickening of their capsule and induces osteoarthritis leading to osteophyte formation. All these changes further aggravate the already narrowed diameter of the spinal canal by the herniated disk, causing spinal canal stenosis.

Clinical Features

Many patients who present with a disk prolapse tend to give a history of lifting of heavy weight in the recent past. The most common presenting symptom is low back pain. Often the pain radiates down the back of thigh and leg when the condition is referred to as “Sciatica”. The pattern of radiation depends upon the nerve root that has been compressed (remember, spinal cord terminates at lower border of L1, so the disk compresses the hanging nerve roots in the canal). In L5 root compression the pain radiates to the antero-lateral aspect of leg and ankle while in S1 nerve root compression the radiation is along the posterolateral calf and heel. Sometimes, the patient may even complain of numbness or paresthesias (pins and needles like sensation) in the dermatome that corresponds to the compressed nerve root. And at times, when the disk material is large and predominantly central, it can cause a significant compression of multiple nerve roots, a condition called “Cauda Equina syndrome”.

Examination

Patient is undressed and local examination of back is done followed by a thorough neurological examination.

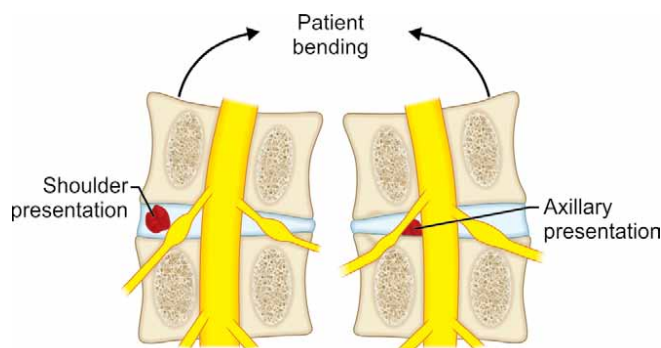


Fig. 3.46: Shoulder and Axillary presentation in disk prolapse.

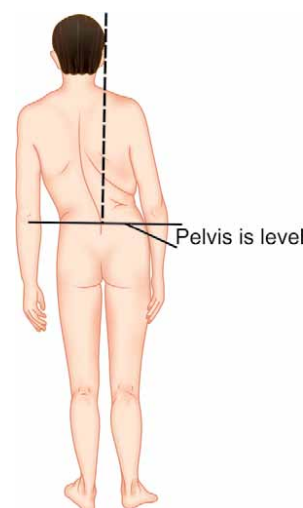


Fig. 3.47: Sciatic list.

Local examination includes assessment of the following:

Posture: When the patient is observed from the back, the central furrow becomes more prominent due to paraspinal (erector spinae) muscle spasm. The spasm obliterates the normal lumbar lordotic curve and the patient’s back goes flat. The trunk may be tilted to one side. This one-plane sideways tilt without an actual structural deformity in the spine is referred to as a “Sciatic list (Fig. 3.47)”. The disk bulge in Shoulder presentation produces a list to the Opposite side while a disk bulge in the Axillary presentation will produce a list to the Same side (Pnemonic: pSOAS).

Spinal tenderness: In the mid-line, the tips of spinous processes should be palpated for any localized tenderness if present, to correlate the level of lesion. Generally, most patients tend to have a diffuse tenderness in lower back owing to the paraspinal muscle spasm in the region.

Movements: Spinal movements become painful. Flexion, i.e. forward bending is relatively more difficult in patients with this condition.

Important Clinical Tests

The important clinical tests signifying nerve root compression that become positive before a detectable neurological

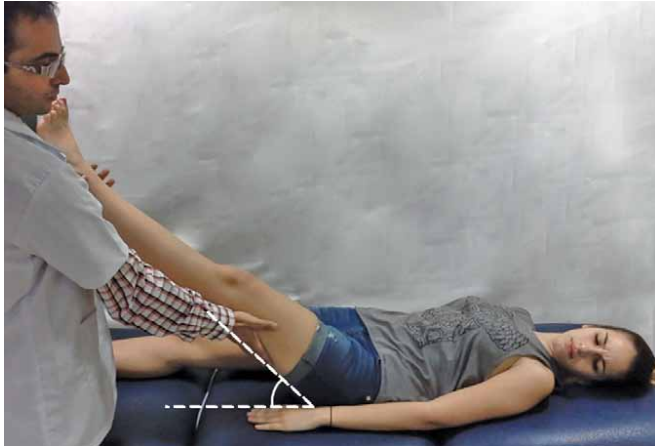


Fig. 3.48: Straight leg raising test.



Fig. 3.49: Bragard's sign (Ankle dorsiflexion produces pain while doing SLRT).



Fig. 3.50: Lasegue test.



Fig. 3.51: Bowstring sign of McNab.

deficit develops include the conventional straight leg raising test (SLRT) and its modified version, the "Lasègue Test".

Straight leg raising test (Fig. 3.48): The patient lies supine on the table. The affected leg is lifted up by flexing the hip with the knee straight. The angle between the back of the leg and the couch is noted when the patient complains of pain radiating down the limb. Test is considered to be indicative of a disk pathology when the leg symptoms are reproduced at an angle between 30° and 70°. (Mechanism of SLRT: Sciatic nerve is tethered at the sciatic notch up and the fibular neck below, so when the leg is elevated the nerve at the back of thigh is stretched and the symptoms become apparent).

Bragard's sign (Fig. 3.49): Straight leg raising test is performed as described above. Just when the patient experiences the radicular symptoms, the leg is just lowered a little. Now, the ankle of the patient is dorsi-flexed and if this reproduces the leg symptoms, it further strengthens the diagnosis (mechanism same as SLRT, ankle dorsiflexion stretches the nerve).

Lasegue test (Fig. 3.50): Lasegue test is performed in two steps. In first step SLR test is done as described above. This produces pain of nerve root compression. Now in second step knee is bent. This relaxes the nerve and pain disappears if it is due to nerve root compression. This further confirms the presence of sciatic pain and helps to differentiate sciatic pain from pain arising due to hip pathology. SLRT will be painful in both conditions but knee flexion in Lasegue test will relieve only sciatic pain and not the hip pain.

Well leg SLRT/contralateral SLRT: When the patient reports sciatic pain in the affected leg upon lifting the limb that does not have the symptoms, this test is said to be positive. It basically signifies a large central disk bulge indenting the thecal sac.

Bowstring sign of McNab (Fig. 3.51): Straight leg raising test is done as described above. The angle at which the pain starts in the leg, the knee is flexed so that the symptoms disappear. Now the tibial nerve is palpated and compressed in the popliteal fossa to replicate the symptoms. This further helps in confirmation of the disease.

Table 3.12: Nerve root involved with resulting deficit

<i>Nerve root compression</i>	<i>Sensory deficit</i>	<i>Motor weakness</i>	<i>Reflex change</i>
C5	Upper lateral arm and elbow	Deltoid, Biceps (C5, C6)	Biceps (variable)
C6	Lateral forearm, thumb, index finger	Biceps (C5, C6), ECRL, ECRB	Biceps, brachioradialis (supinator)
C7	Middle Finger (variable because of overlap)	Triceps, wrist flexors (FCR), finger extensors (variable)	Triceps
C8	Ring and little finger, ulnar border of palm	Interossei, finger flexors (variable), FCU	
T1	Medial aspect of elbow	Interossei	
T2	Medial upper arm and adjacent chest (intercosto brachial)		
T4	Nipple line		
T10	Umbilicus	Trunk flexion (Beevor sign)	Abdominal reflex
L1	Anterior proximal thigh near inguinal ligament	Illiopsoas (seated hip flexion)	
L2	Anteromedial thigh midway between inguinal ligament and patella	Illiopsoas (seated hip flexion)	
L3	Skin just proximal or medial to patella	Quadriceps (L3, L4)	Knee reflex (L3, L4)
L4	Posterolateral thigh, anterior knee, medial leg	Quadriceps (L2, L3, L4), hip adductors, tibialis anterior (heel walking)	Knee reflex (L3—secondary, L4)
L5	Anterolateral Leg, dorsum of foot, great toe (Autonomous zone is dorsal 1st web space and dorsum of 3rd toe)	EHL, gluteus medius, extensor digitorum longus and brevis	Tibialis posterior reflex, medial hamstring reflex
S1	Lateral malleolus, lateral foot, heel, plantar surface of foot, web of 4th and 5th toe (autonomous zone is dorsum of 5th toe)	Peroneus longus and brevis, gastro soleus S1—Toe walking, Gluteus maximus	Ankle (L5, secondary—S1)
S2	Center of popliteal Fossa (best to evaluate) supplies posterior thigh and proximal calf		
S3, S4, S5	Perianal area (arranged in concentric rings around anus) S5—Central, S3—most peripheral		

Neurological Examination

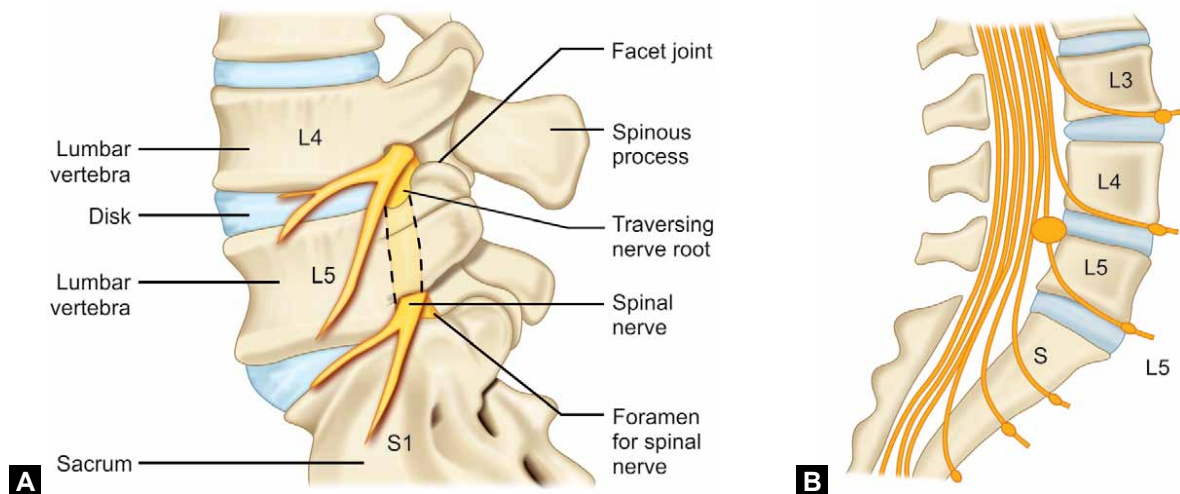
A thorough neurological examination is important to localize the site of spinal lesion (Table 3.12). One must be meticulous in testing reflexes as the search is for a missing reflex since nerve root compressions are lower motor lesions. For motor function assessment, examination of the foot is particularly useful in this setting as one can assess L4, L5 and S1 nerve roots, all at once. L4 supplies tibialis anterior, the dorsi flexor of foot while S1 supplies the gastro soleus, the plantar flexor of foot and L5 brings about the contraction of the extensor Hallucis Longus, the extensor of the great toe. So the patient can be asked to walk on heels (dorsiflexion), that assesses L4, then on toes (plantar flexion) to assess S1 and finally to extend the great toe to assess L5. If motor power in all three activities is normal then good chances are there that no neurological deficit exists. Similarly, abductor weakness or lurch and a positive trendelenburg test are suggestive of L5 weakness and hip extensor weakness or gluteal lurch is found in S1 weakness. But to make the inference, sensory examination of the concerned dermatomes is as important because at times, the deficit is not complete but just in form of a hypaesthetic patch. In every patient with disk disease, especially with bladder or bowel dysfunction, perianal

sensations and voluntary anal contraction must be looked for to rule out “Cauda Equina syndrome”.

Concept of exiting and traversing root: A nerve root in lumbar spine exits the bunc or Cauda Equina at every vertebral level just below the pedicle through the foramen to supply the area which it is meant to. For example for L4–L5 disk, the L4 root which passes beneath the L4 pedicle is the exiting root and L5 is the traversing root (Figs. 3.52A and B). As a rule most disk prolapses are central or paracentral and it is usually the traversing root which gets affected in “lumbar disk diseases”. *Exception:* in far lateral disk herniations, it is the exiting root which gets compressed. And also remember, in cervical disk diseases also, it is the exiting root which gets involved (there is no traversing root in cervical spine).

Investigations

X-ray is generally the first investigation that is ordered. In acute cases the findings are subtle except for loss of the normal lordotic curvature of the lumbar spine. In chronic cases, the disk space may be narrowed and there may be lipping of the vertebral margins or signs of facet joint arthritis (Fig. 3.53).



Figs. 3.52A and B: Traversing nerve root.

Magnetic resonance imaging (Figs. 3.54A and B) is the investigation of choice. It can document compression over the thecal sac as well as the nerve roots. It also helps in identifying the location of the disk (Central, paracentral or far lateral) and to locate any sequestered fragment.

Myelography: This involves injecting a radiopaque dye in the CSF and then taking an X-ray. In case there is disk herniation, there may be an indentation in the thecal sac visible on X-ray. In cases where the disk is lateral and compressing on the nerve root, there may be abrupt blunting of the dye column as it fills the nerve root sheath (the root cut off sign). Myelography has largely been overtaken by MRI.

Treatment

Conservative

Most patients with slip disk are initially given a trial of conservative treatment which includes bed rest for 2–4 days nonsteroidal anti-inflammatory drugs (NSAIDs), muscle relaxants and spinal exercises.

Intermittent lumbar traction (Fig. 3.55) can be used in cases who are not responding wherein a traction belt is used to apply distraction force to the vertebrae to create space for prolapsed disk to retreat and widen the intervertebral foramina. A pull of 30–40 kg is generally needed. The procedure can at times increase the pain. So, it has a little role as per the current evidence.

Local electrotherapy modalities may be added for additional benefit. These deliver heat to the body tissues thereby increasing local blood flow, washing off the inflammatory mediators. Superficial heat modalities (effective up to 0.5 cm from surface) include hot packs, infra-red therapy, etc. while short wave diathermy and ultrasound are deep heat therapies (effective to depth of 3–5 cm from surface). However, the ideal therapy for radicular symptoms is electrical stimulation called as transcutaneous electrical nerve stimulation (TENS).

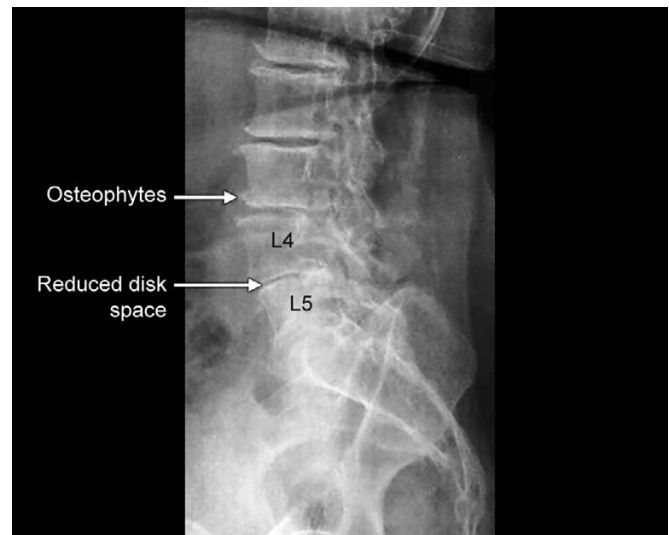
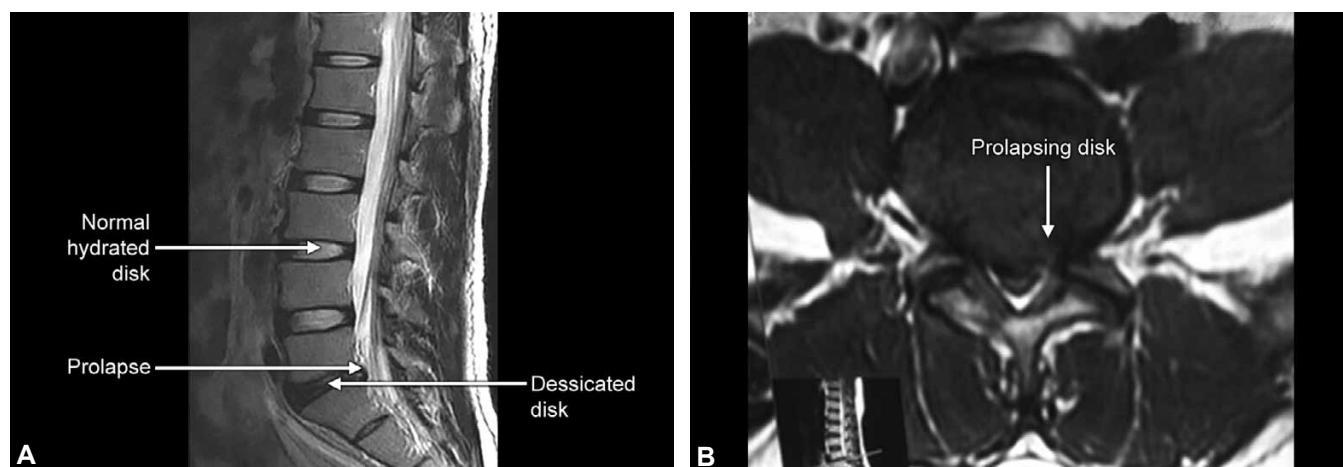


Fig. 3.53: X-ray lumbosacral spine lateral view showing signs of chronic PIVD.

Braces: A lumbosacral corset belt (Fig. 3.56) may be advised for pain relief during the acute stage. Belts increase the intra-abdominal pressure and create the spine and abdomen into a stable cylinder. Current evidence is against prolonged rest and lumbar corsets as they both gradually weaken the muscles and prolong the duration of illness.

Spinal manipulation techniques (Chiropractic medicine) are also described that alter the neurophysiological activity and decrease pain by release of beta endorphins and releasing the muscle spasm. However, it is only recommended in the hands of trained chiropractitioners.

Still those who don't respond can be taken up for spinal epidural injections. The procedure consists of injecting into the dural sac or around the nerve root, a long acting steroid (for decreasing disk edema and local inflammation) along with a local anesthetic (for acute painrelief). Injections can be given under fluoroscopic control via caudal (sacral hiatus) (Fig. 3.57) or transforaminalroute.



Figs. 3.54A and B: MRI of lumbosacral spine: (A) sagittal cut and (B) axial cut showing disk prolapse.



Fig. 3.55: Intermittent lumbar traction.



Fig. 3.56: Lumbosacral corset belt.

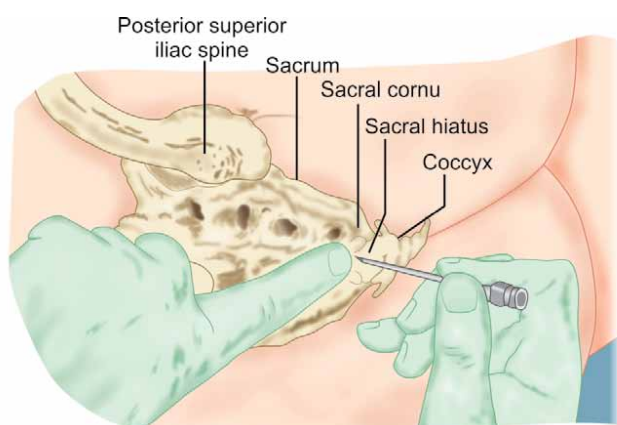


Fig. 3.57: Caudal epidural injection being given.

Surgical

Indications for surgery include:

Absolute indications

1. Progressively increasing neurological deficit
2. Cauda Equina syndrome.

Relative indications

1. Severe sciatic pain persisting despite 6 weeks of conservative treatment and
2. Recurrent incapacitating sciatica attacks (more than three in 1 year).

Surgery: Since a prolapsed disk compresses the neural elements in the spinal canal, surgery involves decompressing the canal by removing a piece of its wall (i.e. the lamina) apart from removal of the herniated disk (discectomy); the surgery being called decompression with discectomy.

Methods of Spinal Decompression (Fig. 3.58)

Fenestration: This involves creating hole in the ligamentum flavum that connects the adjacent laminae, thereby opening up the spinal canal.

Laminotomy: In addition to fenestration, a part of lamina is excised to widen the hole and create wider space for decompressing the canal.

Hemilaminectomy: This involves removing whole of lamina but only on one side.

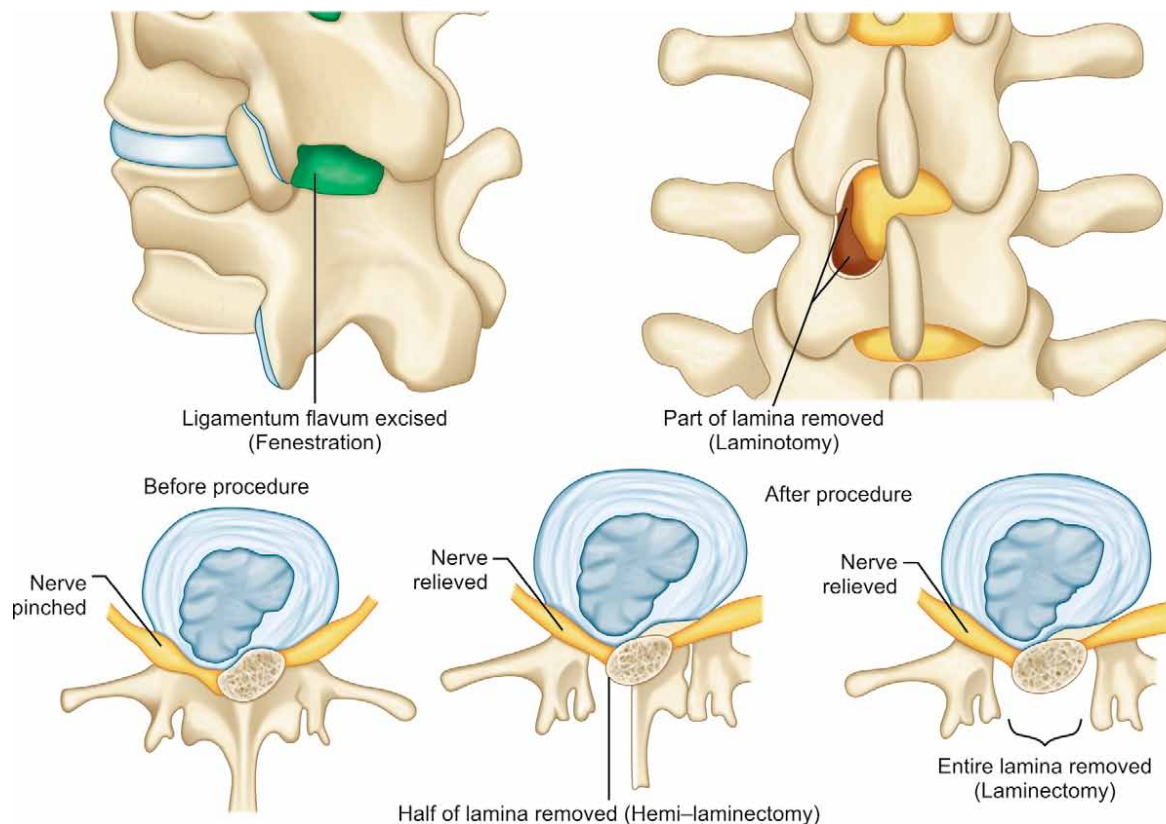


Fig. 3.58: Methods of spinal decompression.

Laminectomy: The lamina on both the sides is removed along with the spinous process. This is generally required for large central disks and patients with Cauda Equina syndrome.

Methods of Disk Excision

Open disk excision: Disk is reached and excised after decompressing the wall by either of the method mentioned above.

Microdiscectomy: This involves a minimal incision where under microscopic view, the herniated disk is excised after creating a fenestration in ligamentum flavum to reach the disk. It is a day care procedure and currently, the method of choice.

Percutaneous/Endoscopic disk excision: Fine instruments (camera, probes and other endoscopic instruments) are inserted via stab incisions and disk is excised in a percutaneous manner. It is a day care surgery that is recently coming up in big way.

Chemoneurolysis: In this an enzyme chymopapain (derived from papaya) is injected into the herniated disk under X-ray control. The enzyme hydrolyses proteoglycans (non-collagenous proteins) which reduces water holding capacity of nucleus pulposus. This decreases the intra diskal tension and reduces the disk bulge. Since the enzyme has no effect on collagen; tendons, bones and ligaments are not affected. An important side effect is hemorrhage since the enzyme can erode glycosa-amino-glycans in the capillary walls. Repeat use of enzyme is to be avoided due to chances of sensitization.

CERVICAL DISK PROLAPSE

After the lumbar spine cervical spine is the next most common site for disk prolapse. The most common level involved is C5–C6 followed by C6–C7. Here also the lower nerve root (exiting nerve root) is involved and hence the most common roots irritated are C6 followed by C7. However, not uncommon is compression of the cord in this region which leads to upper motor features. Diagnosis rests on meticulous examination aided by the same investigations mentioned above. Management principles are also nearly the same. However, as far as surgery is concerned, preferred modality of treatment is removal of the disk via anterior approach (anterior cervical discectomy) with or without spinal fusion with bone graft to achieve stability.

HIGH-YIELD POINTS

- Intervertebral disk is the largest avascular structure in the body and constitutes 33% of the vertebral height.
- No disk exists between C1 and C2.
- The most damaging motion for the disk is axial rotation.
- Thoracic disk prolapse is extremely rare as the thoracic vertebrae are stabilized additionally by the rib cage.
- Brachialgia (pain radiating from the neck down the upper limb) is the upper limb counterpart of sciatica.
- Some newer modalities for disk treatment

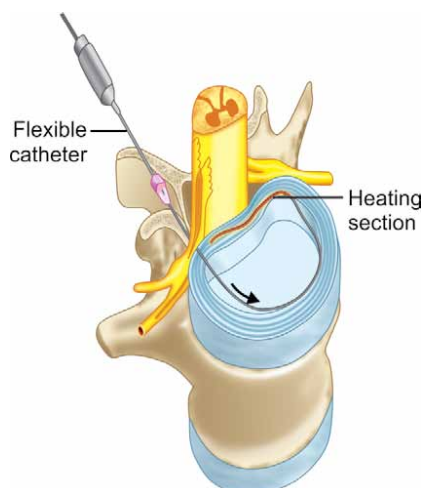


Fig. 3.59: Diagrammatic representation of intra-discal electrothermic therapy (IDET).

- **Ozone therapy:** It is a recently introduced minimally invasive modality where ozone-oxygen mixture is injected into disk to reduce disk volume. Right now there is little evidence of any advantage over other procedures so it is not a preferred treatment.
- **Intra discal electrothermic therapy (IDET):** It is a fairly advanced procedure wherein specially designed electrothermal catheters are introduced into the disk that allows for careful and accurate temperature control (Fig. 3.59). The procedure works by cauterizing the nerve endings within the disk wall to help block the pain signals. This minimally invasive outpatient surgical procedure has been developed over the last few years to treat patients with chronic low back pain caused by small herniations of their lumbar disks.
- **Artificial disk replacement:** It is an upcoming surgical procedure (similar to joint arthroplasty) in which the degenerated intervertebral disk is replaced with artificial device (Fig. 3.60), employed primarily in cases of cervical disk herniation.

SPINAL CANAL STENOSIS

Spinal stenosis is a common and disabling disorder that generally occurs in the elderly in sixth or seventh decade of life. In this disorder diameter of spinal canal is compromised thus causing neural compression and producing symptoms. Lumbar canal is most commonly involved followed by cervical canal.

Causes

Spinal canal stenosis can result from congenital (achondroplasia, scoliosis, kyphosis, etc.) or more commonly acquired causes (degenerative, Paget's disease, hyperparathyroidism, fluorosis, spinal tumors, infection such as TB, surgery and trauma, etc.).

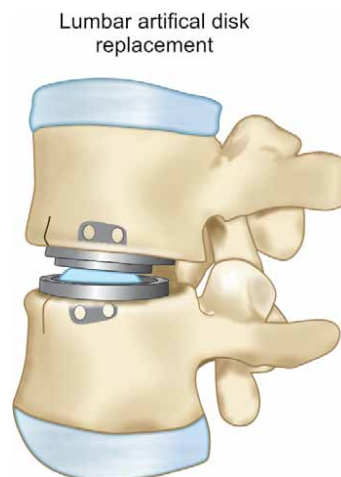


Fig. 3.60: Diagrammatic representation of artificial disk replacement.

Pathophysiology

Degenerative lumbar canal stenosis (LCS) is the most common form of spinal canal stenosis. Degenerative LCS anatomically can involve the central canal, lateral recess, foramina or any combination of these locations (Fig. 3.61A). Degenerative changes in the intervertebral disk result in micro-instability at the facet joints causing weakening of the joint capsule, hypertrophy of facet joints, hypertrophy and calcification of ligamentum flavum, formation of vertebral body osteophytes (in attempt to attain stability) and eventually subluxation of the vertebral joints. These pathological changes ultimately lead to stenosis of the spinal canal. Chronic compression of nerve roots in LCS leads to congestion and ischemia of nerves. Neurogenic claudication results when increased metabolic demands of nerves are not met due to vascular compromise.

Clinical Presentation

Clinical presentation depends on the site of involvement. In the most common lumbar canal stenosis neurogenic claudication pain is the hall mark (i.e. pain arising in the lower back radiating down the buttock, thigh, leg to the foot especially on prolonged physical activity). Pain worsens on standing or walking but is generally relieved by either bending forwards (trunk flexion) or sitting. Posture related pain in LCS is due to the fact that the available space in the central canal decreases in axial loading and extension and increases in axial distraction and flexion. This also explains that why do patients get more relief in lying on the side (allowing flexion posture) than lying flat. For the same reason patients find walking uphill easier and pushing a shopping cart gives them relief (positive shopping cart sign) (Fig. 3.61B). Since they mostly remain stooped forwards to relieve pressure on their neural structures, their posture is said to be Ape like.

Diagnosis

The classical clinical signs point well towards the diagnosis. On examination straight leg raising test and neurological examination tests are usually normal. Diagnosis can be confirmed on CT scan by measuring the canal diameter (less than 10 mm is diagnostic).

Differentials (Table 3.13)

An important differential is vascular claudication pain (i.e. pain due to a peripheral artery disease). Pain on standing alone is the most sensitive symptom to differentiate neurogenic claudication from vascular claudication.

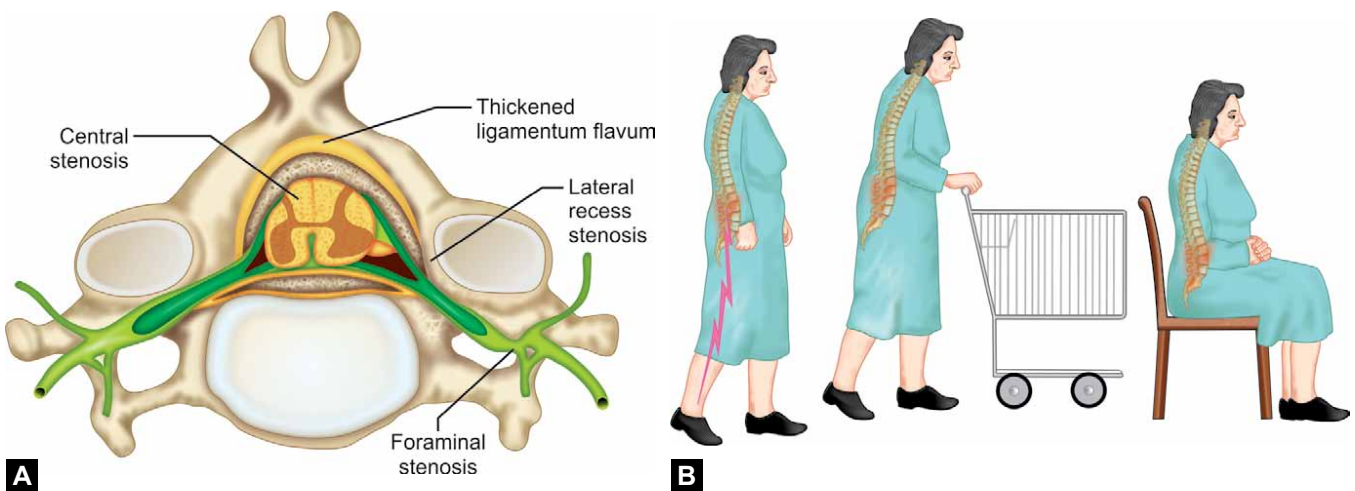
Treatment

Conservative treatment includes rest, NSAIDs, and a spinal rehabilitation program consisting of spinal flexion exercises, electro therapy, intermittent traction and epidural injections. In non-responding cases, surgical decompression (laminectomy) of affected segments is required.

Laminoplasty is a method of spinal decompression mainly used in canal stenosis in cervical spine (use of laminoplasty for disk removal is not advocated). Here the lamina is not removed. Rather bone is cut and swung open to decompress the cord and then repositioned.

HIGH-YIELD POINTS

- Sacralization of 5th lumbar vertebra (Fig. 3.62): In this condition L5 is found fused with sacrum either partially or completely altering mechanics of the region causing lumbar back pain. Treatment is mostly conservative
- Basstrap's disease (kissing spines): This is Degenerative disease characterized by hypertrophy and enlargement of adjacent spinous processes in lumbar spine of elderly leading to focal midline back pain which worsens in extension. Most common level involved is L4-L5. Disk height and neural foramina are normal. Treatment is mostly conservative, rarely surgical excision of bursa or osteotomy may be needed.



Figs. 3.61A and B: (A) Figure showing spinal canal stenosis at different levels. (B) Depicting symptomatology in canal stenosis.

Table 3.13: Differences between neurogenic and vascular claudication		
Features	Neurogenic claudication	Vascular claudication
1. Claudication distance	Variable	Fixed
2. Provoking factors	Walking, standing	Walking
3. Relieving factors	Sitting, bending forward	Sitting, standing
4. Daily activities	Walking uphill, bicycling, pushing a shopping cart relieve the pain due to flexed lumbar posture	These activities provoke pain
5. Pulses and skin	Normal	Pulses are feeble or absent. Skin changes (loss of hair, skin atrophy) may be present.
6. Back pain, back motion	Back pain is usually present and back motion may be limited.	No back pain, back movements are normal
7. Neurological deficit	May be present	Absent
8. Time to get relief	Slow (many minutes)	Quick



Fig. 3.62: X-ray showing sacralization of 5th lumbar vertebra.

SCOLIOSIS

INTRODUCTION

Scoliosis refers to deviation of the normal vertical line of the spine that when measured on a radiograph is deviated for more than 10° (Fig. 3.63).

CLASSIFICATION OF SCOLIOSIS

It can be either nonstructural (mostly transient) or structural (permanent and fixed) deformity.

Non-Structural

This type includes:

Postural Scoliosis

This is the most common nonstructural variety of scoliosis. The curves in postural scoliosis generally disappear when the patient bends forward while in the structural variety, on forward bending the tilt becomes more prominent (Adam's Test).

Compensatory Scoliosis

In this type there is a transient sideways tilt of spine secondary to some condition outside the spine like a leg length discrepancy, a tilted fixed pelvis or a contracture around joints like hip. Scoliotic curve in these patients would disappear when the patient is asked to sit.

A "sciatic scoliosis or sciatic list" is also transient as it results due to spasm of the paraspinal muscles due to irritation of the nerve roots by the prolapsed disk. Appropriate treatment for the disk prolapse eliminates the scoliotic deformity.

Structural/Fixed Scoliosis

This type is a complex deformity representing abnormality in three planes-lateral bending in frontal/coronal plane, rotation of vertebral body around axial plane and lordosis of the spinal column in sagittal plane. Various subtypes under this category include:

Idiopathic Scoliosis

This is overall the most common variety (almost 80% cases of scoliosis). It is further subdivided as follows:

- *Infantile form:* It affects children in 0–3 years age group. Left-sided curves are more common. It affects boys more than girls.
- *Juvenile form:* Affected patients are in age group 3–10 years. Right-sided curves are more common. Affects girls more than boys.
- *Adolescent form:* It is most common amongst idiopathic variety. It affects patients more than 10 years of age till they reach skeletal maturity. Right-sided curves are more common. It affects girls more than boys.
- *Adult form:* Here curves develop after skeletal maturity.

Congenital (Osteopathic) Scoliosis

This kind of scoliosis is associated with either defects of formation (hemivertebra or a wedge vertebra) or defects of segmentation (unilateral bar or a block vertebra) (Figs. 3.64A and B). A fully segmented hemivertebra is the most common pathology. However, in order of severity in descending order, a fully segmented hemivertebra with contralateral bar causes the maximum deformity followed by a unilateral bar, and then a fully segmented hemivertebra. Progression of the deformity is least with a block vertebra as it has lowest growth potential.

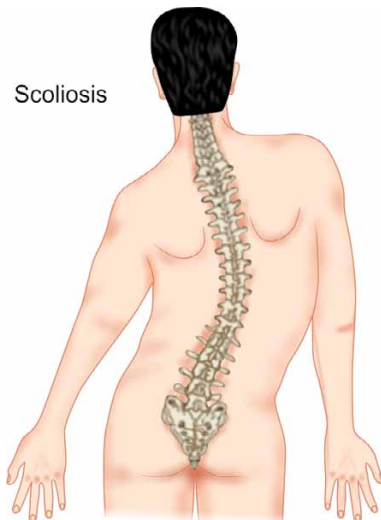
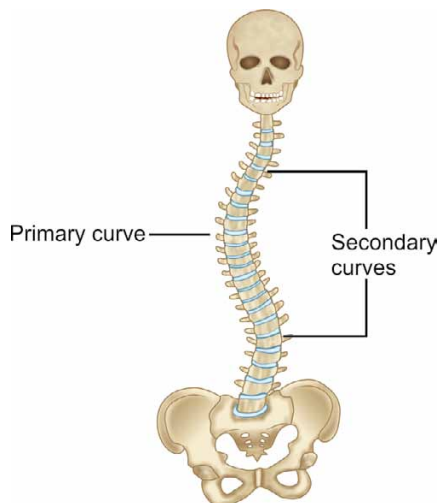


Fig. 3.63: Diagrammatic depiction of scoliosis.



A

Figs. 3.65A and B: Scoliotic curves.

Neuropathic/Myopathic Scoliosis

Scoliosis may be associated with neuromuscular conditions like poliomyelitis (the most common cause in India), cerebral palsy, syringomyelia, etc. which cause an unbalanced trunk muscle paralysis. The curve in these patients is long C-shaped with convex side towards the weaker muscles.

Scoliosis Associated with Neurofibromatosis

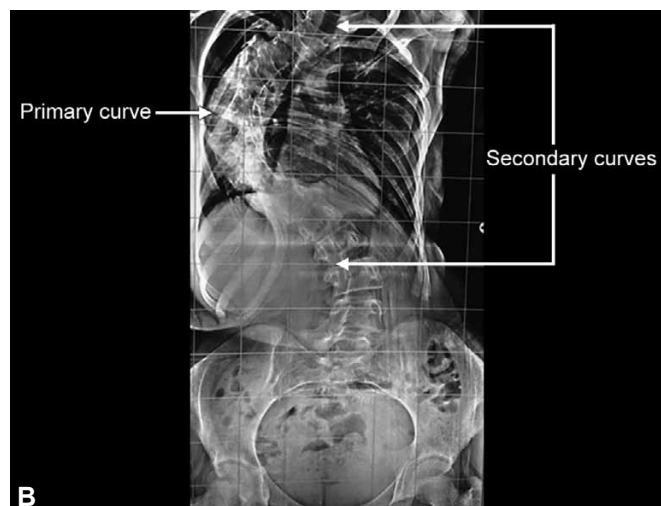
Almost one-third patients with neurofibromatosis tend to have some degree of scoliosis. The curves in these patients are classically short and sharp and are due to bony dystrophy affecting the vertebrae or the ribs.

SCOLIOTIC CURVES (FIGS. 3.65A AND B)

The main lateral curvature of the spine to one side is called the "primary curve". The part of spine above and below the primary curve develops a curve in direction opposite to



Figs. 3.64A and B: X-rays showing a (A) hemivertebra (arrow) and a (B) block vertebra (arrow).



B

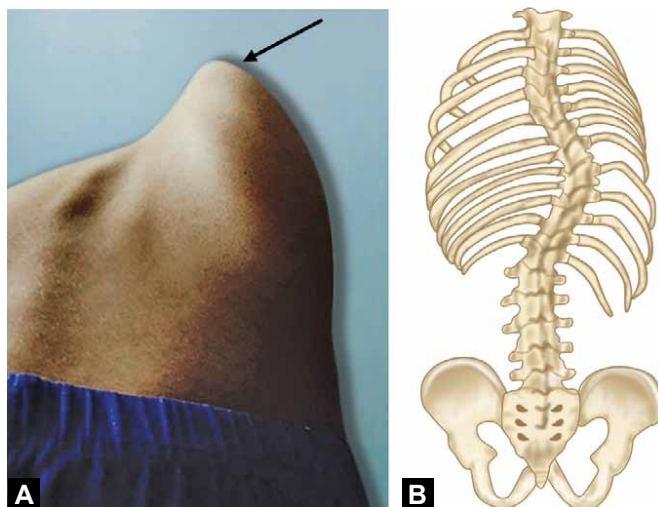
the primary curve, the compensatory curves being referred to as "secondary curves". The prime problem is malrotation of the vertebrae with spinous processes tilting into the concave side of curve and transverse processes occupying the convex side. In the thoracic spine this leads to prominence of the rib cage on the convex side, giving rise to a rib hump called as "Razorback (Figs. 3.66A and B)".

Any part of the vertebral column can be affected commonly giving rise to following patterns—thoracic scoliosis, lumbar scoliosis or combined varieties.

Based upon the position of the head, the curves may be balanced or unbalanced. In balanced curves the occiput is centered in the midline while in unbalanced curves it is not.

CLINICAL PRESENTATION

A visible deformity is by and large the most common complaint, otherwise most patients tend to be asymptomatic. Back pain is generally there in long-standing cases only.



Figs. 3.66A and B: Rib hump (arrow).

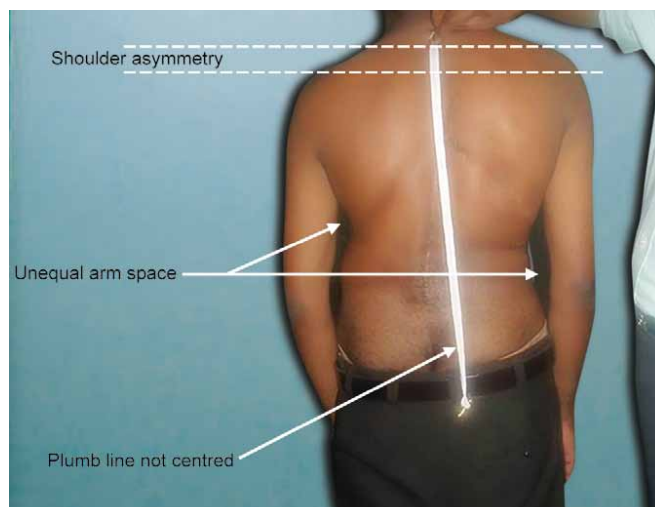


Fig. 3.67: Clinical findings on examination in scoliosis.

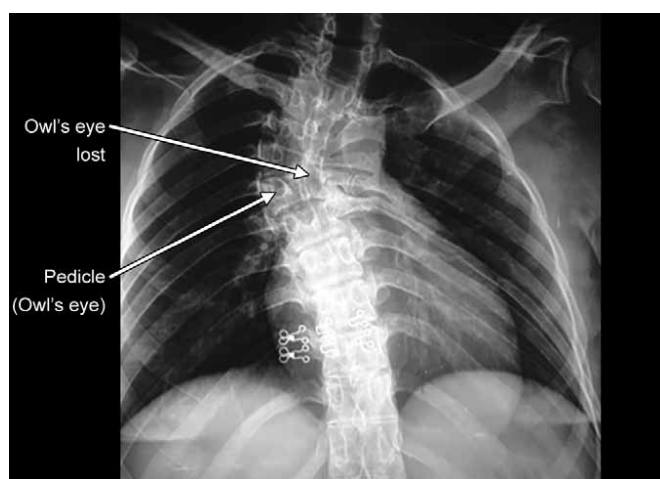


Fig. 3.68: X-ray of scoliotic spine showing loss of owl's eye appearance.

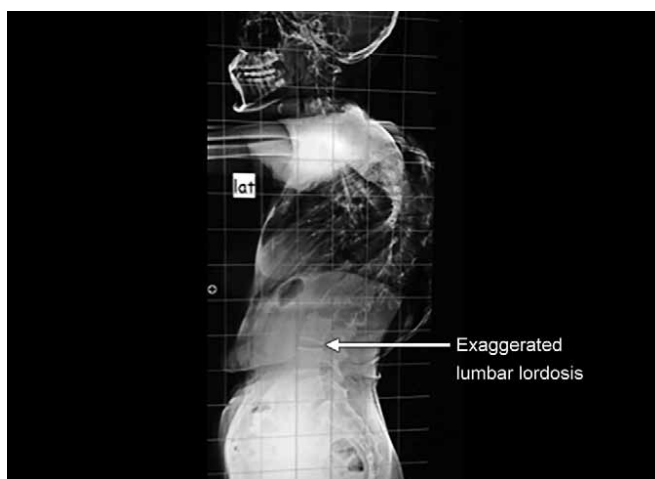


Fig. 3.69: Lateral film of scoliosis showing lordosis.

On examining these patients one may observe asymmetry of shoulders, unequal scapular prominence (more on convex side), elevated/prominent hip (on the concave side), increased space between arm and side of body and a head not centred over the pelvis (Fig. 3.67). All these findings can be used to screen children for the condition. In deformities that have progressed to advanced levels, one may detect a neurological deficit, although it is relatively uncommon presentation.

DIAGNOSIS

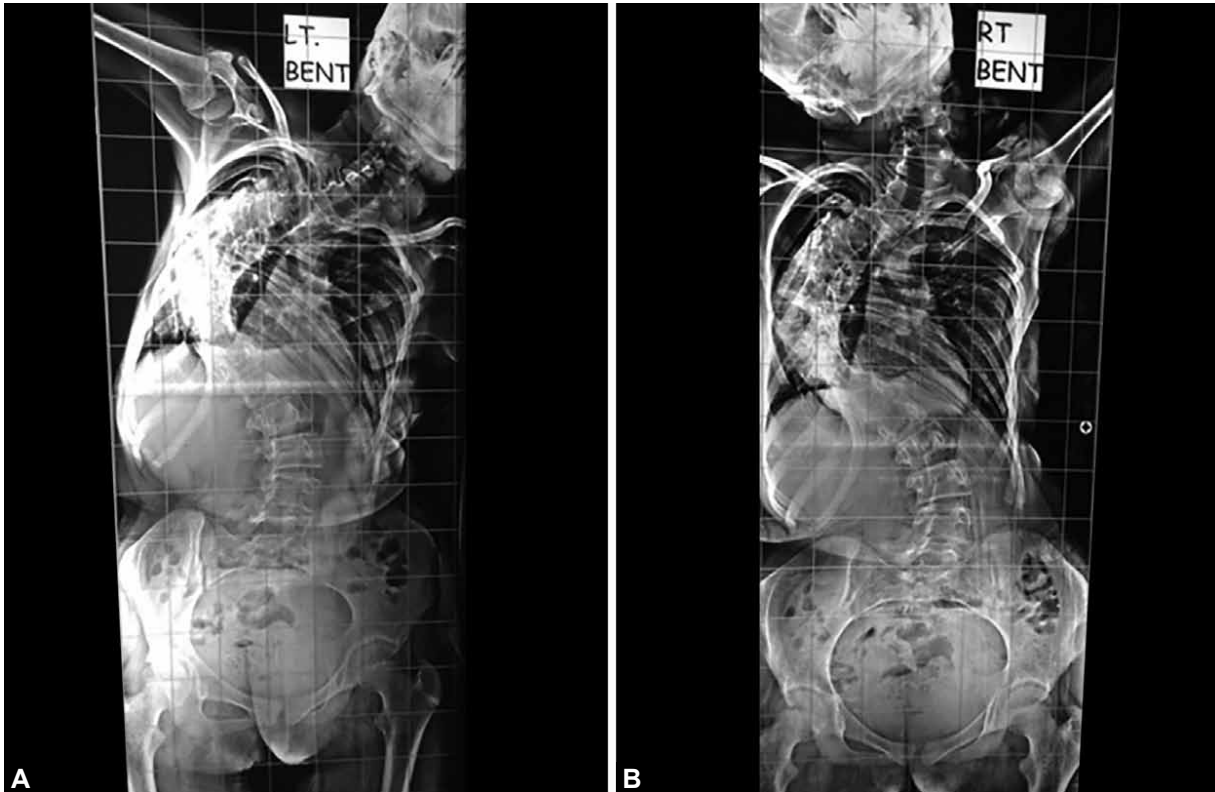
For a thorough assessment of the deformity a full length AP view of spine (Fig. 3.65B) in standing and supine positions along with a lateral view are obtained. Sideways bending of the vertebral column can be clearly appreciated and the primary as well as the secondary curves can be documented. Abnormal rotation of the vertebrae can be appreciated by identifying the spinous processes and the

pedicles. The spinous processes are shifted to one side and the pedicles of two sides lose the normal classical owl's eye appearance (Fig. 3.68). In congenital scoliosis one may find a vertebral anomaly (*see* Fig. 3.64).

A lateral view in idiopathic scoliosis generally shows lordosis of the affected part (Fig. 3.69) and traction or bending X-rays (Figs. 3.70A and B) are needed to see if the deformity is correctable or fixed.

Grading the Severity

The full length AP radiographs are used. The vertebra exactly in the middle of the primary curve is called the "Apical vertebra". To assess the severity, vertebrae at the upper and lower ends of the primary curve are identified. A line is drawn along superior margin of the topmost vertebra and another line is drawn along the lower margin of the bottom vertebra. The two lines are allowed to meet to form an angle called as "the Cobb's angle (Fig. 3.71)". Greater the angle, more severe is the deformity.



Figs. 3.70A and B: Bent films in patient with scoliosis.

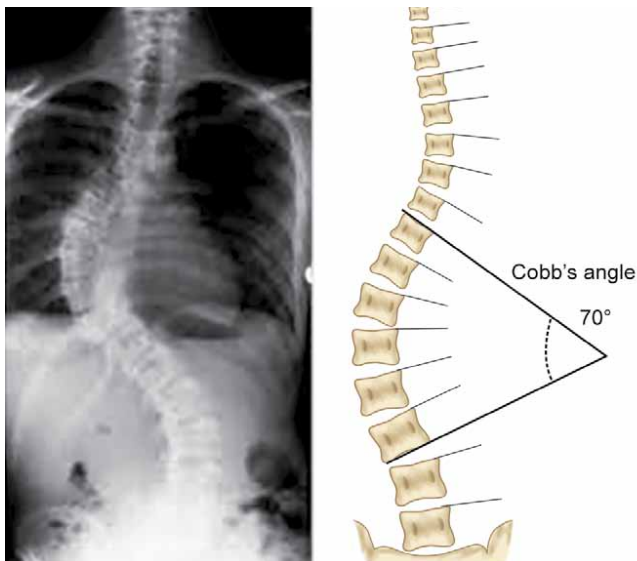


Fig. 3.71: Calculation of Cobb's angle.

Vertebral rotation can be estimated by placing special calibrated instruments on radiographs called as “torsionometers (Perdriolle method)”. Else a CT scan is a more sensitive method.

Predicting Progression of the Deformity

Scoliotic curves tend to worsen up with skeletal growth. A clinical way of estimating progression is by using the

Tanner's index (based on assessment of breasts and genitalia) as the growth potentially slows down after skeletal maturity. A radiological assessment can be made by observing the appearance of iliac apophysis on a pelvis AP X-ray. If the iliac apophysis has fused with the iliac bone, it indicates completion of the growth and hence no likelihood of curve worsening any further. This is called as “Risser's sign”. Five grades of the sign are described that start with the appearance of iliac apophysis till it fuses with the iliac bone (Figs. 3.72A and B). Lesser the Risser's grade, more are the chances of progression.

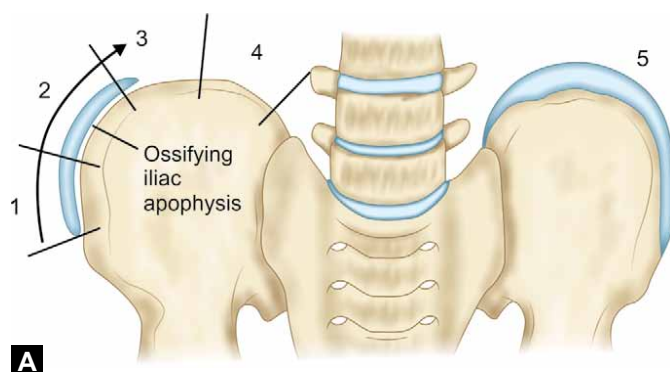
MANAGEMENT

Management is guided by the type of scoliosis.

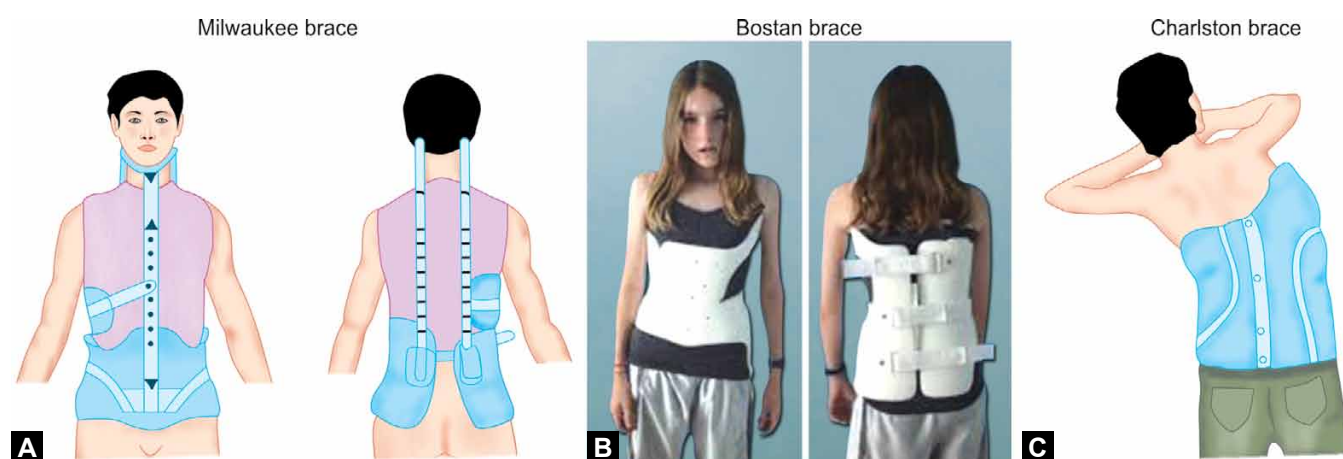
Postural curves: Postural curves can be well managed by conservative methods.

Curves in congenital scoliosis, myopathic scoliosis and scoliosis associated with neurofibromatosis tend to progress very fast and hence mostly need operative management. Only milder curves can be managed conservatively.

Idiopathic scoliosis is mostly treated by conservative means. The indications to operate are cases where deformity is greater than 30° and cosmetically unacceptable to the patient or when the curves are more than 45° . Curves in young patients which have high risk of progression (as per Risser's grading) also are managed with surgery (Table 3.14 for synopsis of treatment).



Figs. 3.72A and B: (A) Pictorial representation and (B) X-ray pelvis with both hips AP view showing ossifying iliac apophysis.



Figs. 3.73A to C: TLSOs used in scoliosis.

Table 3.14: Management of idiopathic scoliosis

Curve magnitude (degrees)	Risser's grade 0/ Premenarchal	Risser's grade 1/2	Risser's grade 3, 4, 5
< 25	Observation	Observation	Observation
25–45	Brace	Brace	Observation
> 45	Surgery	Surgery	Surgery (> 50°)

Conservative Treatment

This involves physiotherapy to tone up appropriate spinal and trunk muscles and thereby strengthen the spinal support and use of spinal braces to prevent progression and hasten correction of the deformity.

Braces: Thoracolumbar spinal orthoses (TLSOs) (Figs. 3.73A to C) are mostly used. They are useful only when the apex of deformity is below T7 vertebra. Patient's compliance is very important as advised brace wear time is 20 hours/day.

Some commonly used braces are as follows:

- Milwaukee brace (named after the city where it was designed)—Only brace that can be used with a higher apex.

- Boston brace (most commonly used)—cosmetically more acceptable. It is made from negative mould of patient's X-ray.
- Reisser's turn buckle cast—body cast with a buckle fitted on concave side. Turning the buckle stretches the concave side.
- Charleston's night time bending brace—To be worn only during the night time.
- *Minerva jacket* (Figs. 3.74A and B): Old method for correction with casting.

Contraindications to brace wear: These are only prescribed in idiopathic varieties. Congenital and neuromuscular scoliosis can worsen while waiting to see the result of brace treatment.

Operative Treatment

The surgery for scoliosis involves correction of the deformity by some form of instrumentation and then fusion of the spine in the corrected position by means of bone grafting. For surgery the spine can be approached from either posterior aspect (more preferred and more surgeon friendly) or anterior aspect (via the transthoracic or transabdominal route). Once approached some form of



Figs. 3.74A and B: Minerva jacket.



Fig. 3.75: Halo pelvic distraction system.

instrumentation (Table 3.15) can be applied to distract the spine and bring it in corrected position for fusion.

Note: In case deformity is very severe to be corrected on table then preoperatively the spine can be stretched to lessen the deformity by using the Halo-Pelvic Distraction system (Fig. 3.75) or a halo femoral traction and thereafter fused after adequate distraction in a staged manner.

Thoracoplasty/Costoplasty: The surgical methods discussed above correct the spinal deformity but may not alleviate the rib hump. In case it is cosmetically acceptable then the same can be managed by surgery called costoplasty which involves excising short sections of multiple ribs close to vertebral articulation.

HIGH-YIELD POINTS

- Thoracic curves have maximum propensity to worsen and lumbar have the least.
- *Crank shaft phenomena:* It is seen in children less than 8 years when only posterior Harrington systems is used. With only posterior fusion, in young children the anterior body would continue to grow leading to

Table 3.15: Various forms of instrumentation used for spinal fixation in scoliosis

Posterior instrumentation methods (applied via posterior approach)

- Hartshill rectangles
- Harrington rod system
- Luque rods and sublaminar wire fixation
- Pedicle screws (modern day preferred instrumentation).

Anterior instrumentation methods (applied via anterior approach)

- Dwyer Zielke instrumentation.

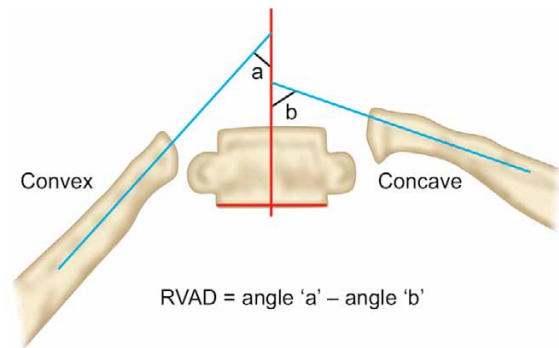


Fig. 3.76: Mehta's rib vertebral angle difference.

increased deformity known as crankshaft phenomena. It is not seen nowadays due to use of pedicle screw system that fixes all the three columns of the vertebra.

- *Mehta's rib vertebral angle difference (Fig. 3.76):* This is a trustable method of predicting curve progression in infantile idiopathic scoliosis. It is an angle between end plate of vertebra at the apex of curve and ribs attached to it on either side of curve. A difference more than 20 degrees is linked to high chance of curve progression. Difference less than 20 degrees indicates likelihood of spontaneous recovery.
- *Early onset scoliosis:* All forms of structural scoliosis that are diagnosed before the age of 5 years, are likely to progress and need an early surgical intervention and thus fall in this category. The management in such cases differs as the lungs and thoracic cavity are not developed till 5 years and so fusion of the spine at this stage would lead to a compromised pulmonary function. So concept of fusion-less surgery has been introduced into this group whereby two techniques are used:
 - *Growth Rod technique:* Upper and lower vertebra of the curve are instrumented and connected via rods and then distracted at 6 monthly intervals to keep the deformity in check so that at a later stage, fusion can be done.
 - *Vertically expandable prosthetic titanium rib (VEPTR):* VEPTR is used to distract between the ribs so that chest and spine keep growing till the age lungs mature and allow a fusion.

KYPHOSIS

INTRODUCTION

Kyphosis refers to excessive forward bending of the vertebral column. Normally also the thoracic vertebral column has a forward bend around 20–45°. When the bend is exaggerated the deformity appears at the back (Fig. 3.77).

Some common terms used for description of deformity:

- *Knuckle kyphus*: Involving 1 vertebra
- *Angular kyphus*: Involving 2–3 vertebra
- *Rounded kyphus*: Involving more than 3 vertebra

(Note: *Gibbus* is an old term not used these days more or less equivalent to *Angular Kyphus*.)

TYPES OF KYPHOSIS

Nonstructural Kyphosis (Correctable)

Postural kyphosis is a non progressive condition that is due to flexibility of spine in adolescents. It appears when child stands and resolves in supine position. It is a self limiting condition with no vertebral abnormality and postural training and exercises are all that is required.

Compensatory kyphosis occurs in compensation to some other deformity in spine, usually increased lumbar lordosis.

Structural Kyphosis (Noncorrectable)

In contrast to nonstructural kyphosis, structural kyphosis is associated with vertebral structural abnormality.

Different conditions lead to structured or fixed kyphosis in different age groups:

- *In Infants and children*: Congenital kyphosis is due to either failure of formation defect or failure of segmentation defect of vertebrae. Failure of formation defect may present at birth as kyphotic deformity and

worsen with growth. Failure of segmentation defect is slow to grow and usually become apparent when child starts walking. For progressive deformity fusion of deformed vertebrae may be required. Braces have no role in congenital kyphosis.

- *In adolescents*: Scheuermann's disease (see below) is the most common cause of fixed kyphosis in adolescents. Tuberculosis of spine can also lead to the problem.
- *In adults*: Traumatic kyphosis (due to spinal trauma), tuberculosis and ankylosing spondylitis are common causes in this group. Traumatic kyphosis mainly involve the thoracolumbar or lumbar regions and usually associated with paraplegia.
- *Elderly*: Osteoporosis resulting in multiple compression factors is the main culprit for kyphosis in the elderly although metastatic vertebral tumors or TB spine can be other causes leading to vertebral collapse.

SCHEUERMANN'S DISEASE

(Adolescent idiopathic kyphosis)

Scheuermann described this disease in 1920 as Juvenile dorsal kyphosis. Exact etiology of Scheuermann's disease is not clear. Radiological findings suggest it to be osteochondritis of ring epiphyses of vertebra. Defective endochondral ossification in the vertebral end plates is also a consistent pathological finding. After idiopathic scoliosis it is the 2nd most common spinal deformity.

Clinical Presentation (Fig. 3.78A)

It affects adolescents (usually between 13 to 17 years). Painless kyphotic deformity of thoracic spine (apex between T7 and T9) is the most common presenting symptom (Fig. 3.78A). Back pain may be there with tendency to aggravate on exertion. Compensatory lumbar and cervical lordosis, cutaneous pigmentation at the apex of deformity due to continuous friction at the back of the chair are other associated signs, flexion contractures of hip and shoulder joints and hamstring spasm are the other common findings. It mainly involves the thoracic spine but can also affects thoracolumbar and lumbar regions. Lumbar Scheuermann's disease does not produce typical kyphosis but have similar radiological changes. Neurological deficits are rare.

X-ray findings (Fig. 3.78B): Sorenson criteria are used to diagnose Scheuermann's kyphosis.

1. Anterior wedging of more than 5 degrees of three consecutive adjacent vertebrae at the apex of deformity.
2. Irregular vertebral apophyseal lines.
3. Presence of schmorl nodes
4. Narrowing of intervertebral disk spaces.

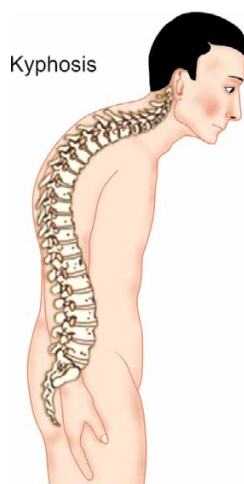
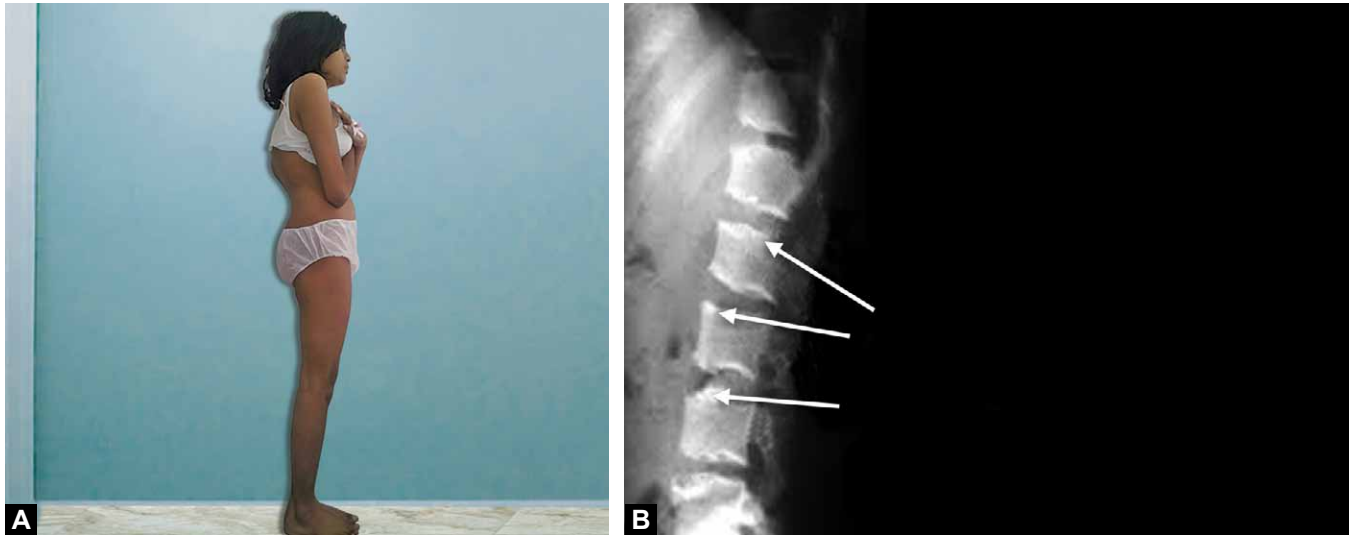


Fig. 3.77: Diagrammatic representation of kyphosis.



Figs. 3.78A and B: (A) Clinical presentation (Thoracic kyphosis) and (B) X-ray lateral view of dorsal spine showing irregular and fragmented vertebral end plates (arrows).

Differential diagnosis: Condition has to be differentiated from other causes of kyphosis in this age group.

Treatment

Natural history is benign. So majority of patients are managed conservatively.

Conservative Management

- Postural training and back exercises.
- Serial cast treatment
- *Brace therapy:* Only brace available is Milwaukee brace.

Surgery

Reserved for patients with pain, a rigid deformity, a curve of more than 70–75° and an unacceptable cosmetic appearance. Anterior release and fusion followed

by posterior instrumentation and fusion is the accepted standard of care.

Rule of thumb: Never correct more than 50% of the deformity as it can cause neurological deficits.

HIGH-YIELD POINTS

- Osteoporotic fractures of vertebrae is the most common cause of kyphosis in adults.
- Scheuermann's disease is the most common form of fixed kyphosis in adolescents.
- Red flag and yellow flag signs in backache: Red flag signs are those signs that indicate serious spinal pathology like neurological deficit, positive SLR etc. Yellow flag signs are psychological factors indicative of problems ending up in long term chronicity like fear or avoidance of activity or movement or tendency to low mood etc.

Peripheral Nerve Injuries



PERIPHERAL NERVE INJURY—ANATOMY, CLASSIFICATION AND DIAGNOSIS

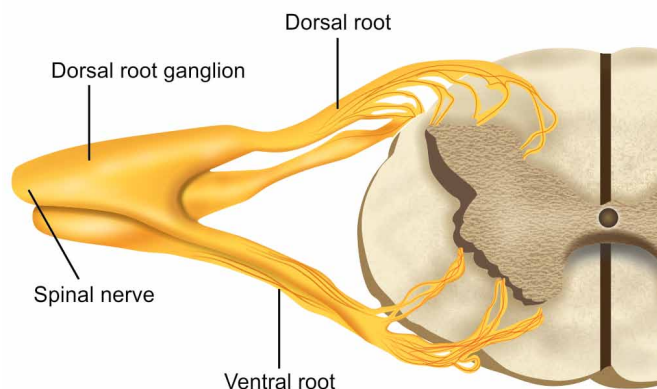
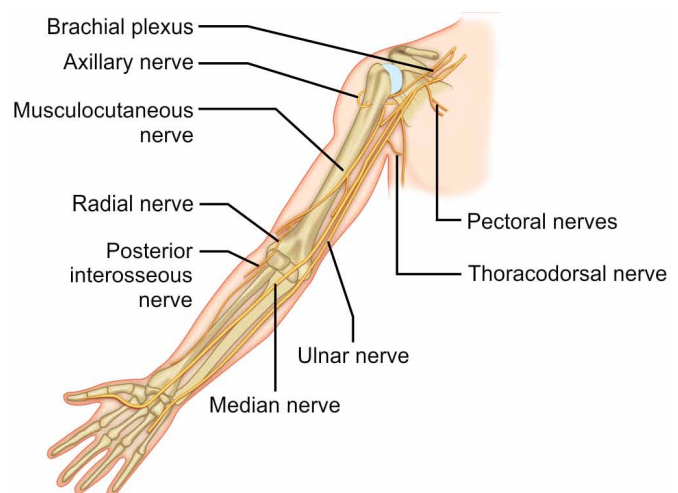
GROSS ANATOMY

Every segment of spinal cord gives rise to a nerve called as spinal nerve (total being 31 pairs). Each spinal nerve is a mixed nerve, formed at the intervertebral foramen by the union of its dorsal or sensory root with its ventral or motor root (Fig. 4.1A). Now for supplying the trunk, these spinal nerves divide into ventral and dorsal rami, which further subdivide into motor and sensory branches, which finally supply the targeted trunk areas. However, the supply to limbs is very different and peculiar. For the upper limb, the spinal nerves C5-T1 join in front of the scapula and form the brachial plexus (cf. lumbosacral plexus for lower limb). From this plexus, the nerves that sprout are the peripheral nerves (viz. median, ulnar, radial, etc.) (Fig. 4.1B) again each being a mixed nerve. So, these peripheral nerves are basically distributing the fibers of spinal nerves to the skin and musculature of the limb. By the same token, one can well imagine that one peripheral nerve may contain fibers from several spinal nerves or the fibers of single spinal nerve may get divided amongst several peripheral nerves.

MICROSCOPIC ANATOMY (FIG. 4.2)

Each nerve fiber, or axon, is either a direct extension of a dorsal root ganglion cell (sensory), an anterior horn cell (motor), or a postganglionic sympathetic nerve cell, and it is either myelinated or unmyelinated. In the myelinated fibers, the Schwann cell forms a multilaminated structure, the myelin sheath around the axon. The point at which one Schwann cell ends and the next begins is relatively sparse in myelin and is called the nodal gap, or node of Ranvier. This axon with its myelin sheath is surrounded by delicate fibrous tissue called the endoneurium. A group of axons, each bound by endoneurium, cluster together to form a fascicle. Each fascicle is surrounded by a denser layer of perineurium. The entire group of fascicles with their surrounding perineurium is encased as a peripheral nerve in a denser layer called as epineurium.

The blood supply to the peripheral nerve enters through the mesoneurium, which is loose connective tissue extending from the epineurium to the surrounding tissues.


A

B

Figs. 4.1A and B: Spinal nerve diagrammatic depiction and the peripheral nerves of upper limb.

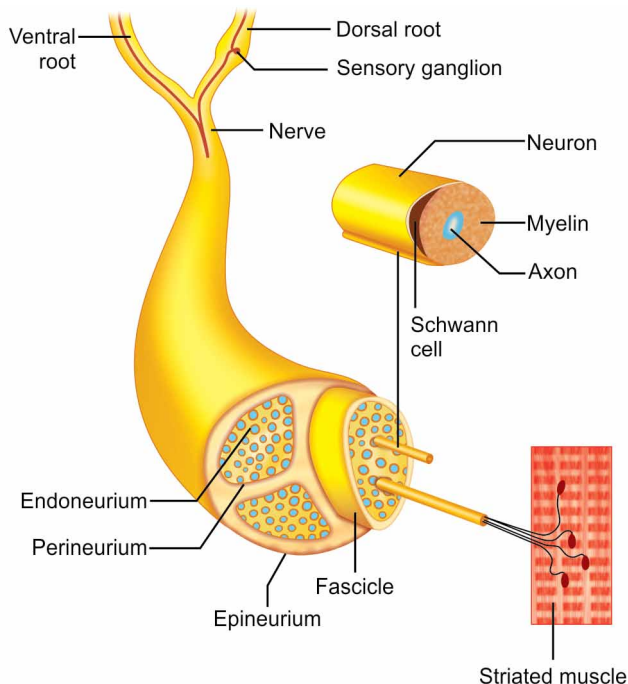


Fig. 4.2: Microscopic anatomy of a nerve.

NEURONAL DEGENERATION AND REGENERATION

Any part of the axon that is detached from the cell body, degenerates, and is destroyed by phagocytosis. This process of degeneration distal to a point of injury is called secondary or Wallerian degeneration (named after English neurophysiologist August Waller who described it about 160 years ago in sectioned IX and XII cranial nerves of a frog). The reaction proximal to the point of injury is called primary, traumatic or retrograde degeneration. The primary retrograde degeneration proceeds proximally for at least an internode or more, depending on the degree of insult, and it is histologically identical to Wallerian degeneration. When an axon is cut, degeneration starts in the axon stump lying distal to the level of injury after 24–36 hours. However, during these 1–3 days, the distal axon stump may remain electrically excitable. After 3 days, the axonal skeleton disintegrates, and the axonal membrane breaks apart. However, the axon's neurilemma (the outermost layer of Schwann cells) does not degenerate and remains as a hollow tube encircling the debris. By 4–7 days, macrophages start entering the transacted area and start clearing the axonal and some myelin debris, a process virtually completed by 15–30 days.

Meanwhile, the Schwann cells that make up the hollow tube, synthesize growth factors which attract axonal sprouting from the proximal axon stump that try to reach the distal axon stump. If an axon sprout reaches the tube, it grows into it and advances about 1 mm per day. The tubes thus provide pathways for the regenerating axons to follow to their innervation of muscles and skin. The Schwann

cells then remyelinate the newly formed axons which eventually reach and innervate the target tissue.

As this reinnervation proceeds, the muscles nearest to the site of injury are reinnervated first, followed by others. This phenomenon of reinnervation of muscles from proximal to distal is referred to as motor march, and is an evidence of recovery.

The clinical evidence of regeneration is a *progressive Tinel's sign (Hoffman's sign)*. As the regenerating axonal sprouts that have not obtained complete myelination are progressing along the endoneurial tube, a gentle tap along the course of the nerve (from distal to proximal) elicits a transient tingling sensation felt by the patient in the distribution of the injured nerve (rather than at the area percussed), owing to hyperexcitability of the regenerating fibers. A positive Tinel's sign is presumptive evidence that regenerating axonal sprouts are progressing along the endoneurial tube. With progressive regeneration, the positive response fades proximally, presumably because of progressive myelination along the more proximal part of the regenerated segment and moves further distally. It is important to note that Tinel's sign is a reflection of sensory recovery and does not give any idea about motor recovery.

In some severe cases of nerve injury, the endoneurial tube also gets damaged. Then the sprouting axons from proximal stump fail to enter the guiding tube and wander aimless in the adjacent tissues and form an end neuroma. End neuroma forms when there is complete cut of the peripheral nerve with widely separated ends while a partial cut with a similar situation ends up in "neuroma in continuity". Full functional return would not be possible in these situations.

MECHANISMS OF NERVE INJURIES

Although the commonest cause of nerve injuries remain fracture dislocations, a number of other mechanisms may be involved which include a cut/laceration, crushing, thermal injury (frost bite/electrical shock), ischemia to nerve (see Volkman's ischemia), radiation exposure and iatrogenic causes like accidental drug injections into the nerves.

CLASSIFICATION OF NERVE INJURIES

Seddon's Classification (1943)

Neurapraxia

It designates a situation where transmission of impulses is physiologically interrupted for a time but there is no cut in the nerve (generally only compression of the nerve is there). Recovery is complete in a few days or maximum by 6 weeks and no Wallerian degeneration occurs. Recovery is complete all at once and all groups of muscles recover at the same time so no motor march or no advancing Tinel's sign are seen.

Axonotmesis

It designates more significant injury with damage to the axon that causes a partial cut. Distal Wallerian degeneration is present but with preservation of the Schwann cell and endoneurial tubes. Spontaneous regeneration (motor march and progressive Tinel's sign) occurs with reasonably good functional recovery.

Neurotmesis

It is a more severe injury with complete anatomical severance of the nerve. The axon and the Schwann cell and endoneurial tubes are completely disrupted. The perineurium and epineurium also are disrupted to varying degrees. Significant spontaneous recovery cannot be expected unless nerve is surgically repaired.

High versus Low Nerve Palsy

By convention, the major nerve injuries of upper limb are divided into high and low types depending on whether the injury site is proximal to elbow (high injury) or distal to elbow (low injury).

DIAGNOSIS OF A NERVE INJURY

A thorough history and a meticulous examination forms the cornerstone of making diagnosis of any nerve injury and localizing the site of affection.

Examination in a Case of Nerve Injury

Look (observing the attitude of the limb): Many nerve injuries make the limb end up in a specific attitude that may be of diagnostic significance (e.g. wrist drop in radial nerve palsy). Wasting of the innervated muscles is evident in long-standing cases of nerve injury that provide clue to diagnosis.

Feel (sensory examination): For performing a thorough sensory examination, one needs to confront with the concept of maximal, submaximal and autonomous zones. Every nerve supplies a large area of skin often overlapped by adjacent nerves, referred to as its maximal zone while the area that is exclusively supplied by each nerve is called its autonomic zone (Fig. 4.3). Interruption of a nerve causes complete insensibility in the autonomic zone while only a decreased sensibility in the maximal zone.

Move (motor examination including reflexes): Functional tests are described for all nerves which basically work on the same underlying principle, i.e. making the innervated muscle contract and preferably testing it against resistance to grade strength.

Checking for reflexes: Since injury to a nerve is a lower motor neuron type of lesion, the reflexes are absent in the area of nerve distribution.

Examination of autonomic function: The sympathetic nerve fibers are generally considered to be the most resistant.

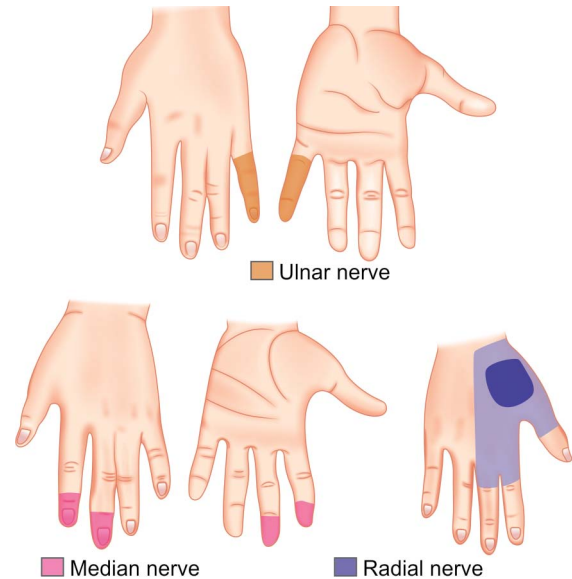


Fig. 4.3: Autonomic zones of major peripheral nerves of upper limb.

They can be tested by the conventional sweat test (iodine starch test). An intact sympathetic function may reassure the surgeon that the injury to the nerve is not complete.

SPECIAL INVESTIGATIONS

Electrodiagnostic Studies

These are sequential studies, complementary to each other performed in cases with a PNI that provide the clinician with a base of knowledge as follows:

1. Confirmation of diagnosis
2. Locating the site of injury
3. Estimating the extent of injury
4. Determining chances of recovery
5. Documenting recovery if any
6. Selection of suitable donor nerves for reconstruction of lost function.

Electrodiagnostic studies (EDS) include:

Nerve Conduction Studies

Stimulation of a peripheral nerve by an electrode placed on the skin overlying the nerve readily evokes a response from the muscle innervated by that nerve. This response can be picked up either from surface electrode placed into the innervated muscle or even from a distant area of the nerve trunk itself. The measurements that are of interest include the Latency, the Amplitude and the conduction velocity. Latency is the time (in milliseconds) taken by the impulse to reach the muscle and amplitude is the magnitude of response obtained from the muscle stimulated, measured in millivolts. The velocity of conduction can also be calculated by estimating the distance between the measuring electrodes and noting the time taken by impulse to travel the distance.

For sensory nerve studies: An individual sensory nerve is electrically stimulated at the skin surface and the sensory nerve action potential (SNAP) is recorded from a distant point on the nerve. The response can be recorded orthodromically with a stimulus applied distally and recorded proximally. Alternatively, an antidromic response can be recorded with the stimulus applied proximally and recorded distally.

For motor or mixed nerve studies: When a motor or a mixed nerve is stimulated, the response recorded is a compound muscle action potential (CMAP). This CMAP represents a summation of motor unit responses beneath the stimulating electrode and its amplitude is directly proportional to the number of motor units stimulated. For e.g. in nerve injury where one-half of nerve fibers are lost the amplitude of the compound muscle action potential will be reduced by 50% compared to normal side.

Interpretation of nerve conduction studies: In the first several days (7 to 10 days) after nerve transaction, the distal axon fragment remains intact and is electrically excitable. So stimulation distal to the site of injury may result in normal response despite severe proximal nerve injury. However, the nerve transaction will cause both sensory and motor responses to be absent in case the stimulation is done proximal to the site of injury thereby indicating the site of injury.

After 10–12 days, in axonotmesis/neurotmesis, due to wallerian degeneration the distal axon will degenerate. Hence, there will be no sensory and motor response on stimulation distal to injury site. However, in neuropraxia (focal demyelination of the nerve) distal responses will be preserved because of the underlying intact axons. Only decreased amplitude may be noted or conduction velocity may be slowed, reflecting loss of vulnerable large diameter, rapidly conducting myelinated axons (Conduction block). Therefore, if an acute nerve injury is suspected best time to perform nerve conduction studies is 10–14 days after the injury as at this time the studies will reveal the severity of injury (demyelination or partial or complete cut) that can be correlated with the prognosis.

Electromyography

Electromyography (EMG) is a graphical recording of the muscle activity observed with a needle electrode placed in muscle. The test involves observation of muscle activity at rest and then with voluntary contraction and various patterns recorded are analyzed to reach the conclusion.

Interpretation (Fig. 4.4)

Normal: A normal muscle has no activity at rest. As voluntary contraction is initiated, action potentials begin to develop in the muscle. In the beginning, only a few motor units are firing, so recordings show single motor unit potentials

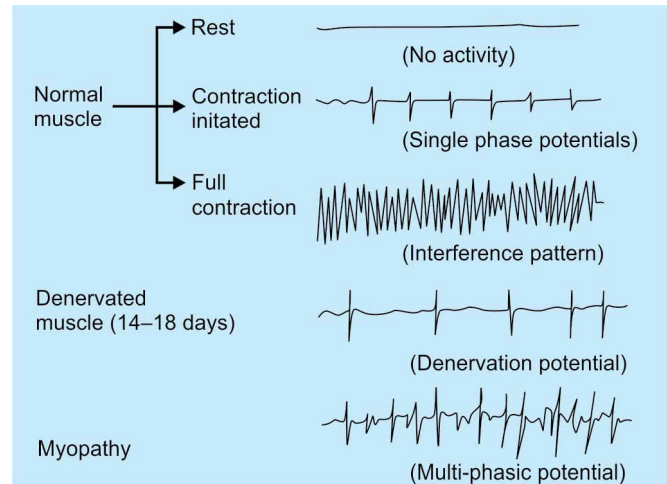


Fig. 4.4: Electromyographic record interpretation.

on the graph. As the contraction becomes stronger, there is progressive increase in the number and then increased amplitude of the motor unit action potential (recruitment pattern) is seen. Finally a large number of motor units fire all together, the action potentials get superimposed and the graph shows the characteristic “interference pattern”.

Nerve injury: In a denervated muscle, even at rest, there is some spontaneous electrical activity. These potentials are called as positive sharp waves (10–14 days) and fibrillation potentials or denervation potentials (by 14–18 days) and represent embryonic electrical activity of muscle that was getting suppressed due to inhibition by the stronger nerve action potential. At times, these fibrillations are so strong that they can be seen and are then called fasciculations. However, one must remember that these potentials develop by about 2 weeks after the injury. So absence of these potentials by about 3 weeks would signify a good prognosis as the muscle in that case would not be denervated. In case these potentials develop, then they last indefinitely until the muscle is reinnervated or becomes fibrotic. Analysis of motor unit action potential (MUAP) morphology and recruitment pattern is the key element of needle EMG to diagnose myopathy. Small, polyphasic MUAPs (due to dysfunctional muscle fibers) is a characteristic finding of myopathy. Other commonly seen findings of myopathies in needle EMG are fibrillations and positive sharp waves which are waxing and waning action potentials in both frequency and amplitude. Occasionally, in chronic myopathies, complex repetitive discharges (CRDs) may be seen.

Application: The clinical value of an EMG test lies in that it can determine whether the nerve injury is complete or an incomplete one. If the injury would be incomplete, there will be evidence of reinnervation that appears much before visible muscle contraction. EMG also differentiates a myopathy from a neuropathy (see Fig. 4.4). By performing an EMG of all the muscle supplied by a nerve, it is even

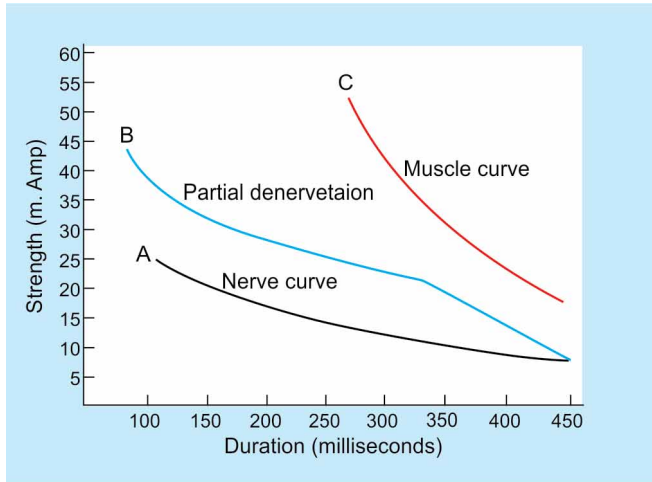


Fig. 4.5: Strength duration curve.

possible to decide the possible site of injury, as only those muscles will be paralyzed which are being supplied distal to the site of lesion.

Strength Duration Curve (Fig. 4.5)

This is a graphical method of quantifying the excitable property of the nerve and the muscle under consideration and thereby quantifying the amount of recovery that has taken place.

Underlying principle: A normal muscle can be excited by a small amount of current if the stimulation reaches the muscle via the neuromuscular junction. A denervated muscle would thus need a higher strength of current.

Procedure: A low strength current is given to excite the muscle contraction, for a fixed duration for example say 300 millise. The minimum current required to elicit muscle contraction is noted and is called rheobase for that muscle. As the duration is decreased, the amount of current needed to elicit the contraction proportionally increases and the recording follows the pattern shown in curve A, in the Figure 4.5. Next, a double the rheobase current is given, and the time interval is gradually reduced, carefully noting the minimum time for which a double rheobase current needs to be given to elicit the muscle contraction.

This minimum time period required to elicit contraction (at double rheobase current) is called chronaxie.

Interpretation: A normal pattern curve is called as nerve curve (curve A). If the muscle is denervated, then for eliciting contraction, a greater amount of current would be needed at every time duration, and hence the curve would shift to right (curve C). Such a curve is called as muscle curve. In cases of partial denervation, the curve of the recovering muscle lies between the nerve and muscle curves and is characterized by a kink at some point as shown (curve B). Thus, strength duration (SD) curve can differentiate a completely and a partially denervated muscle and also quantify the rate of recovery, as with recovery, the curve will shift from right to left (curve C–curve A).

HIGH-YIELD POINTS

- Loss of SNAP indicates a disease distal to spinal foramen (peripheral nerve entrapment) and intact SNAP indicates a proximal disease differentiating it from peripheral entrapment neuropathy.
- *Late potentials (H and F reflex):* Late potentials are electro-diagnostically elicited responses in muscle that appear more than 10–20 milliseconds after stimulation of motor nerves. They have been termed “late potentials” because they take substantially longer to appear than the direct responses to stimulation of motor nerves. There are two distinct types of late responses, the H-reflex and the F-response. Traditional nerve stimulation techniques used in an electrophysiology laboratory primarily assessed the distal segments of the peripheral nerves. Methods of testing the proximal nerve segments or the central nervous system include F wave and the H reflex. In fact, these reflex studies can reveal conduction characteristics along the entire course of the sensory and motor axons. H-reflex was described by Hoffmann in 1918. It is a monosynaptic reflex whose pathway is similar to a muscle stretch reflex. It includes submaximally stimulating the tibial nerve and then recording potentials from the calf muscle (gastrosoleus). It is useful for diagnosis in many conditions but has been extensively tested in diagnosing the S1 radiculopathy.

PERIPHERAL NERVE INJURIES OF UPPER LIMB

RELEVANT ANATOMY

The musculature of the arm is divided into an anterior, medial and a posterior compartment. Medial compartment is largely rudimentary and in it lies the coracobrachialis, originating from coracoid process of scapula. Although vestigial, the muscle is incredibly important landmark as all peripheral nerves change their compartments just distal to

the place where this muscle is inserted into the medial aspect of middle humerus. The main bulk of anterior compartment is composed of the biceps (supplied by musculocutaneous nerve) and the brachialis (motor supply by musculocutaneous and sensory fibers by radial nerve). The posterior compartment mainly comprises of the triceps with its three heads, supplied by the radial nerve. So, no muscle in the arm is supplied by the median and ulnar nerves.

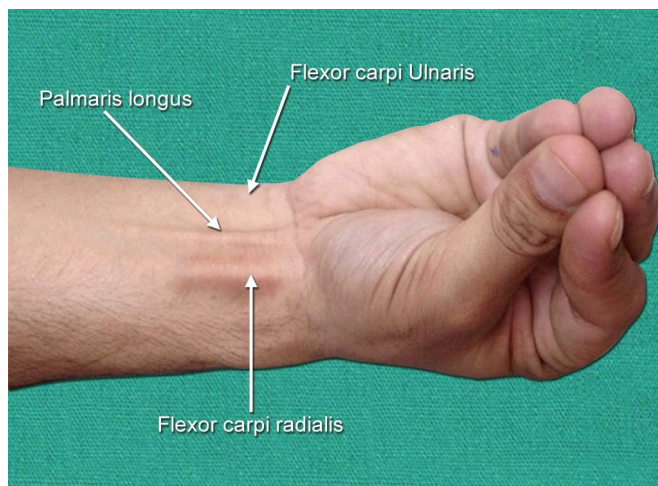


Fig. 4.6: Superficial flexors of forearm.

The forearm has the flexors on the anterior aspect and the extensors on the dorsal aspect.

The forearm flexor muscles are classified as superficial, intermediate and deep. The superficial group includes those muscle tendons that are visible under the skin (Fig. 4.6), viz. palmaris longus (PL), flexor carpi radialis (FCR), flexor carpi ulnaris (FCU) and pronator teres (PT). Underneath it lies the intermediate group [flexor digitorum superficialis (FDS)] while the deep group comprises of the flexor digitorum profundus (FDP) and flexor pollicis longus (FPL) tendons. All these flexors have a common origin, the medial epicondyle of humerus but varying insertions. The superficial group inserts onto the corresponding carpal bones just as the tendons cross the wrist. The intermediate and deep groups extend beyond and play a role in the flexion of the digits. FDS splits in front of proximal phalanx and the two slips insert onto the sides of the middle phalanx. The FDP and for thumb the FPL, are the only tendons that reach till the distal phalanges inserting at its base, and thereby acting as sole flexors of the distal interphalangeal (DIP) joints. All flexors of forearm are supplied by median nerve except one and a half flexors (the FCU and the medial tendons of FDP), that are supplied by ulnar nerve.

The extensor side of the forearm comprises of six compartments as shown in Figures 4.7A and B. The extensor carpi radialis longus (ECRL) and extensor carpi radialis brevis (ECRB) are primary extensors of the wrist while the extensor indicis (EI) and extensor digitorum communis (EDC) play a prime role in finger extension. All these extensor muscles have a common origin from the lateral condyle of humerus and are supplied by posterior interosseous branch of radial nerve.

The palmar aspect of the hand comprises of the thenar and the complimentary hypothenar muscles. The thenar muscles are short muscles that guide the movements of the thumb (Fig. 4.8). There are four thenar muscles, namely flexor pollicis brevis (FPB), adductor pollicis, abductor

pollicis brevis and opponens pollicis (no extensor pollicis as it is an extensor compartment muscle). Just like all flexors, all thenar muscles are also supplied by median nerve except one and a half muscles (deep head of FPB and adductor pollicis), that are supplied by the ulnar nerve.

The peripheral nerves that supply the skin and musculature of the upper limb arise from the brachial plexus. The plexus finally ends as three cords: lateral, middle and posterior. The cords are named so because of their relation to the axillary artery in the axilla and the upper arm. The medial cord continues as the ulnar nerve, the posterior as the radial nerve and the lateral cord is joined by a twig from medial cord to continue as the median nerve.

ULNAR NERVE INJURY (C8-T1) (MUSICIAN'S NERVE)

Course (Fig. 4.9)

Arm

Ulnar nerve is a continuation of the medial cord of brachial plexus. Hence, in the upper arm, it lies medial to the axillary artery. At the junction of middle and distal thirds of humerus, just distal to the insertion of coracobrachialis, the ulnar nerve pierces the medial intermuscular septum to enter the posterior compartment. At the elbow, the nerve lies behind the medial epicondyle, almost superficially palpable in a bony tunnel called the cubital tunnel.

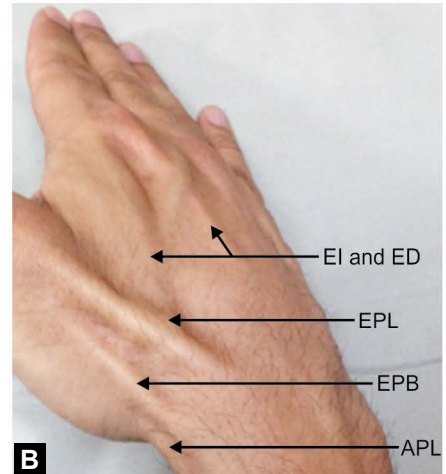
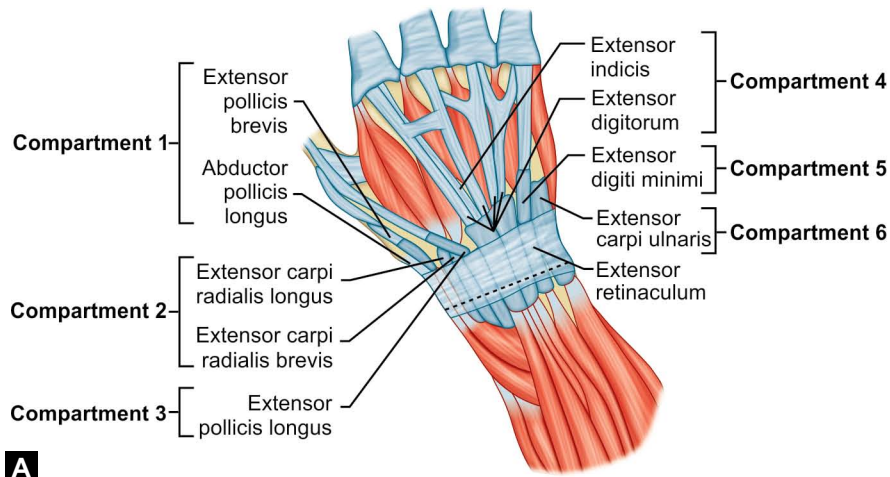
Forearm

It is a general dictum in anatomy that every nerve when it enters the forearm, it enters between two heads of a muscle. The ulnar nerve enters the forearm passing between the two heads of FCU. From here, the nerve travels under the FCU, accompanied by the ulnar artery (the neurovascular bundles generally travel together), to lie at the wrist just underneath the fleshy tendon of this muscle. Before entering the hand the nerve gives two sensory branches for the hand- the palmar cutaneous branch (supplies the hypothenar eminence) and the dorsal cutaneous branch (supplies the medial dorsum of hand and the proximal parts of dorsum of 2 and a 1/2 digits).

Hand

The ulnar nerve enters the hand by passing superficial to flexor retinaculum lying between the pisiform bone medially and the ulnar vessels laterally.

The FCU tendon that was overlying the ulnar nerve in forearm also enters the hand. Although the tendon is inserted into pisiform which is a sesamoid in the tendon, the true insertion of FCU is the hook of hamate, the terminal part being called as the pisohamate ligament. The ulnar nerve courses under this pisohamate ligament (an area called as Guyon's canal). Here the nerve divides



Figs. 4.7A and B: Extensor compartment of wrist.

Extrinsic thumb muscles

- Abductor pollicis longus
- Extensor pollicis brevis
- Extensor pollicis longus
- Flexor pollicis longus

Thenar eminence

- Adductor pollicis (transverse)
- Adductor pollicis (oblique)
- Flexor pollicis brevis
- Abductor pollicis brevis
- Opponens pollicis

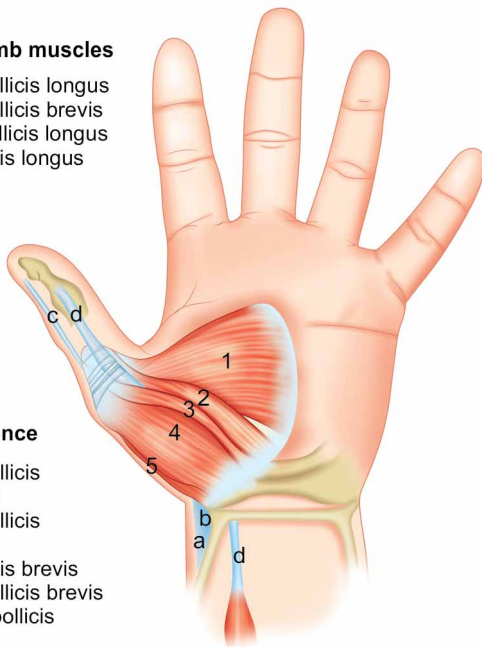


Fig. 4.8: Thenar muscles.

into superficial terminal branch which is primarily a sensory branch (Palmaris brevis in only muscle supplied) and supplies the skin of medial one and a half digits with their nail beds. The deep branch is primarily motor and ends by supplying muscles of the hand.

Muscles Innervated (Fig. 4.9)

Arm

No muscle is supplied by the ulnar nerve in arm.

Forearm

Since the nerve enters the forearm between two heads of FCU, it is the first muscle to be supplied. Now, all flexors of forearm are supplied by median nerve except one and a

half flexors supplied by ulnar nerve—the one flexor is FCU, the half flexor is medial half of the FDP.

Hand

Deep branch supplies three hypothenar muscles—the abductor digiti minimi, flexor digiti minimi, and opponens digiti minimi (palmaris brevis the fourth hypothenar muscle is supplied by the superficial branch).

Amongst the thenar muscles, it again supplies one and a half muscles—the adductor pollicis and deep head of FPB.

It innervates all the interossei muscles. The interossei bring about adduction and abduction of the fingers (PAD, palmar interossei are adductors and DAB, dorsal interossei are abductors) and hence this movement is brought about by the ulnar nerve. One can well imagine the importance of adduction and abduction of fingers for playing a piano and thereby the use of the term musician's nerve.

Lumbricals originate from the tendons of FDP only, so just like FDP, they have a dual nerve supply. So, only the medial two lumbricals get supplied by ulnar nerve.

Important Sites of Compression

Arm

Arcade of Struthers (the arcade is a thin aponeurotic band lying approximately 8 cm above medial epicondyle, extending from medial head of triceps to the medial intermuscular septum) may be a compression site in cases where a transposition of ulnar nerve has been done as a surgical treatment (not a site in ordinary cases).

Elbow

Behind medial epicondyle: Cubitus valgus deformity (tardy ulnar nerve palsy) or compression in the cubital tunnel (most common site) when the nerve passes between two heads of FCU.

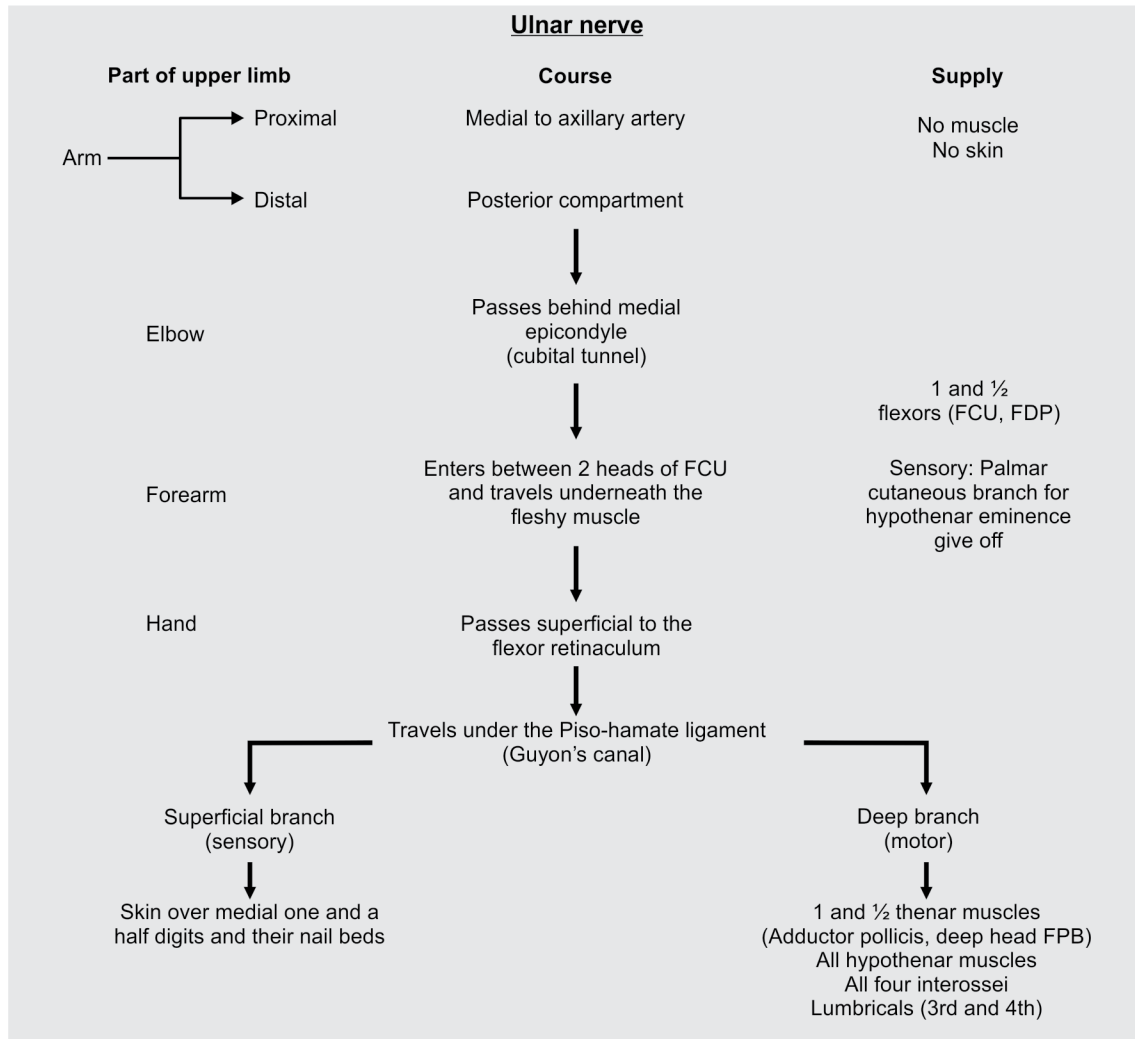


Fig. 4.9: Ulnar nerve course and distribution.

Hand

Guyon's canal (area under the PISO-hamate ligament).

Clinical Testing

Forearm

Flexor carpi ulnaris: The muscle is tested by asking the patient to flex the wrist. If the FCU is paralyzed, the wrist deviates toward radial side (Fig. 4.10) due to pull by FCR (supplied by median nerve).

Flexor digitorum profundus (medial half): This is the sole flexor of the DIP joints and is tested by asking the patient to make a fist. While all fingers close, the DIP joints of the medial two digits remain extended (Fig. 4.11).

Hand

In chronic cases there may be atrophy of the hypothenar eminence and hollowing of intermetatarsal spaces due to atrophy of the interossei.



Fig. 4.10: Testing for flexor carpi ulnaris.

Adductor pollicis: The muscle is tested by the book test. The patient is asked to hold a book by the side of thumb and medial border of palm by just adducting the thumb.



Fig. 4.11: Testing for flexor digitorum profundus of medial two digits.

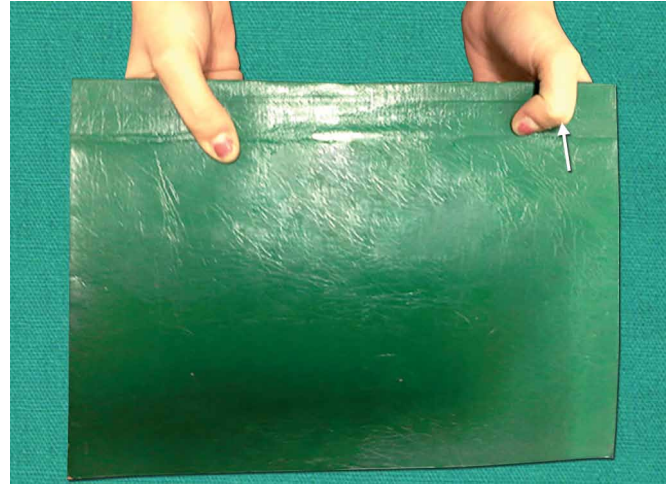
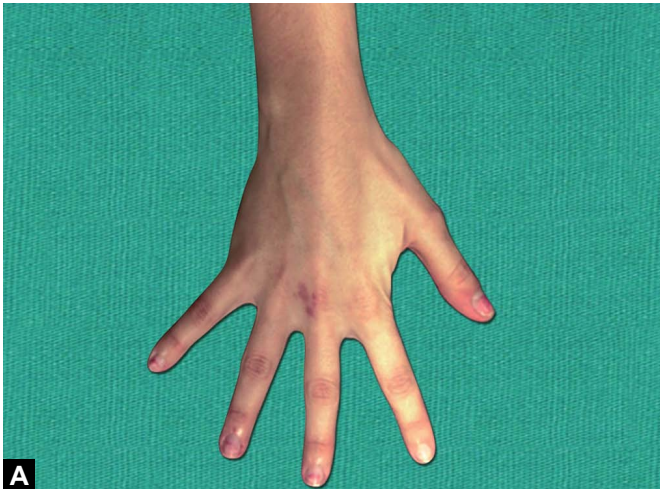


Fig. 4.12: Book test [On left side due to adductor pollicis palsy patients holds the book by flexing the IP joint of hand (arrow)].



A



B

Figs. 4.13A and B: Egawa's test and card test.

When this muscle is paralyzed, the patient holds the book by flexing the thumb at the interphalangeal joint, due to action of FPL (which is supplied by median nerve). The test is called book test and the sign is called Froment's sign (Fig. 4.12).

Interossei: Both dorsal and palmar interossei are tested. Dorsal interossei are abductors of fingers and are tested by the Egawa's test (Fig. 4.13A). The patient is asked to place his hand on the table and fan all the fingers. The Palmar interossei are adductors of fingers and are tested by the card test (Fig. 4.13B). The patient is asked to hold a card by adducting the fingers while the examiner tries to pull the card away.

Lumbricals: The function of the lumbricals is flexion of the metacarpophalangeal (MCP) joints and extension of the IP joints [or simply they make an "L" shape of the hand]. When the lumbricals are paralyzed, the opposite group of muscles will overact with resultant hyperextension at MCP joints and flexion at IP joints, with the end result being

claw hand (Fig. 4.14). Since only medial two lumbricals are supplied by ulnar nerve, there will be a partial clawing of the hand.

Sensory testing: The autonomous zone of ulnar nerve includes tip of little finger (see Fig. 4.3).

High versus Low Palsy

In high ulnar nerve palsy, the injury will be above the elbow and thus all muscles supplied by the nerve would be paralyzed. However if the injury site is distal to the elbow as in a low palsy, the FCU will be spared.

Ulnar Paradox

Going by common sense, one would expect that high palsy is associated with greater paralysis and hence should have more clawing while the reverse should be expected in low palsy. However, what is seen is absolutely opposite. Low

lesions have greater paralysis than high lesions. This is due to preserved long finger flexor function in low ulnar nerve palsy, as when the injury is distal to elbow many a times the FDP gets spared and causes exaggerated flexion of DIPs, accentuating clawing.

MEDIAN NERVE INJURY (C5-8, T1)
(LABORER’S NERVE)

Course (Fig. 4.15)

It is formed by joining of medial and lateral (main contribution) cords of brachial plexus.

Arm

In the upper arm, it runs around the lateral side of the axillary/brachial artery till middle of arm where it crosses medial to the artery just distal to coracobrachialis insertion, lying in the anterior compartment. Thereafter, the

nerve runs along the medial side of the brachial artery occupying the cubital fossa at the elbow. The nerve enters the forearm passing between two heads of PT.

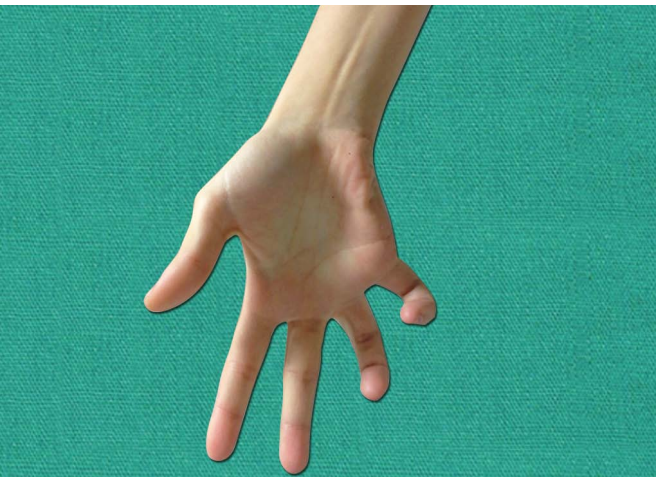


Fig. 4.14: Clawing of medial two digits in ulnar nerve palsy.

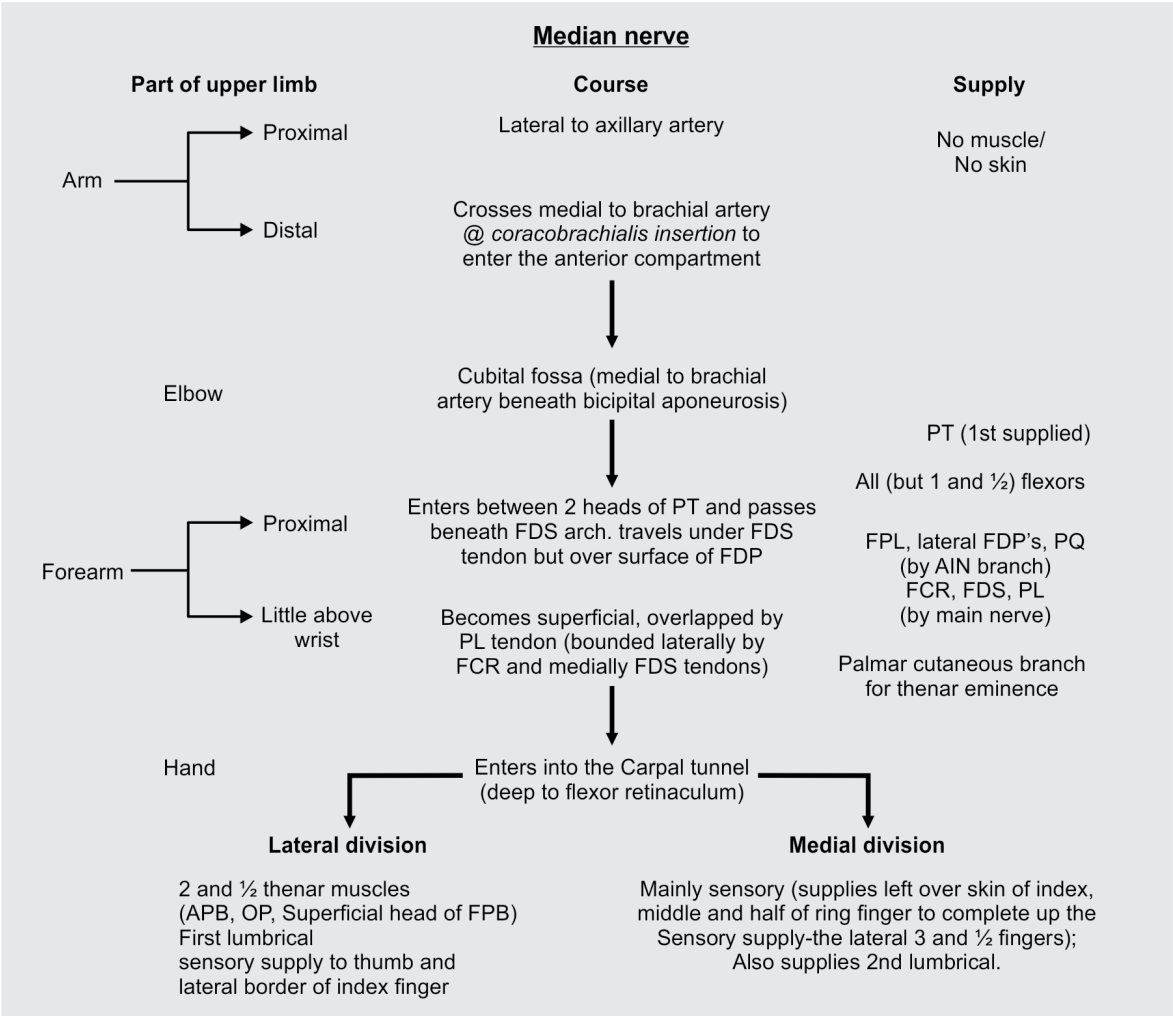


Fig. 4.15: Median nerve course and distribution.

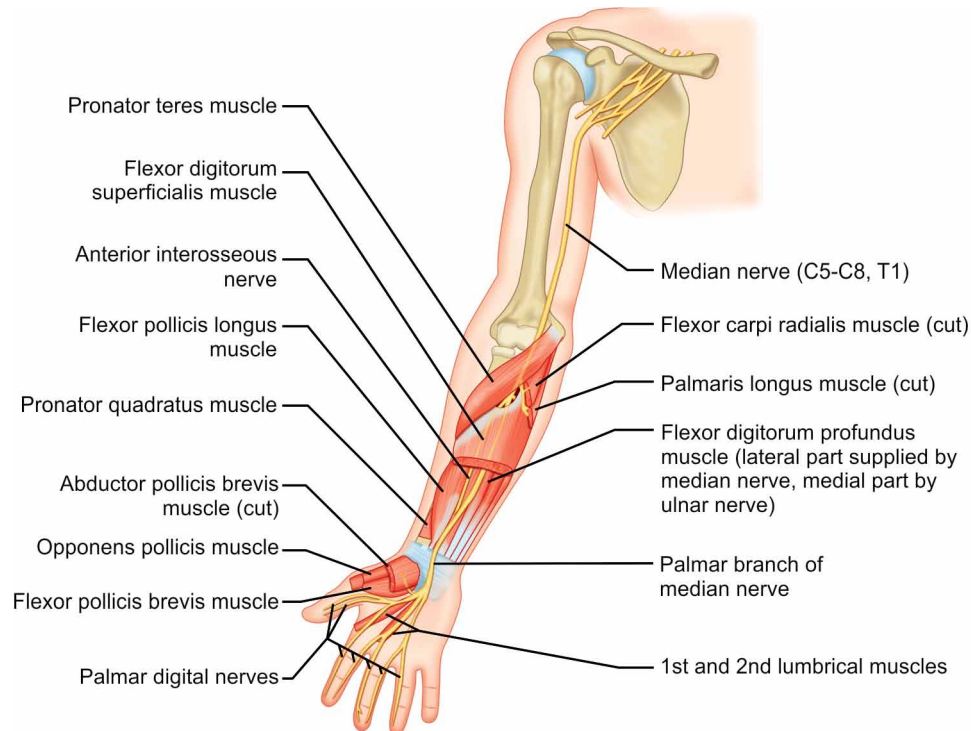


Fig. 4.16: Median nerve in forearm.

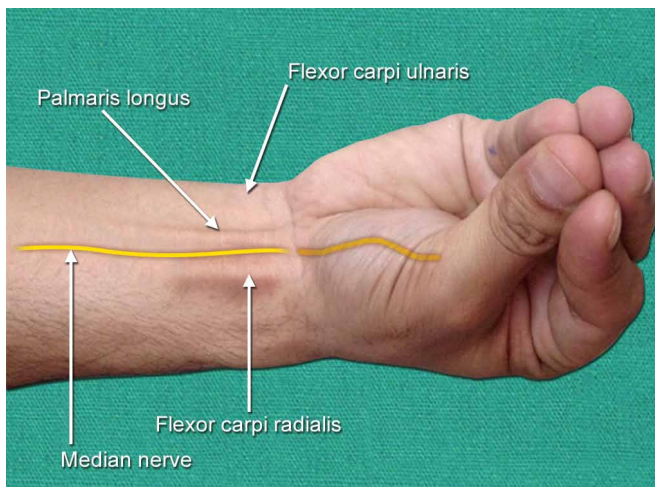


Fig. 4.17: Median nerve at wrist.

Forearm

Just on entering the forearm, it passes under the fibrous arch of the FDS. It travels in the forearm (giving anterior interosseous branch in proximal forearm) lying deep to FDS and over the surface of FDP, to reach near the wrist (Fig. 4.16). About 5 cm proximal to the flexor retinaculum (wrist), the nerve comes toward the lateral side of FDS tendons, becomes a bit superficial and can be traced between the tendons of FCR (lying laterally) and FDS (lying medially) with tendon of PL almost overlapping the nerve (Fig. 4.17). Just before entering the hand (a short distance above flexor retinaculum) the nerve gives the

palmar cutaneous branch that supplies the skin over the thenar eminence.

Hand

The nerve enters the hand deep to the flexor retinaculum (area called as the Carpal tunnel). Immediately below the retinaculum the nerve divides into lateral (stouter branch) and medial divisions. The lateral division primarily supplies the two and a half thenar muscles and first lumbrical (sensory supply is only to thumb and lateral border of index finger) while the medial division is primarily sensory (supplies the left over index, middle and half of ring finger to complete up the sensory supply—the lateral three and a half fingers; it also supplies 2nd lumbrical).

Muscles Innervated (Fig. 4.15)

Arm

No muscle in the arm is supplied by median nerve.

Forearm

The nerve passes between two heads of PT and thus it is the first muscle to be supplied. Then it supplies all (but one and a half) flexors of the forearm. These include the superficial flexors, viz. PL, FCR and the intermediate group, viz. FDS and the deep flexors (more specifically, these are supplied by the anterior interosseous branch given off in the proximal forearm), viz. FPL, pronator quadratus and the lateral two tendons of FDP.



Fig. 4.18: Testing for flexor carpi radialis.

Hand

The lateral division supplies all (but one and a half) thenar muscles, viz. FPB (superficial head), abductor pollicis and opponens pollicis. The lateral two lumbricals are the only other muscle group in hand supplied by the median nerve (first lumbrical by lateral and second by medial division).

Important Sites of Compression

Distal Arm

Supracondylar humerus fracture is an important cause of median nerve injury.

Proximal Forearm

The nerve may be compressed as it passes between two heads of PT (pronator syndrome). The anterior interosseous branch (AIN) may be compressed by the deep head of pronator teres, edge of laceratus fibrosus or by the tendinous FDS arch (see AIN syndrome/Kiloh Nevin syndrome below).

Wrist (Most Common Site)

Compression may be there in the carpal tunnel (see carpal tunnel syndrome), fracture of distal end radius, lunate dislocations.

Clinical Testing

Forearm

Flexor carpi radialis: Ask the patient to flex the wrist. The wrist deviates to ulnar side (Fig. 4.18) if the FCR is paralyzed (due to unopposed action of the FCU supplied by the ulnar nerve).

Flexor pollicis longus: This muscle is inserted onto the base of distal phalanx of thumb and is the sole flexor of the IP joint of thumb (FPB inserts at base of proximal phalanx

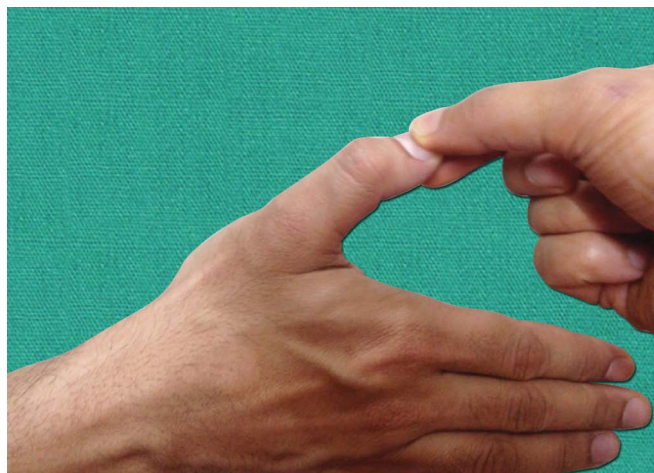


Fig. 4.19: Testing for IP joint flexion thumb.

and flexes MCP joint of thumb). So, FPL is tested by checking flexion of the thumb IP joint (Fig. 4.19).

Flexor digitorum superficialis and lateral FDPs: These are tested together by eliciting the pointing sign. When a patient with median nerve palsy is asked to close the hand and make a fist, he closes the ring and little fingers as these fingers have intact FDPs (supplied by ulnar nerve). The middle finger also partially closes (as all FDPs are partially interlinked) but the index finger remains open and gives the pointing sign (Fig. 4.20A). The other ways of eliciting this test are the benediction/Pope's hand or the Osner's clasping sign (Fig. 4.20B).

Hand

Abductor pollicis brevis: Can be tested by the pen test (Fig. 4.21). The patient places his hand flat on the table. Examiner brings a pen in front of the palm and the patient is instructed to abduct the thumb and touch the pen with the tip of the thumb. However, the other way of identifying paralysis of this muscle is by looking at the attitude of the thumb. If abductor pollicis is paralyzed, then thumb will go into adduction (by overaction of adductor pollicis, supplied by ulnar nerve) and hence the patient will land up with ape thumb deformity (thumb in the same plane as the palm).

Opponens pollicis: Tested by asking the patient to touch the little finger with the pulp of the thumb by swinging the thumb across the palm (Fig. 4.22).

Lumbricals: Ideally, the paralysis of the lateral two lumbricals should cause clawing of the lateral two digits. However, due to complex cross connections between the lumbricals (just like the FDPs), clawing gets masked in isolated median nerve palsy. Clawing gets manifested either in ulnar nerve palsy where only the medial two digits show clawing or in combined median and ulnar nerve injuries where all the four digits show clawing.

Sensory testing: Tips of index and middle finger form the autonomous zone (see Fig. 4.3).



Figs. 4.20A and B: Pointing sign or Osner's clasp sign.

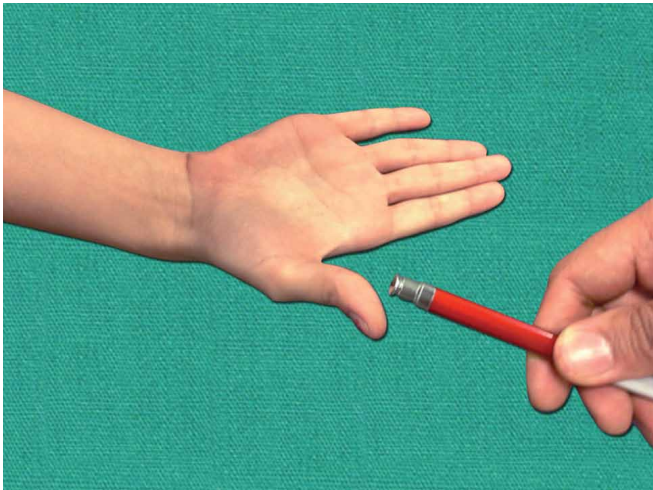


Fig. 4.21: Pen test.

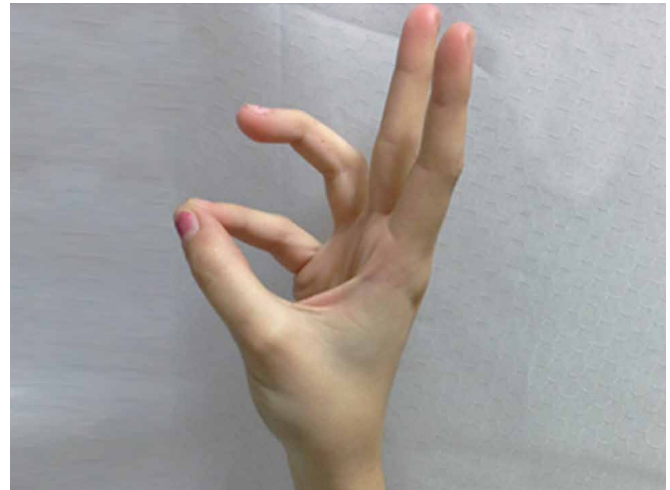


Fig. 4.22: Testing for opponens pollicis.

High versus Low Palsy

Median nerve injuries are classified as “high” or “low,” specifically depending on whether the lesion is proximal or distal to the origin of the anterior interosseous nerve in the proximal forearm but grossly that simulates with the lesion being proximal or distal to the elbow as with the ulnar nerve. In high lesions, all muscles supplied by the nerve would be paralyzed, but in low lesions classically only the hand function is affected.

RADIAL NERVE PALSY (C5-8, T1)

Course (Fig. 4.23)

The radial nerve is the largest branch the posterior cord and is primarily its continuation.

Arm (Fig. 4.24)

In the upper arm, it lies posterior to the artery and travels into the lower triangular space. Then the nerve enters into the radial groove on the posterior aspect of humerus, traveling between medial and lateral heads of triceps. Here, it crosses from medial to lateral aspect. At the junction of middle and distal third of humerus (bit distal to coracobrachialis insertion) the nerve pierces the lateral intermuscular septum to enter the anterior compartment. At the elbow, it is sandwiched between two muscles (c.f. other nerves that pass between two heads of same muscles) the brachialis on medial side and brachioradialis (BR) and extensor carpi radialis longus (ECRL) on lateral side. In front of the lateral epicondyle of humerus (c.f. ulnar nerve is behind medial epicondyle) the nerve

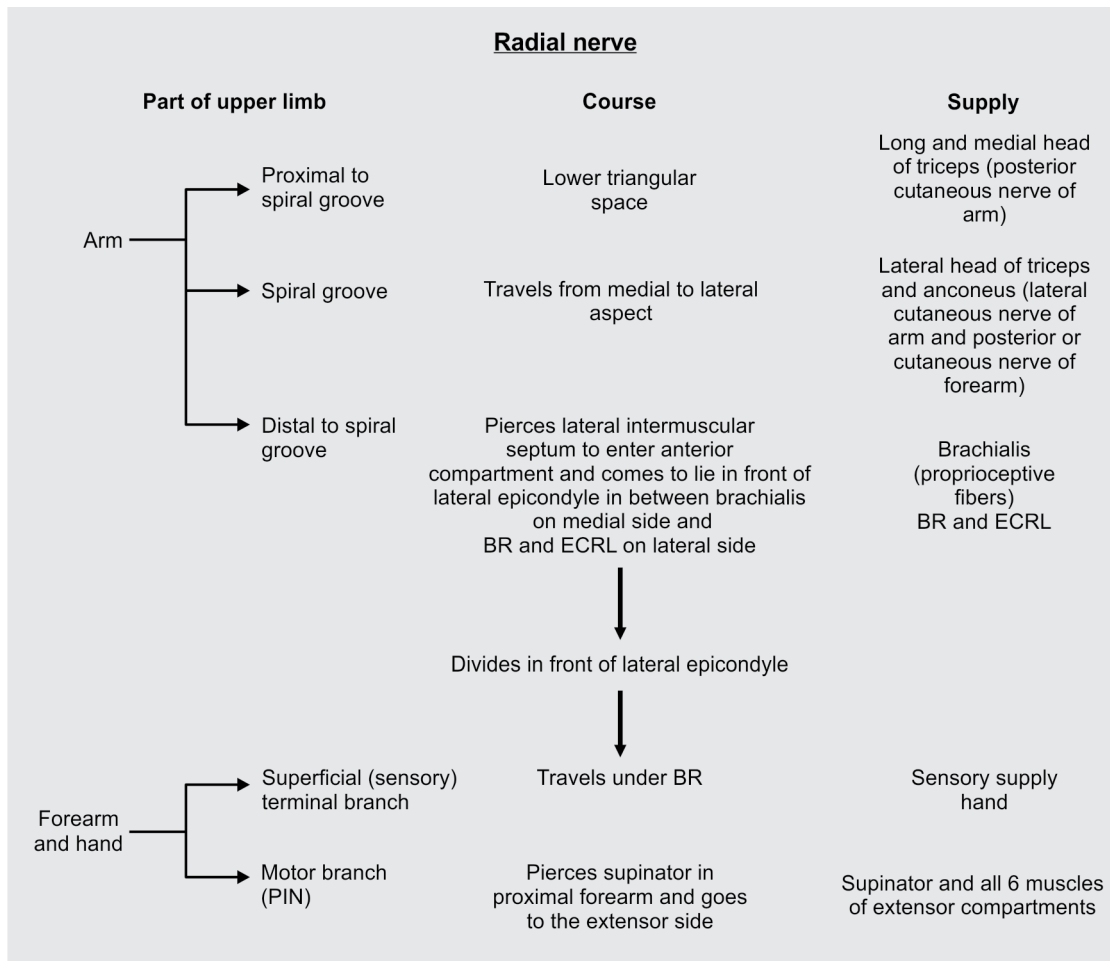


Fig. 4.23: Radial nerve course and distribution.

divides into a superficial sensory branch and a deep motor branch, the posterior interosseous nerve (PIN).

Forearm

The sensory branch travels alongside the radial artery, going underneath the brachioradialis and gives sensory supply to lateral part of dorsal aspect of hand and dorsal aspect of lateral two and a half fingers (see Fig. 4.3). The PIN is a pure motor nerve. It pierces the supinator in the proximal forearm and comes to lie on the extensor side of forearm (about 8 cm below the elbow joint). Here, it travels a very short distance before dividing into terminal branches that supply all the six extensor compartments of the forearm (PIN itself is part of fourth extensor compartment).

Muscles Innervated (Fig. 4.23)

Arm

Before spiral groove: Triceps (long and medial head)

In the spiral groove: Lateral heads of triceps, anconeus

Below the spiral groove: Brachialis (only sensory supply, motor supply is from Musculocutaneous nerve), BR and ECRL

Forearm

The PIN supplies supinator and all six extensor compartment muscles on the dorsal aspect of forearm, viz. abductor pollicis longus (APL), extensor pollicis brevis (EPB), extensor carpi radialis brevis (ECRB), extensor indicis proprius (EIP), EDC, extensor digiti minimi (EDM) and extensor carpi ulnaris (ECU).

Sensory Supply

Posterior cutaneous nerve of the arm (given off above spiral groove), the lateral cutaneous nerve of arm and posterior cutaneous nerve of forearm (given in the spiral groove). The autonomous zone of the radial nerve is the dorsal aspect of the first web space, through the superficial terminal branch (see Fig. 4.3).

Important Sites of Compression

Common sites of compression of radial nerve include:

Arm (most common site): Compression high up in axilla above the spiral groove by an axillary crutch (crutch palsy), in the spiral groove (Saturday night palsy) or in or below the

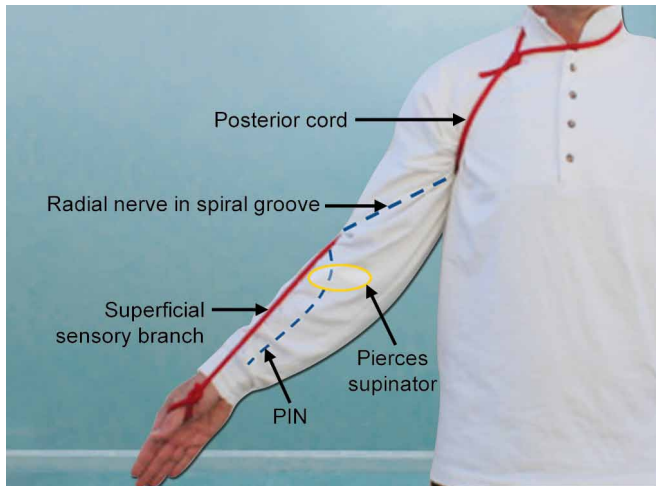


Fig. 4.24: Diagrammatic representation of radial nerve course in arm and forearm.



Fig. 4.25: Testing for triceps.



Fig. 4.26: Testing for brachioradialis.

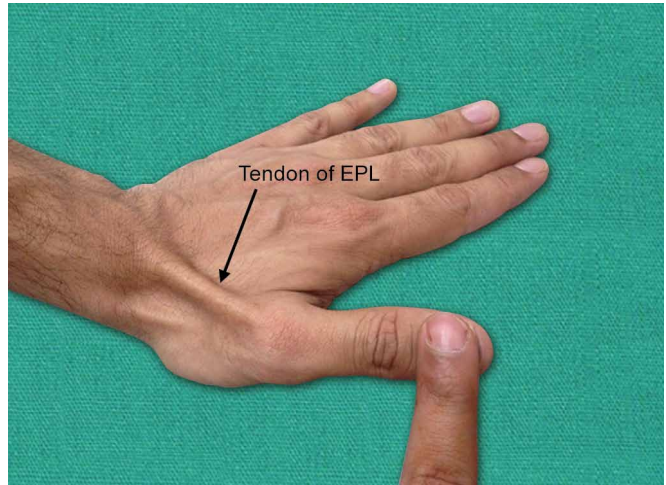


Fig. 4.27: Testing for Extensor pollicis longus.

groove as in injury during fractures of the shaft humerus (most common cause) and elbow region and intramuscular injections of the arm.

Forearm: PIN can be injured either in fracture dislocations in the area (e.g. Monteggia fractures) or by compression from various structures in the vicinity (see Radial tunnel syndrome).

Clinical Testing

Arm

Triceps: Patient is asked to extend the elbow against gravity as in lifting the hand off the head (Fig. 4.25).

Brachioradialis: This muscle arises from the lateral aspect of supracondylar region of humerus and inserts laterally over the radial styloid. It is tested by asking the patient to flex the forearm in mid-prone position against resistance. The muscle stands out in the proximal forearm when this is being done (Fig. 4.26).

Extensor pollicis longus (EPL): It can be tested by asking the patient to extend the IP joint of the thumb (Fig. 4.27).

Extensor carpi radialis longus and all wrist extensors: They are checked together by observing the attitude of the limb. Paralysis of all wrist extensors leads to wrist drop (Fig. 4.28).

Caution: In case the injury involves PIN branch of radial nerve, then wrist drop is not a dependable sign. In many patients wrist can still be extended as their ECRL is intact (supplied high up in the arm directly by radial nerve when it lies sandwiched between brachialis medially and brachioradialis and ECRL laterally). In such cases, better is to look for a “finger drop”, which is a more specific sign. PIN supplies EDC, and if EDC gets paralyzed, then finger extension at the MCP joints is not possible, rather the knuckles are flexed due to the action of lumbricals (supplied by median and ulnar nerves). However, these same lumbricals can extend IP joints of fingers and thus it is finger drop at MCP joints that is specific for PIN palsy and one must not get mis-lead by extension of fingers at IP joint.

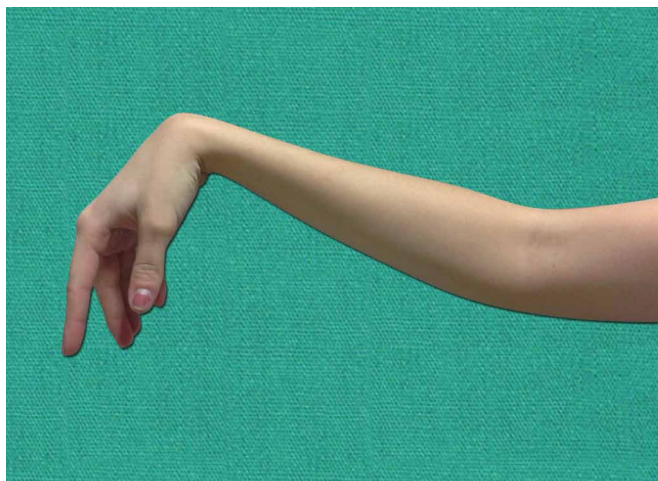


Fig. 4.28: Wrist drop after radial nerve palsy.

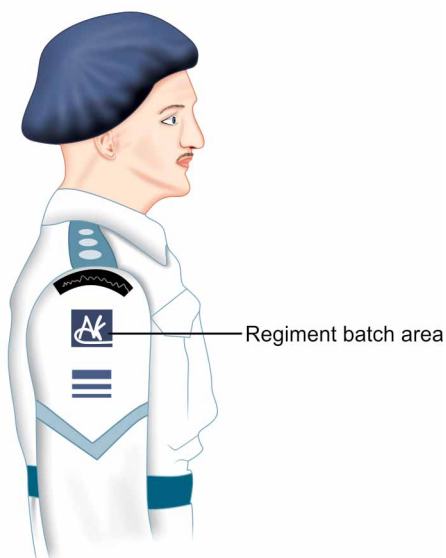


Fig. 4.30: Diagrammatic depiction of regiment badge sign.

High versus Low Paralysis

Paralysis of the radial nerve is generally classified as very high when it is injured above the spiral groove paralyzing all the muscles. An injury at or distal to the spiral groove but above the elbow is designated as high palsy and triceps is the first muscle to be spared which differentiates the very high and high lesions. The low lesions involve injury of the PIN mostly below the elbow and in these injuries testing for intact brachioradialis is used as a distinguishing factor. Also since it is entirely a motor nerve, the sensations in the autonomous zone are intact.

AXILLARY NERVE PALSYP (C5–6)

Course

It is a branch of the posterior cord of the brachial plexus. It winds around the neck of humerus (around 4–5 cm

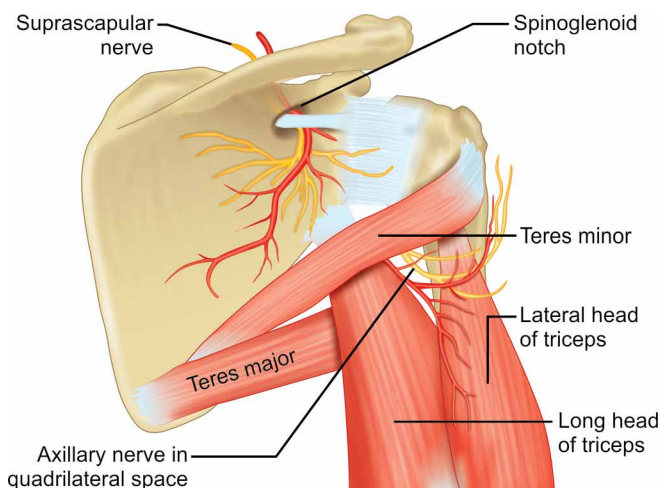


Fig. 4.29: Axillary nerve in quadrangular space.

distal to acromion) to pass through the quadrangular space (Fig. 4.29) and supplies the deltoid and the teres minor muscle (nerve to teres minor bears a pseudoganglion). The nerve gives sensory innervation to lateral aspect of lower deltoid (regimental badge area).

Muscles innervated: Deltoid and teres minor

Sensory supply: Regimental badge area (lateral aspect of shoulder and upper arm).

Injury Sites

It is commonly injured in fractures of the surgical neck of humerus and shoulder dislocation. Other important causes are iatrogenic injury during lateral approach to shoulder and shoulder arthroscopy.

Most common site of injury is just proximal to quadrangular space.

Clinical Testing

Examination reveals loss of contour of affected shoulder and weakness of abduction from 15 to 90 degrees. Sensations are lost in the regimental badge area (regiment badge sign) (Fig. 4.30).

SUPRASCAPULAR NERVE PALSYP (C5–6)

Course (Fig. 4.29)

Arises from upper trunk of brachial plexus and lies in the posterior triangle of neck. Passing under the belly of omohyoid muscle, the nerve enters the suprascapular notch of scapula. The notch is bridged on top by the transverse scapular ligament. The nerve passes beneath the ligament and travels the suprascapular fossa where it supplies the supraspinatus. Then it arches around the lateral border of the spine of the scapula (area called spinoglenoid notch) to enter the infraspinatus fossa, where it sends a muscular branch to the infraspinatus muscle.

Muscles Innervated

- Supraspinatus (before entering the spinoglenoid notch)
- Infraspinatus (after crossing the spinoglenoid notch).

Sites of Injury

- *Posterior triangle of neck*: Penetrating trauma, cancer surgery
- *Suprascapular fossa*: Fractures of scapula involving suprascapular notch, entrapment in the notch due to thickened transverse scapular ligament and rarely anterior dislocation of shoulder
- *Spinoglenoid notch*: Commonly compressed by a space occupying lesion like a ganglion in the notch.

Clinical Presentation

If the nerve is compressed proximal to spinoglenoid notch (usually in the suprascapular fossa), both the supraspinatus and the infraspinatus show atrophy.

A compression in the spinoglenoid notch (distal to the suprascapular fossa) manifests only with atrophy of the infraspinatus.

LONG THORACIC NERVE PALSYP (C5–7) (NERVE OF BELL)

It arises from the ventral rami of C5–7 and descends behind the brachial plexus to supply the serratus anterior muscle. This muscle works in conjunction with the trapezius in aiding overhead abduction. This nerve is generally injured in traction injuries to the shoulder while few other causes may include exposure to cold, viral infections, and placing patients in the Trendelenburg position with shoulder braces that compress the supraclavicular areas.

Paralysis of the nerve makes it difficult for the patient to flex the arm above shoulder level. When these patients attempt forward pushing movements pressing hands against a wall, “winging” of the scapula occurs (Fig. 4.31) and its vertebral border and inferior angle become unduly prominent.

SPINAL ACCESSORY NERVE PALSYP

The spinal accessory nerve supplies the trapezius. It is susceptible to damage from penetrating injuries or during



Fig. 4.31: Winging of scapula.

operations such as lymph node biopsy or radical neck dissection that involve the posterior triangle of neck. The patient reports generalized weakness in the affected shoulder girdle and arm, inability to abduct the shoulder more than 90 degrees. On examination, one may find winging of the scapula, but it is bit different from classical winging. Here, the scapula rotates laterally such that the superior angle moves away from midline while the inferior angle moves toward midline. In such a position, the medial flare of scapula is accentuated when the arm is abducted but the same disappears when the arm is flexed forward (unlike classical winging seen in serratus anterior palsy).

MUSCULOCUTANEOUS NERVE PALSYP (C5–6)

The nerve is a branch of lateral cord of brachial plexus. It is mostly injured by penetrating injuries but seldom in anterior dislocation shoulder or fracture of humerus neck. The nerve supplies coracobrachialis (vestigial), brachialis and biceps brachii. This nerve palsy is generally overlooked as it hardly causes any problems. Sensory loss is ill-defined and even though biceps and brachialis are paralyzed, elbow can still be flexed by a strong brachioradialis.

PERIPHERAL NERVE INJURIES OF LOWER LIMB

RELEVANT ANATOMY (FIGS. 4.32A AND B)

Sciatic Nerve (L4–S3)

This is the main nerve of the lower limb and is a continuation of the sacral plexus. It is composed of two parts: the

outer common peroneal part that arises from dorsal divisions of anterior primary rami of L4–S3 and an inner tibial part that arises from ventral divisions of anterior primary rami of L4–S3. After arising from the plexus, the nerve exits out of the pelvis via the sciatic notch (passing below the piriformis) to enter the gluteal region. Here, it can be located at the midpoint between the greater trochanter

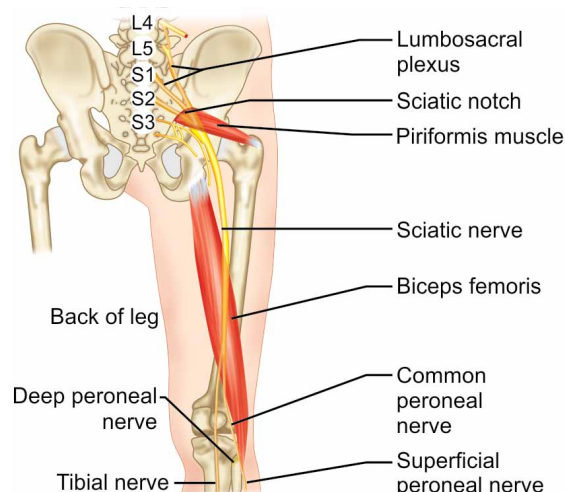


Fig. 4.32A: Course of sciatic nerve (diagrammatic representation).

and ischial tuberosity. It descends down under the gluteus maximus, crossing its lower border to enter the back of the thigh and finally terminates at the apex of popliteal fossa by dividing into the common peroneal (a.k.a. lateral popliteal) and tibial branches. The tibial part supplies the hamstrings, viz. semimembranosus, semitendinosus, long head of biceps and ischial head of adductor magnus. The common peroneal part supplies the short head of biceps femoris.

The *tibial nerve* descends at the back of the leg and supplies the calf muscle (soleus) and the plantar flexors of the foot [flexor digitorum longus (FDL), flexor hallucis longus (FHL), tibialis posterior (TP)]. Sensory supply covers the region of the back of the leg and the sole of the foot (latter is the autonomous zone). In the popliteal fossa, it gives off a sensory branch, the sural nerve (L5, S1-2) that descends between the two heads of gastrocnemius passing

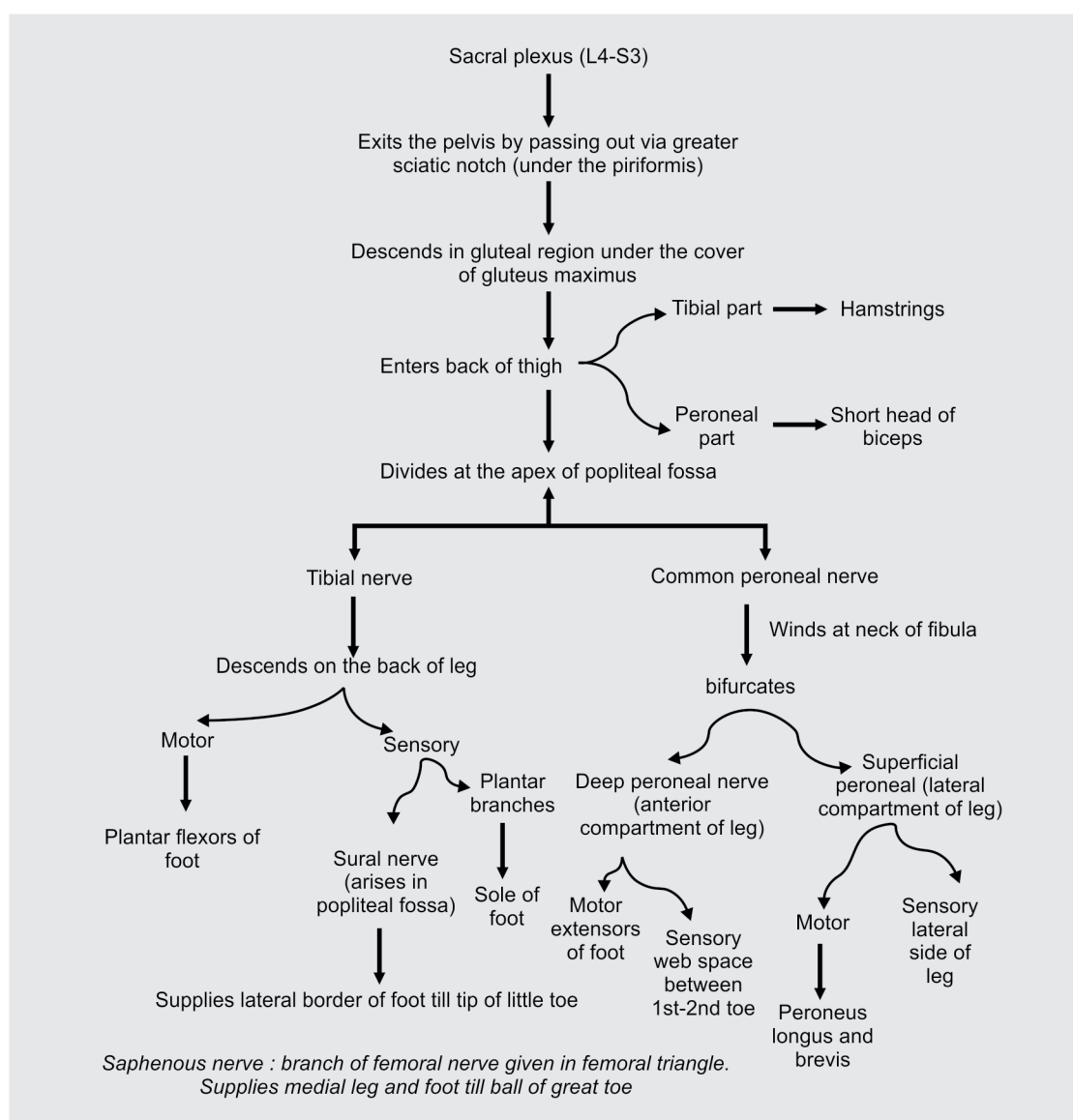


Fig. 4.32B: Sciatic nerve course and distribution.

across the lateral border of the foot to end at the tip of the little toe supplying the skin in these areas.

The *common peroneal nerve* (CPN) descends on the lateral aspect of lower thigh under the biceps femoris to wind around the neck of fibula. Soon thereafter, it divides into superficial peroneal and deep peroneal branches.

The *superficial peroneal* supplies the peroneus longus and brevis and terminates by supplying the skin over the lateral aspect of leg and majority of the dorsum of the foot.

The *deep peroneal nerve* (counterpart of PIN in forearm) pierces the anterior intermuscular septum, to enter the anterior compartment of leg. It is the main nerve of this extensor compartment of leg and foot and supplies the dorsiflexors of the foot [tibialis anterior, extensor digitorum longus (EDL), extensor digitorum brevis (EDB), extensor hallucis longus (EHL) and peroneus tertius]. It also gives sensory supply to the skin of the first web space between the first and second toes (autonomous zone).

Femoral Nerve (L2, L3, L4)

The main nerve on the front of the thigh is the femoral nerve. This is a relatively rarely injured nerve as it lies quite near to the femoral artery and the arterial injury takes precedence in these patients. The nerve travels across the femoral triangle lying 1–2 cm lateral to the femoral artery and supplies the quadriceps (Fig. 4.33). In the triangle, it gives a saphenous branch (L3–4) (arising from posterior division) that supplies the skin over the medial leg and medial foot till ball of great toe.

SCIATIC NERVE PALSY

Traumatic injury is the most common cause (gunshot/fracture dislocations) followed by iatrogenic injury due to intramuscular injections and surgery around hip. However, complete lesions of sciatic nerve are rare. Most lesions injure the common peroneal part as these are the outermost fibers. Moreover, CPN is relatively a fixed nerve as it winds around the neck of fibula and is hence more amenable to injury. CPN may also be injured in fracture dislocations around the knee, especially fibular neck fractures and knee dislocation, iatrogenic injuries by insertion of pins for skeletal traction, compression by tumors and leprosy are other rare causes of CPN palsy.

Clinical Testing

A complete lesion of sciatic nerve will lead to paralysis of both the dorsiflexors and plantar flexors of the foot. Majority of the sensations would be lost except the area supplied by saphenous nerve (medial aspect till ball of great toe) as the latter is a branch of femoral nerve.

Common peroneal nerve palsy manifests as paralysis of the dorsiflexors and evertors of the foot, thereby leading to a complete foot drop. The patient walks with the classical “high stepping gait”. The plantar flexors on examination are normal (as they are supplied by tibial nerve).

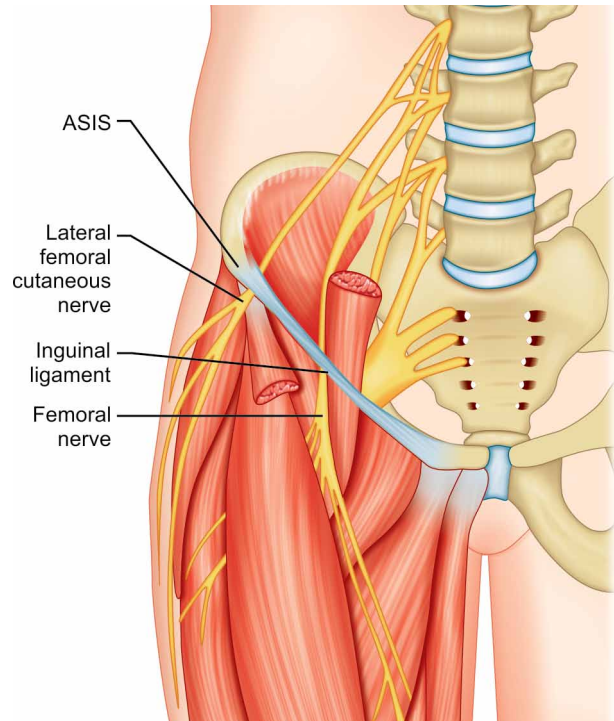


Fig. 4.33: Anatomy of femoral nerve.

At times only the *deep peroneal nerve* may be injured. It supplies the dorsiflexors of foot. Injury would lead to foot drop but since peronei escape (supplied by superficial peroneal) the drop is not complete as eversion masks the drop to some extent. One can detect good power in the peronei (evertors) in such cases and finding sensory loss in the autonomous zone (first web space), with intact sensation over lateral leg (from superficial peroneal) further strengthens the diagnosis.

In injuries of the *tibial nerve*, the plantar flexors are paralyzed and can be evaluated by asking the person to plantar flex the foot against resistance. Moreover, sensations on the sole of the foot may also be lost.

HIGH-YIELD POINTS

- Most common PNI is Radial nerve. Most common nerve injury in athletes is stingers (see page 220)
- Least common nerve involved in entrapment is femoral nerve.
- Most common cause of wrist drop is fracture shaft humerus causing Radial nerve palsy.
- Most common cause of neurological deficit in upper limb is Erb's palsy.
- Commonest cause of sciatic nerve injury is iatrogenic (total hip replacement that causes traction injury mostly). Other causes include gunshot injury (most common cause for complete division), hip dislocations, intramuscular gluteal injections and acute compression (coma, drug overdose, intensive care unit, prolonged sitting), etc.

- Most common nerve injury in total hip arthroplasty is sciatic nerve.
- Most common nerve injury involved in intramuscular injection injury is sciatic nerve > radial nerve.
- Post injection palsy is neurotmesis.

MANAGEMENT OF NERVE INJURIES

The first step for deciding the line of management in the patient presenting with nerve injury depends upon the presentation, whether the injury is open or closed (Fig. 4.34).

Open Laceration

In case there is an open laceration of the nerve, the wound is inspected, debrided and if clean, the nerve is directly repaired end to end with fine sutures under an operating microscope. This is called as primary repair (primary neurorrhaphy). However, at times the wound is dirty, contaminated and not fit for a primary closure. In such cases after

thorough debridement, the nerve ends are tagged. Patient comes for regular dressings and after around 2 weeks, once the tissue condition improves, the nerve is repaired and the wound closed (delayed primary repair).

Closed Injury

In cases where the nerve injury is closed, time is given to the nerve to heal and repair itself, as many cases may be only a neurapraxia of nerve. The patient is observed for a period of 6 weeks to 3 months to assess any signs of nerve recovery which may include a progressive Tinel's sign, motor march or sequential electrodiagnostic study (EDS) analysis indicating nerve regeneration.

If there is positive evidence of regeneration, conservative treatment is continued. But if there are no signs of recovery by 3 months or a maximum by 6 months, the patient is planned for a nerve exploration procedure. The nerve is explored and the further treatment decided by the results of exploration.

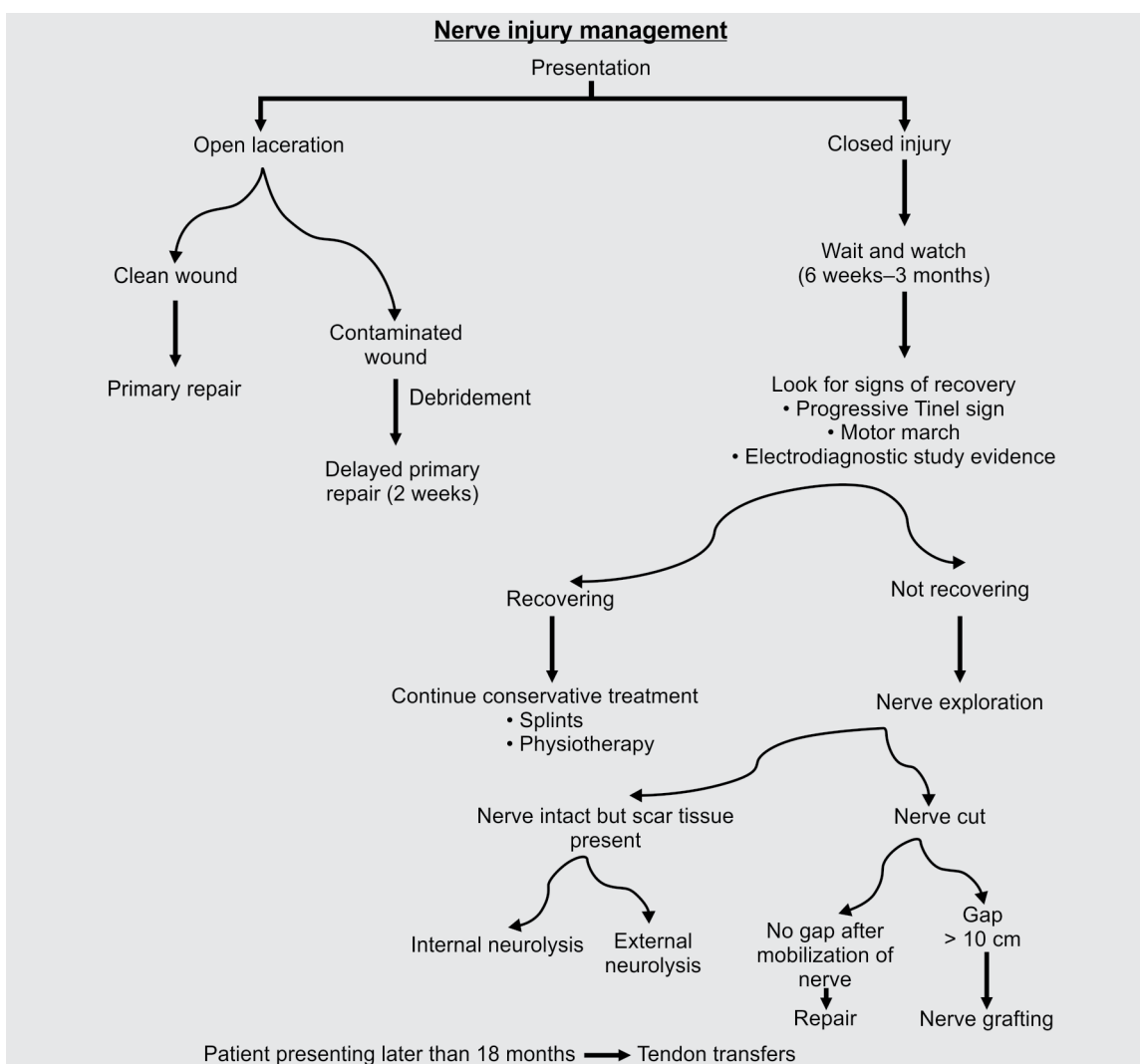


Fig. 4.34: Protocol for management of nerve injuries.

Two situations are possible on exploring the nerve:

1. *Nerve is found intact but engulfed in scar tissue, as would be the scenario in cases with partial cuts/axonotmesis:* In such cases, the appropriate management is neurolysis. This procedure involves relieving the nerve from the enveloping scar when it is called external neurolysis or splitting the nerve sheath and then longitudinally dissecting the nerve to relieve pressure from the fibrous tissue inside, called internal neurolysis.
2. *Nerve if found to be completely transacted:* In these cases, a nerve repair is planned (called secondary repair or secondary neurorrhaphy as it is being done after few weeks or months). If the two ends of the nerve can be brought together without any tension on the suture line, the nerve is repaired end to end. In cases where there is an anticipation of tension on the stitches, a nerve grafting procedure is generally opted for.

Important sites of harvesting nerve grafts include: Sural nerve (most common and largest donor graft of approximately 10 cm), superficial radial nerve, cutaneous nerve grafts.

However, before deciding to opt for nerve grafting, one must adequately mobilize the nerve trunk to ensure easy approximation of nerve ends. There are various methods of mobilizing a nerve which include mobilization of the nerve, positioning of the limbs, transposition, bone resection, nerve stretching and bulb suture, nerve grafting and nerve crossing.

Nerve repairs can have good results up to a year after injury. At times the patient may present even late. If the time since injury has been more than 18 months to 2 years, then repairing the nerve is generally of no use as the neuromuscular junctions have already degenerated by this time. The treatment under such circumstances is tendon transfers.

Tendon Transfers

These are reconstructive surgical procedures where the lost function of a denervated muscle/tendon is reconstructed by using an expendable/extra donor tendon.

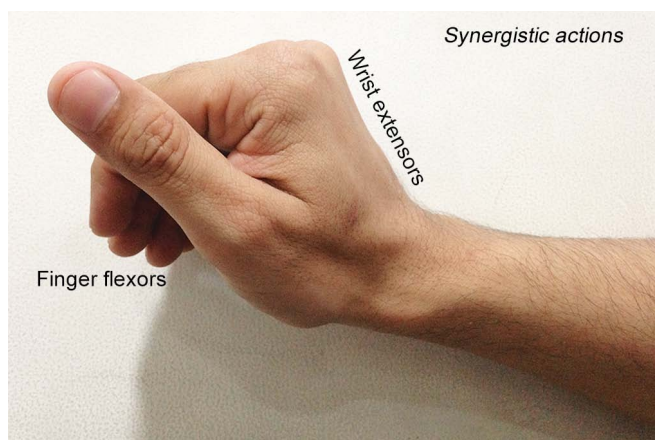


Fig. 4.35: Depiction of synergistic muscles.

Important principles of tendon transfers to decide appropriate donor include:

- The donor muscle should be expendable, powerful enough (more than grade 4 power) and be an agonist or synergist. Synergist muscles are those that simultaneously contract during single movement, e.g. in gripping an object, wrist dorsiflexes while fingers flex (Fig. 4.35). So, wrist dorsiflexors and finger flexors are synergistic muscles and can be used to replace each other.
- The recipient site must have supple and mobile joints
- The transferred tendon should be routed subcutaneously and placed in straight line of pull.
- The patient should be motivated and cooperative enough to attend physiotherapy and rehabilitation clinics.

Role of Conservative Treatment

While these patients are undergoing management suitable to the injury, splints are given throughout the time to prevent the development of deformities. The list of commonly prescribed splints is given in Table 4.1. Routine physiotherapy is advised to all patients to prevent contracture formation. Once the muscle function adequately recovers, the splints can be taken off and patients encouraged to return back to work.

Prognosis after Nerve Injuries

Following factors can predict the prognosis after nerve repair:

- *Age of patient:* Children tend to recover faster than adults.
- *Type of injury:* Neurapraxia recovers completely while neurotmesis does not recover unless repaired.
- *Time since injury:* More the time since injury, poorer are the results after repair.
- *Level of injury:* More distal the lesion, the earlier and better is the recovery.
- *Type of nerve:* Pure motor or sensory nerves recover better than mixed nerves. The best prognosis after nerve repair can be expected with the radial nerve (purely motor) > median nerve > ulnar nerve > peroneal while the worst is with the sciatic nerve.
- *Tissue equilibrium:* Infection, contaminated wounds, crush injuries all may alter the prognosis.

Table 4.1: Commonly used splints in nerve injuries.

Cock up splint	Radial nerve palsy
Knuckle bender splint	Ulnar nerve palsy
Turn buckle splint	Volkmann ischemic contracture
Aeroplane splint	Brachial plexus injury
Thumb abduction splint, opposition splint	Median nerve palsy
Ankle foot orthosis (foot drop splint)	Common peroneal nerve palsy

HIGH-YIELD POINTS

- Earliest indicator of nerve recovery is EMG.
- Recovery pattern of sensation after nerve injury- Pain, Temperature are first sensations to return as these are carried by small diameter A delta fibers and unmyelinated C fibers. Touch recovers next and vibration is last to recovers as these are carried by large A beta fibers.
- Peripheral nerves can propagate action potentials for up to 1 hour after complete ischemia and can survive with only neurapraxic damage for up to 4 hours. In the setting of complete ischemia, muscles remain electrically responsive for 3 hours and can tolerate up to 8 hours maximum before there is permanent damage to muscle.
- The most common site for taking nerve graft is sural nerve.
- The most common site for taking muscle graft is Palmaris Longus.
- Schaefer's Test: This test is for assessment of Palmaris Longus. Subject is asked to oppose the thumb to little finger and then flex the wrist which makes the tendon prominent.

NERVE ENTRAPMENT SYNDROMES (COMPRESSION NEUROPATHIES)

Few nerves have some part in their course when they have to travel in a confined space. In such areas, these nerves or their branches are highly susceptible to compression (Table 4.2). Some important compression neuropathies include:

Carpal Tunnel Syndrome

Definition

It is the compression neuropathy of the median nerve below the flexor retinaculum. It is the most common compression neuropathy.

Etiology

This entity is common in middle-aged females and is associated with rheumatoid arthritis, hypothyroidism (second commonest cause), pregnancy, acromegaly, diabetes, amyloidosis and hyperparathyroidism. However, the most common cause is idiopathic.

Clinical Features

The patient usually presents with pain, paresthesias in the wrist and hand and sensory motor weakness in the median nerve distribution. Pain characteristically occurs at night awakening the patient from bed and increases on activity.

Diagnosis

Examination reveals a positive Phalen's test (symptoms reproduced when wrist is kept in flexion; Fig. 4.36), Durkan's test (compression over the flexor retinaculum reproduces symptoms) and a positive Tinel's sign. Symptoms are reproduced when a tourniquet is applied and inflated. Positive hand diagram and Semmes-Weinstein monofilament testing are other tests of less practical utility. Durkan's test is best out of these.

Investigations

Diagnosis is usually confirmed by delay in conduction velocity on NCV. A distal motor latency of more than 4.5 ms and distal sensory latency of more than 3.5 ms is considered positive.

Treatment

Management involves treatment of the underlying condition. Nonsteroidal anti-inflammatory drugs (NSAIDs)

Table 4.2: Compression neuropathies.

Carpal tunnel syndrome	Median nerve at wrist
Pronator syndrome	Median nerve between two heads of pronator teres
Kiloh Nevin syndrome	AIN branch of Median nerve
Radial tunnel syndrome	PIN branch of radial nerve
Cubital tunnel syndrome	Ulnar nerve behind the medial epicondyle
Guyon's canal	Ulnar nerve at wrist below pisohamate ligament
Piriformis syndrome	Sciatic nerve compression
Meralgia paresthetica	Lateral cutaneous nerve of thigh (branch of femoral nerve)
Cheralgia paresthetica	Superficial sensory branch of radial nerve
Tarsal tunnel syndrome	Posterior tibial nerve
Morton's metatarsalgia	Interdigital nerve compression



Fig. 4.36: Phalen's test.

and steroid injections are useful in selected patients while nonresponders need surgical decompression of the nerve.

Cubital Tunnel Syndrome

Cubital tunnel syndrome involves compression of ulnar nerve in the cubital tunnel under Osborne's ligament. It is the 2nd most common compression neuropathy after carpal tunnel syndrome. Causes of ulnar nerve compression in cubital tunnel may be primary (idiopathic) or secondary (following trauma, arthritis, lipoma, ganglion, etc.)

Clinical Features

Patients present with forearm pain and numbness and paresthesia in of the 4th and 5th fingers. Examination may reveal typical features of ulnar nerve involvement (i.e. positive book test, card test, etc.). Atrophy of the intrinsic muscles of the hand and clawing is seen in long standing cases.

Management

Diagnosis is mainly clinical and can be confirmed by positive electro diagnostic studies. Mild cases with a recent history are observed with physiotherapy and nocturnal elbow splinting. In non-responding cases cubital tunnel decompression (either open or endoscopically assisted) is done.

Tarsal Tunnel Syndrome

It is analogous to carpal tunnel syndrome in the upper limb. The nerve involved is the tibial nerve at the flexor retinaculum or the lacinate ligament.

Etiology

It is usually idiopathic in nature but may occur in association with rheumatoid arthritis (most common cause), ankylosing spondylitis, ganglion or tumors encroaching the tarsal tunnel or in talar and calcaneal fractures.

Clinical Features

The patient presents with burning pain or paresthesias over plantar aspect of the foot more at night and on bearing weight.

Examination

Positive Tinel's sign is evident. Muscle weakness may not be severe and sensory signs predominate. Diagnosis is confirmed by increased difference of the conduction velocities between lateral and medial plantar nerves.

Management

Treatment by release of tarsal tunnel is not as satisfactory as carpal tunnel syndrome.

Radial Tunnel Syndrome

Radial tunnel is approximately 5 cm long space in front of elbow extending from the radio-capitellar joint to proximal margin of supinator. The term Radial tunnel syndrome (RTS) indicates compression of PIN in radial tunnel by fibrous-fascial bands coursing superficial to the radial head, the radial recurrent artery, the fibrous edge of the extensor carpi radialis brevis (ECRB), the proximal and distal edges of the supinator. The most common point of compression is the arcade of Fröhse (free aponeurotic proximal margin of supinator, in which case the condition is specifically designated as PIN syndrome).

Radial tunnel syndrome and posterior interosseous nerve (PIN) syndrome (supinator syndrome) both are cause of intractable lateral elbow pain and can present with similar symptoms. The clinical presentation includes pain 5 cm distal to the lateral epicondyle over the course of the radial nerve down the forearm. Typically patients have pain with resisted extension of the long finger with the elbow in extension, forearm in pronation and the wrist in neutral.

Both syndromes can be differentiated by the fact that patients with PIN syndrome have a loss of motor function whereas patients with RTS have only lateral forearm pain without motor involvement. The difference in clinical presentation may be due to differences in the degree of compression.

Nonsurgical treatment of radial tunnel syndrome includes rest, NSAID and steroid injection if associated with lateral epicondylitis. Surgical decompression provides excellent result in most of patients.

Anterior Interosseous Syndrome (Kiloh Nevin Syndrome)

It refers to compression of the AIN branch of Median nerve usually by the deep head of Pronator teres, FDS arch, edge of lacertus fibrosus or Gantzer's muscle (accessory head of FPL). Typically, these patients have only motor deficits) and they fail to make an 'O.K.' sign (Kiloh Nevin sign, Fig. 4.37), as flexion of the interphalangeal joint of the thumb (FPL) and

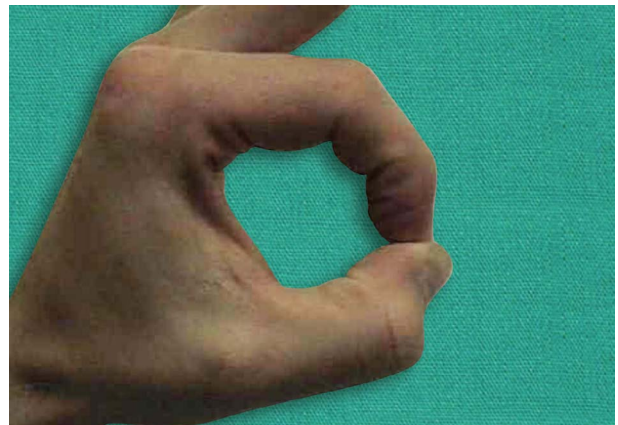


Fig. 4.37: Kiloh Nevin sign in AIN syndrome.

the distal interphalangeal joint of the index finger (FDP) is impaired. Parsonage-Turner syndrome is a variant where there are bilateral AIN signs caused by viral induced brachial plexus neuritis.

Nonsurgical treatment is same as above but surgical decompression may be needed in non-responding cases.

Morton's Neuroma/Morton's Metatarsalgia

It is a benign neuroma of an intermetatarsal plantar nerve, most commonly of the second and third intermetatarsal spaces. It presents with pain and numbness or paresthesias, particularly on weight bearing. On examination, one may find Mudler's click (a click on squeezing the two metatarsal heads). Ultrasound accurately demonstrates thickening of the interdigital nerve within the web space of greater than 3 mm, diagnostic of a Morton's neuroma. Biopsy reveals that the affected nerve is markedly distorted, with extensive concentric perineural fibrosis. Orthotics, steroid injections and neurectomy are methods of management. Radiofrequency and cryoablation is upcoming treatment modality.

Meralgia Paresthetica

This chronic neurological disorder involves entrapment or compression of the lateral cutaneous nerve of thigh where it passes between the iliac crest and the inguinal ligament near the attachment at the anterior superior iliac spine. Injury to the nerve can also occur after performing McRobert's maneuver for delivering a child. Pain on the lateral side of the thigh radiating to the groin or outer side of the knee is the usual presenting complaint in the adult. It may be associated with a burning sensation, tingling and numbness in the same area. EMG nerve conduction studies may help in the diagnosis. NSAIDs and heat therapy may help initially. Refractory cases respond to surgical decompression of the nerve.

HIGH-YIELD POINTS

Sunderland classification of nerve injuries

Sunderland's classification: In 1951, Sunderland expanded Seddon's classification to five degrees of PNI.

First degree (Class I): Same as Seddon's neurapraxia.

Second degree (Class II): Same as Seddon's axonotmesis.

Third degree (Class II): Sunderland's third degree is a nerve fiber interruption. In third-degree injury, there is a lesion of the endoneurium, but the epineurium and perineurium remain intact. Recovery from a third-degree injury is possible, but surgical intervention may be required.

Fourth degree (Class II): In fourth-degree injury, only the epineurium remains intact. In this case, surgical repair is required.

Fifth degree (Class III): Fifth-degree lesion is a complete transection of the nerve. Recovery is not possible without an appropriate surgical treatment.

Anomalous Connections between Median & Ulnar Nerves

- Martin-Gruber anastomoses can occur when branches of the median nerve cross over in the forearm and merge with the ulnar nerve to innervate portions of the ulnar supply in the hand.
- Riche-Cannieu anastomoses can occur when there is connection between recurrent branch of the median nerve and deep branch of the ulnar nerve of the hand.

Mobile wad of Henry: It consists of three forearm muscles—brachioradialis, extensor carpi radialis longus and brevis. It presents in dorsolateral aspect of forearm and is important landmark for surgical approaches in this area.

Wartenberg sign: Refers to the slightly greater abduction of the fifth digit, due to paralysis of the abducting palmar interosseous muscle and unopposed action of the radial innervated extensor muscles (digiti minimi, digitorum communis). This should not be confused with Wartenberg's syndrome which is also called cheiralgia paresthetica. It is a rare condition in which compression of the superficial branch of the radial nerve causes pain and paresthesiae on the radial side of the dorsum of the hand, and in the thumb.

Even though there is more clawing in low ulnar nerve palsy (ulnar paradox), the sensory loss in hand is same in both high and low palsies.

Double-crush phenomena: The double-crush syndrome was initially described by Upton and McComas in 1973. They postulated that nonsymptomatic impairment of axoplasmic flow at more than one site along a nerve might summate to cause a symptomatic neuropathy. The hypothesis was postulated to explain the frequent association of a proximal and distal nerve compression syndrome, including carpal tunnel syndrome associated with cervical radiculopathy, brachial plexus compression with diabetic neuropathy.

Causes of winging of scapula: Serratus anterior (true winging), trapezius paralysis and paralysis of rhomboides.

Vasa nervorum are small blood vessels that supply the peripheral nerves. Sciatic nerve vasa nervorum is a branch of inferior gluteal artery.

The growth potential of adult nervous system is limited. The lack of axonal growth after injury is due to several factors:

- Due to formation of glial scar (formed by astrocytes and acts as a physical barrier to growth)
- Intrinsic growth state of neuron
- Absence of neurotrophic growth factors
- Presence of myelin associated growth inhibitory molecules i.e. Myelin associated glycoproteins (MAG), Oligodendrocyte myelin glycoprotein (Omgp) and Nogo-A (an integral membrane protein predominantly expressed by oligodendrocytes).

Most common cause of carpal tunnel syndrome is idiopathic followed by hypothyroidism.

Most common combined nerve injury involves median and ulnar nerve.

BRACHIAL PLEXUS PALSY

The brachial plexus is formed by the union of the anterior rami of C5, C6, C7, C8 and T1. Just distal to the scalene muscles, the C5 and C6 roots unite to form the upper trunk, the C7 root continues alone to form the middle trunk, and the C8 and T1 roots unite to form the lower trunk. The three trunks formed proceed inferolaterally behind the clavicle, and each divides into anterior and posterior divisions. The three posterior divisions unite to form the posterior cord, the anterior divisions of the upper and middle trunks unite to form the lateral cord, and the anterior division of the lower trunk continues alone to form the medial cord. These three cords embrace the axillary artery in the relationships that their names imply. A diagrammatic description of the plexus and its branches is shown in Figure 4.38.

Common causes of injury to the brachial plexus include traction injuries to the nerves during birth (most common cause) or during an accident and rarely fractures and dislocations around the shoulder or penetrating injuries of the axilla.

Injuries of the plexus can be either preganglionic or postganglionic. Avulsion of the nerve root from the spinal cord is a preganglionic lesion, i.e. disruption proximal

to dorsal root ganglion. Rupture of a nerve root distal to ganglion or of a trunk or peripheral nerve is a postganglionic lesion. It is important to differentiate the two lesions (Table 4.3) as they have prognostic significance with preganglionic lesions seldom showing recovery.

Based upon the location of injury, the lesions can be classified into upper plexus injuries (almost 90% cases), lower plexus injuries and pan plexus lesions.

The upper plexus lesions tend to have a very good prognosis while the lower and pan plexus lesions have a poor prognosis.

Important features of the upper and lower plexus injuries are as follows:

UPPER PLEXUS INJURY (ERB'S PALSY)

It is the commonest plexus injury causing neurological deficit in the upper limb. The injury occurs due to undue traction to the plexus when the shoulder is pulled to one side and head bends on to the opposite side as may occur during a difficult delivery or at times during anesthesia. Rarely, the cause may be a direct blow to the shoulder.

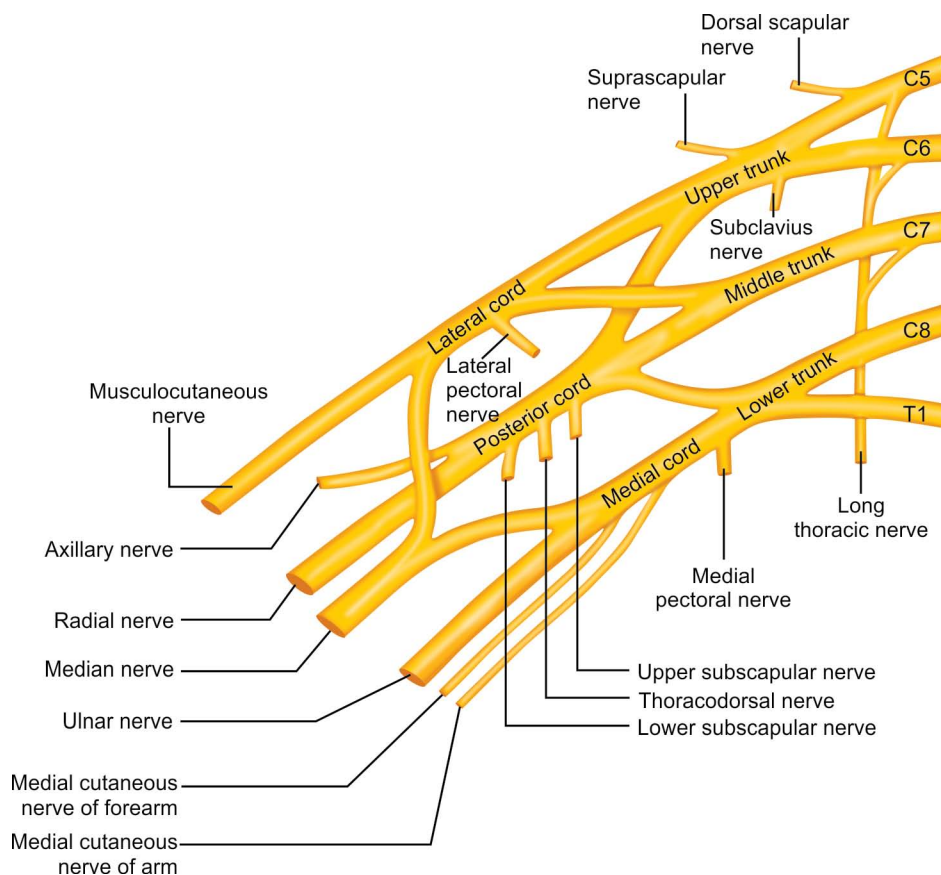


Fig. 4.38: Diagrammatic representation of brachial plexus.

Table 4.3: Preganglionic versus postganglionic lesions.

	<i>Preganglionic lesion</i>	<i>Postganglionic lesion</i>
Site	Proximal to the dorsal root ganglion (avulsion of root from cord)	Distal to dorsal root ganglion (disruption of peripheral nerve)
Histamin test	Intact (Put histamine on skin. There is cutaneous vasodilatation followed by wheal and then flare response.)	Flare response is absent.
MRI	Pseudomeningomyeloceles are produced due to root avulsion.	—
Nerve conduction study	Intact somatosensory conduction with absent somatosensory evoked potentials	—
Recovery	Poor	Potentially capable of recovering
Horner's syndrome	Present	Not seen

The lesion involves injury to upper trunk of brachial plexus (mainly C5 and partly C6) at the Erb's point which is meeting point for six nerves.

The nerves involved and the muscles thus paralyzed have been depicted below.

- Musculocutaneous: Biceps, brachialis, coracobrachialis
- Axillary: Deltoid, teres minor
- Nerve to subclavius: Subclavius
- Suprascapular nerve: Suprascapularis, infraspinatus

Clinical Presentation

These patients present with the characteristic policeman tip hand/porter's hand (Fig. 4.39). The arm is adducted and internally rotated, elbow is extended and forearm is pronated. The opposite movements are lost, i.e. there is loss of abduction and external rotation of arm, loss of flexion of elbow, loss of supination of forearm and loss of supinator and biceps reflexes. Sensations may be lost over the regimental badge area (lateral aspect of upper arm).

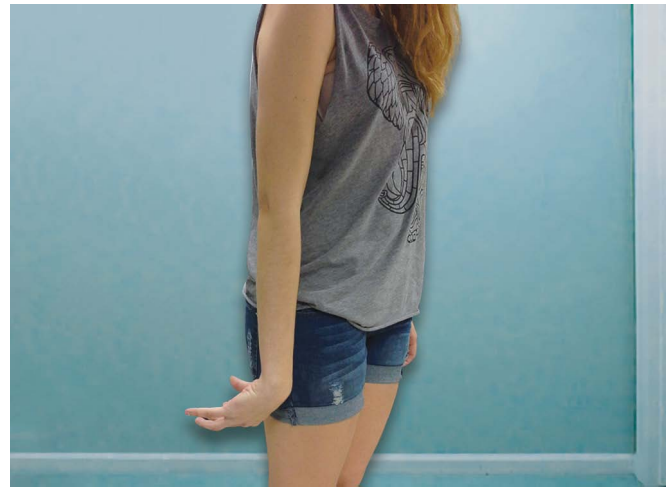


Fig. 4.39: Policeman tip/Porter's hand.

narrow zone on the medial side of the forearm and hand may be diminished.

LOWER PLEXUS INJURY (KLUMPKE'S PARALYSIS)

This type of lesion generally is caused by hyperabduction of the arm as in catching hold of a support while falling from height. The injury tears the lower trunk of the brachial plexus (mainly T1 and partly C8).

Muscles Paralyzed

- Intrinsic muscles of the hand (lumbricals and interossei) due to T1 involvement
- Ulnar flexors of the wrist due to C8 involvement.

Clinical Presentation

Paralysis of the intrinsic muscles of the hand causes the claw hand deformity. Horner's syndrome may be associated due to injury to sympathetic fibers to head and neck that leave the spinal cord through T1. The sensations in a

MANAGEMENT

Most injuries initially are managed conservatively with appropriate physiotherapy to prevent contractures. An aeroplane splint (Fig. 4.40) is given to keep shoulder abducted. Patient is observed for recovery of biceps function. If no recovery in the muscle is documented by 3 months, then the patient is advised a microsurgical exploration of the plexus and surgical repair of the lesion. Late cases present often with a deformity that may need appropriate release operations.

HIGH-YIELD POINTS

- In preganglionic lesions, repair is not possible and these avulsion injuries are managed by special procedures called neurotization which involve nerve transfers like suprascapular to spinal accessory or intercostal nerves to musculocutaneous.
- *Burners/stingers*: These are mild traction injuries of brachial plexus in sports persons.



Fig. 4.40: Aeroplane splint.

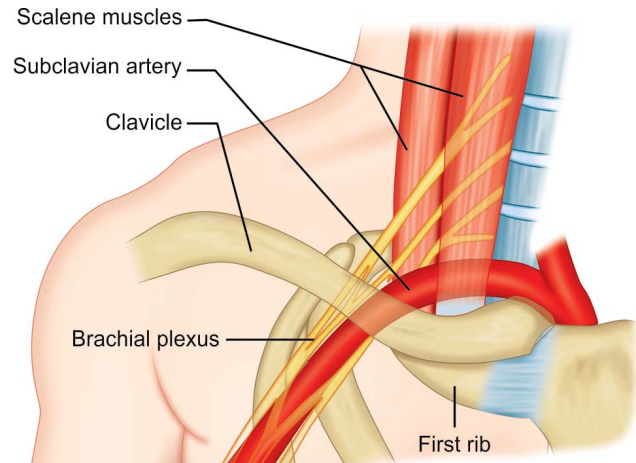


Fig. 4.41: Diagrammatic depiction of thoracic outlet.

THORACIC OUTLET SYNDROME

The thoracic outlet syndrome (TOS) describes a constellation of symptoms that arise from compression of the neurovascular structures as they course through the axilla to pass from base of neck to the arm. The outlet is basically bounded by the clavicle above, the first rib below, the scalenus anterior in front and scalenus medius behind (Fig. 4.41). The structures mainly involved are the brachial plexus, the subclavian vein, and rarely, the subclavian artery. The outlet comprises of three narrow passages:

1. *Interscalene triangle*: Its boundaries are the scalenus anterior anteriorly, the scalenus medius muscle posteriorly and the medial surface of the first rib inferiorly. The triangle becomes even narrower with certain provocative maneuvers. Important pathologies causing constriction in this area are fibrous bands, cervical ribs and anomalous muscles.
2. *Costoclavicular triangle*: It is bounded by the clavicle anteriorly, the first rib posteromedially and the upper border of scapula posterolaterally.
3. Subcoracoid space which lies beneath the coracoid process deep to the pectoralis minor tendon.

Etiology

The most common cause of TOS is physical trauma from probably nonergonomic postures and sports-related activities (repetitive stress injury). TOS results due to decreased outlet space due to abnormal posturing, hypertrophy of scalenus muscles (scalenus anticus syndrome), by compression from the cervical rib (fibrous/bony) or fractures/anomalies of nearby bones and shoulder girdle on arm movement. A pancoast tumor (superior sulcus pulmonary tumor) can also lead to TOS. Pregnancy can predispose to development of TOS as well. Rib exostosis and osteomyelitis in the area are few rarer causes.

Clinical Presentation

Thoracic outlet syndrome manifests with signs and symptoms involving the arms and hands. Involvement may be unilateral or bilateral. The manifestations depend upon which structure (isolated or combinations) is compressed in the area of thoracic outlet: axillary/subclavian artery, subclavian vein or neurological structures (brachial plexus or the sympathetic nerves). Pain and paresthesia in ulnar nerve distribution are the most common symptoms.

Neurological Presentation

This is the most common presentation and account for more than 95% cases of TOS. Most patients complain of pain and paresthesias travelling down the arm from base of the neck that are aggravated by postural changes especially abduction of arm and neck hyperextension. True motor weakness is rare but can be there with muscle atrophy evident mostly in distribution of ulnar nerve (C8, T1).

Arterial Presentation

It is least common subtype (< 1% cases) and symptoms mimic neurologic type, although cause here is ischemia. It can present with a poststenotic dilatation or aneurysm of subclavian artery. There can be discoloration of the hands and difference in temperature on examination. Patients may report Raynaud's phenomena precipitated by carrying heavy weights.

Venous Presentation

It accounts for 2-3% cases of TOS. A painful, swollen and blue arm, particularly after strenuous physical activity, could be the first sign of a subclavian vein compression. This rare entity is known as Paget-Schroetter syndrome (PSS) or effort-induced thrombosis syndrome. The main



Fig. 4.42: Adson's test.

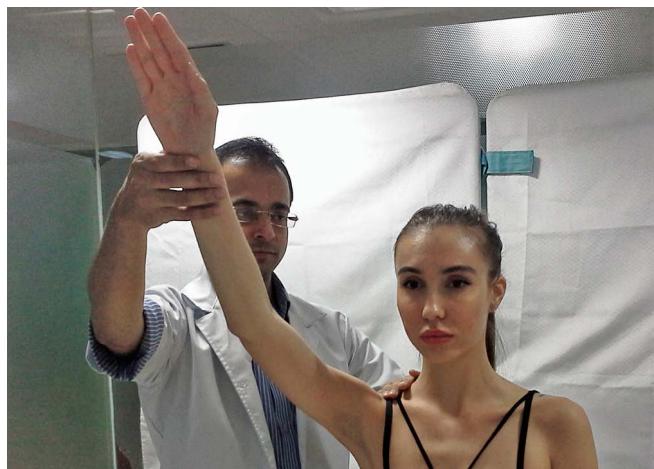


Fig. 4.43: Hyperabduction maneuver (Wright's test).

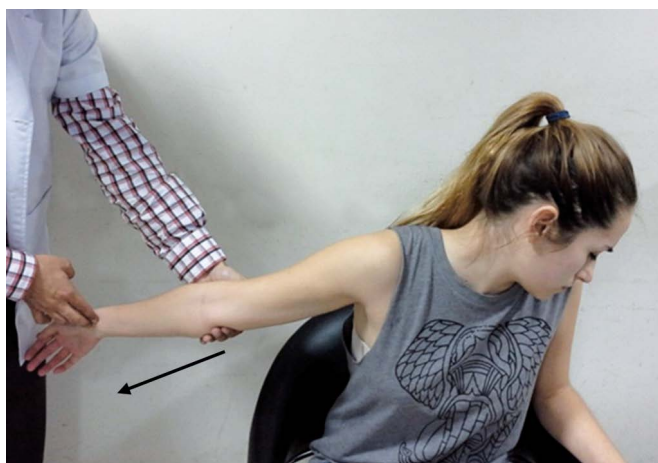


Fig. 4.44: Halstead's maneuver.



Fig. 4.45: Military posture.

pathophysiology of PSS involves congenital aberration of the costoclavicular ligament, which inserts far lateral to its usual insertion on the first rib. In the presence of hypertrophied scalenus anticus muscle vein is compressed and occluded.

Orthopedic Clinical Testing Maneuvers

Adson's test (Fig. 4.42): Radial pulse is palpated with the arm by the side of the body. Now patient's arm is slightly abducted and extended. Patient is asked to turn the head to the side of symptomatic arm. A decreased pulse volume indicates positive compression. However, the sensitivity and positive predictive value of Adson's test is low and some surgeons have modified this test by tilting neck to opposite side or by looking for aggravation of symptoms rather than an absent pulse.

Wright's test (Fig. 4.43) (also called *hyperabduction maneuver*): Palpate the radial pulse of the patient when the arms are by the side of the body. Now examiner places the patient's shoulder into hyperabduction above the head and holds this position for 1 to 2 minutes. Positive test is

indicated by diminution of radial pulse and/or symptom reproduction.

Halsted's test (Fig. 4.44): The examiner palpates the radial pulse and applies downward traction on the test extremity. The patient's neck is hyper-extended and rotated to the opposite side. Disappearance of the radial pulse indicates a positive test.

Military posturing/costoclavicular maneuver (Fig. 4.45): Patient stands in "attention position" with shoulders drawn posteriorly and inferiorly. Patient holds this position for one minute. Diminution of radial pulse constitutes a positive test.

Roos stress test/EAST test (*Elevate abduct stress test: test for intermittent claudication*): With the arms abducted, externally rotated and elevated overhead, patient is asked to open and close fingers, time and again for 1 to 3 minutes. A positive test is indicated by reproduction of symptoms (pain, numbness, tingling, etc.) (Fig. 4.46).

Spurling's test (Fig. 4.47): Patient's head is placed in extension and lateral flexion and axial compression applied to the patient's head in an effort to simulate radicular pain.

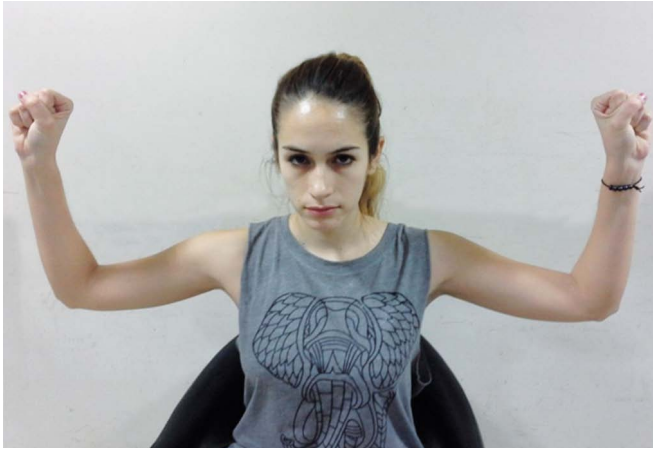


Fig. 4.46: Roos test.

Upper Limb Tension Test (ULTT) of Elvey: Patient's arm is abducted to 90° with elbows extended now wrist is dorsiflexed. These maneuvers progressively stretch the brachial plexus and cause symptoms on ipsilateral side. Now patient is instructed to tilt the head to contralateral side, ear to shoulder. This will further increase the stretch on the brachial plexus. Reproduction of nerve compression signs and symptoms (Pain, paresthesia and numbness) indicate neurogenic TOS. This test can be done simultaneously for both sides.

Gilliat-Sumner hand: Atrophied abductor pollicis brevis, interossei, hypothenar muscles (ulnar distribution) can point toward the diagnosis.

Establishing the Diagnosis

Although a number of cardiac, pulmonary and esophageal disorders may mimic the presentation, the prime conditions to be ruled out include:

- Cervical discogenic pain
- Peripheral neuropathies (like carpal tunnel syndrome)
- Shoulder impingement syndrome.

Careful examination and serial X-rays (Fig. 4.48) are required to differentially diagnose between the positional/static and dynamic etiologies like first rib anomalies, scalene muscle spasm, and a cervical rib or fibrous band. CT scan and MR scan may be helpful in dubious situations. Adson's test, wright's test and costoclavicular maneuver are vascular tests they are of little value in diagnosis of much more common neurological TOS. Provocative clinical testing for TOS has been reported to display high rates of false positive findings. Diagnosis can be supported by vascular and electrodiagnostic studies. Venous ultrasound studies, venous scintillation scans and venography for venous TOS and Doppler ultrasound and angiography for arterial TOS can establish the diagnosis. Similarly nerve conduction velocities and electromyography of the medial antebrachial cutaneous nerve for the true neurogenic TOS are helpful investigations. Although these tests can support the diagnosis but diagnosis is mainly based on clinical findings as negative tests do not rule out the disease.



Fig. 4.47: Spurling's test.

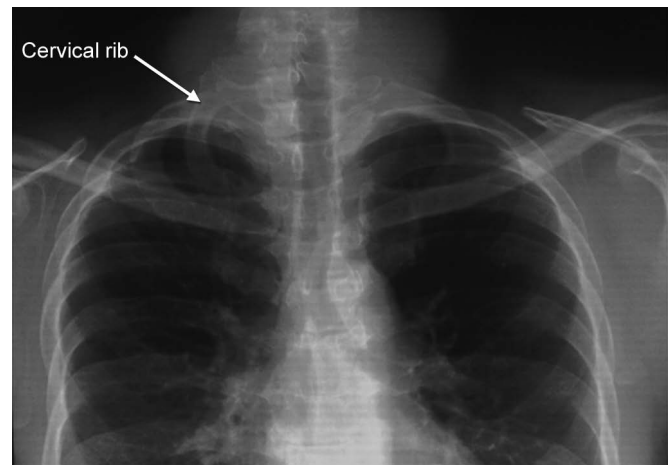


Fig. 4.48: X-ray showing cervical rib on right side.

Treatment

All other patients should receive nonoperative treatment that includes adequate rest, NSAIDs, cervicospinal strengthening exercises and modalities to counter pain and muscle spasm such as ultrasound, transcutaneous nerve stimulation and biofeedback.

Surgery in cases of TOS is indicated for acute vascular insufficiency (arterial/venous), progressively increasing neurological deficit and intractable pain for more than 3 months. Postoperative use of warfarin/low-molecular-weight heparin is mandatory.

HIGH-YIELD POINTS

Allen's test: This is a test for patency of ulnar artery and collateral circulation of the hand. Here, the ulnar and radial arteries are occluded and hand is exercised. The pressure on ulnar artery is released. In normal cases, the blanching completely disappears and this test is considered *positive* in such a case. If blanching persists in a specific distribution, it indicates absence of normal collateral supply—*negative test*.

CHAPTER 5

Bone and Joint Infections



OSTEOMYELITIS

INTRODUCTION

Osteomyelitis (term coined by Nelaton) refers to inflammation of the bone and the marrow caused by an infecting organism.

Osteomyelitis can be classified, based on duration of symptoms as acute (<2 weeks), subacute (2–3 weeks) or chronic (>3 weeks). Based on mode of spread, it can be exogenous/direct (open fractures, surgery, or contiguous spread) or hematogenous (commoner).

PATHOGENESIS

The infection usually starts in the metaphysis of long bones (lower end femur > upper end tibia) because of vascular stasis due to hair pin like arrangement of metaphyseal blood vessels. As shown in Figure 5.1, as the arteries take a U-turn at the growth plate and return to become venous channels, there occurs stasis of blood flow which leads to accumulation of bacteria that over power host's immunity.

Bacterial seeding in metaphysis leads to inflammatory reaction which causes local tissue necrosis and thus metaphyseal abscess formation. As the abscess enlarges,

intramedullary pressure rises and pus escapes through the cortex into subperiosteal space. The periosteum is lifted from the bone and new bone formation occurs (it is an innate response in bone that whenever periosteum is lifted, there occurs new bone formation), which is referred to as periosteal reaction. This periosteal reaction is seen after 7–10 days of onset of symptoms (Fig. 5.2).

Now, after 2 weeks, acute osteomyelitis enters into the chronic phase. As periosteum is lifted, blood supply to underlying bone is damaged and a part of bone is rendered avascular. This avascular segment becomes dead, gets surrounded by infected granulation tissue and segregates from viable parent bone to form “sequestrum” (sequestrum means separated). Lack of blood supply makes it difficult for body to halt infection, so body tries to wall off sequestrum by forming reactive new bone around it which is referred to as “involucrum”. But the organisms in the sequestrum have proteolytic enzymes and create openings in the involucrum that are called as Cloaca. Pus travels out from these cloacae out of the bone and finally out of the tissues and skin thereby creating openings in skin, forming sinuses, the clinical hallmark of chronic osteomyelitis (Fig. 5.3).

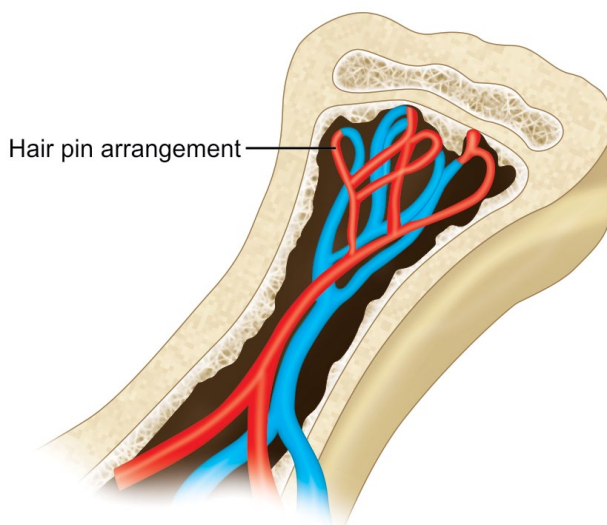


Fig. 5.1: Hair pin arrangement of vessels at metaphysis.

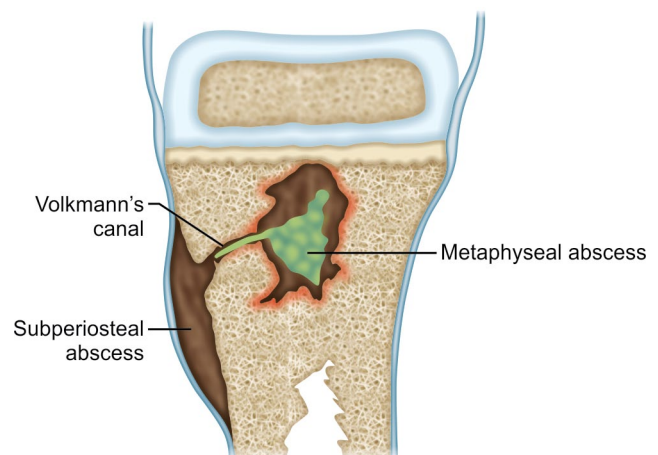


Fig. 5.2: Pathological changes of acute osteomyelitis.

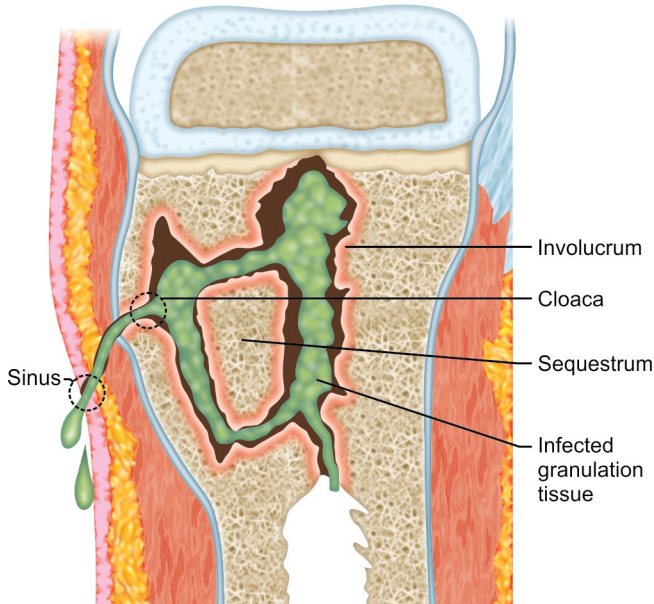


Fig. 5.3: Pathological changes of chronic osteomyelitis.

At times, rather than discharging out, pus can also enter the nearby joint. This is usually the case where metaphysis is intracapsular like proximal femur (hip) and proximal humerus (shoulder).

ACUTE HEMATOGENOUS OSTEOMYELITIS

Acute hematogenous osteomyelitis is the most common type of osteomyelitis and is predominantly a disease of children. Risk factors to cause infection in adults in rare instances include diabetes, steroid therapy, leukemia, chemotherapy, or immunosuppressive therapy.

Etiology

Presently, in all age groups (in both developing and developed countries) *staphylococcus aureus* (*S. aureus*) is considered to be the most common causative organism, seen in 80–90% culture positive cases. Group B *Streptococci* are commonly (but not most common) seen in 0–6 months old infants and *H. influenzae* infections were commonly seen in 6 months–4 years age group of children, the number having gone down significantly after introduction of Hib vaccine.

Also know the most common causative organisms:

- In Sick cell disease patients—*Salmonella*
- In I/V drug abusers—*Pseudomonas*
- In HIV/immune-compromised—*S. aureus*
- In patients with prosthetic material—Coagulase negative staph > *Propionibacterium*
- After animal bite—*Pasteurella multocida*
- After human bite—*Eikenella corrodens*
- Diabetic foot ulcers/Fight bite—*Anaerobes*



Fig. 5.4: X-ray of thigh with knee and hip joint showing periosteal reaction in acute osteomyelitis.

- In open fractures and post traumatic cases—*Staph aureus*
- In post surgery cases—*Staph aureus*.

Clinical Features

The child classically presents with acute febrile illness with pain and swelling in the involved area. A history of injury may co-incidentally be obtained. The cause is often difficult to trace unless the clinician has a high index of suspicion. The only clinical sign that may suggest the diagnosis is tenderness on pressing the metaphysis.

Investigations

Blood investigations: The white blood cell (WBC) count, erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) are elevated. Blood culture is positive in 50% of cases.

X-ray: Haziness/soft tissue shadow due to increased blood flow is the earliest sign seen on X-ray within 48 hours of infection although the classical sign is periosteal new bone formation evident on x-rays after around 7–10 days (Fig. 5.4).

Bone scan (Indium-111 labelled leukocytes) is useful for early diagnosis. It shows an area of increased uptake within 24–48 hours.

Magnetic resonance imaging (MRI) provides the earliest diagnosis and it is the investigation of choice of acute osteomyelitis. However mostly the diagnosis can be made on the clinical ground.

Bone aspiration of pus, gram stain and culture sensitivity is considered the gold standard for confirming diagnosis.

Differential Diagnosis

- **Acute septic arthritis:** Movements at joint are extremely painful. Aspiration of joint would reveal pus.

Box 5.1: empirical antibiotic therapy for acute osteomyelitisAgent active against *S. aureus*—Cephalosporins

+

For Gram-negative coverage—Fluoroquinolones

- *Scurvy*: Bone pain due to subperiosteal hemorrhages (pseudoparalysis of parrot) simulates acute osteomyelitis. Look for other features of malnutrition.
- *Ewing sarcoma*: Can be differentiated on MRI.
- *Osteosarcoma*: Dilated veins in osteosarcoma arouse the suspicion.
- *Acute rheumatic arthritis and juvenile rheumatoid arthritis (JRA)*: Usually multiple joints are involved. Rheumatic arthritis has the characteristic fleeting and flitting nature of joint pains.
- *Sickle cell crises*: Blood smear will solve the diagnostic dilemma.

MANAGEMENT

Acute osteomyelitis is an emergency. The key to management is early diagnosis.

General principles: General supportive care is given to the patient consisting of splintage and rest to the affected limb, elevation of the extremity, intravenous (IV) fluids and analgesics.

Antibiotics: Empirical broad spectrum antibiotics (Box 5.1) are started and are changed to definitive on the basis of culture and sensitivity report. The antibiotics are given via IV route for first 2 weeks and oral for next 4 weeks. But the antibiotic therapy is effective before pus formation.

Surgery: Pus formation occurs by 2–3 days and hence if there is failure to improve despite appropriate antibiotic therapy for 72 hours, patient is undertaken for urgent surgery.

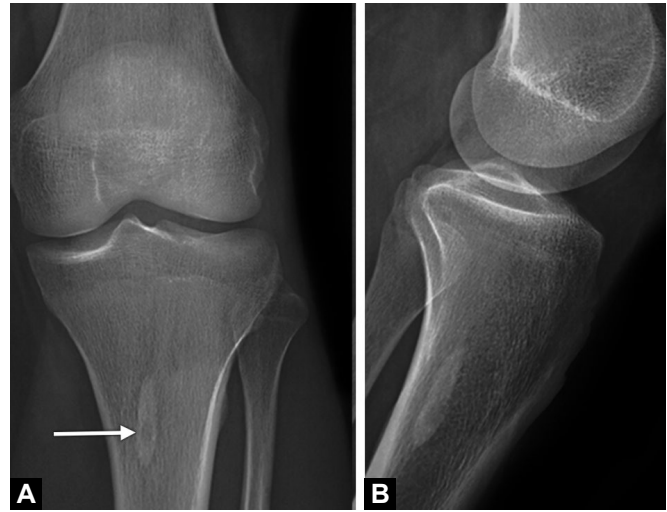
Incision and drainage is the mainstay of surgical treatment. If no pus is found in soft tissue planes, drill holes are made in the metaphyseal area of bone and still if no pus comes out, one can go on to make a small metaphyseal bone window to drain out pus.

Complications

- *Chronic osteomyelitis*: Most common complication. It is almost the outcome in immunocompromised patients.
- Metastatic abscess
- Septicemia in untreated cases
- Septic arthritis usually in joints where metaphysis is intra-articular
- Pathological fractures
- Growth plate disturbances ending up in limb length discrepancy.

BRODIE'S ABSCESS

This is a long standing localized form of subacute osteomyelitis seen in cases where either the virulence of the



Figs. 5.5A and B: X-ray AP and lateral views of knee joint showing Brodie's abscess (arrow) in proximal tibia.

infecting organism is low or the immunity of the host is good, such that the host is able to localize the infection within the metaphysis. Proximal tibia is the most common site and mostly affected patients are 10–20 years old. Classical presentation is with local tenderness and intermittent pain that is worse at night.

X-ray (Figs. 5.5A and B) shows cavity at metaphysis-epiphyseal junction with rim of reactive new bone. Diagnosis is confirmed by bone biopsy. Treatment is curettage and bone grafting under antibiotic cover.

CHRONIC OSTEOMYELITIS

Osteomyelitis with symptoms persisting for more than 3 weeks is chronic osteomyelitis.

Etiology

Chronic osteomyelitis, most commonly is a sequelae of acute osteomyelitis because of delay in its diagnosis or when osteomyelitis is inadequately treated. Open fractures, surgery and impaired host immunity are other important causes that lead to persistence of infection.

Most common causative organism again is *S. aureus*.

Clinical Features

There are usually no systemic symptoms. Discharging sinus (especially with history of discharge of bony chips) is the clinical hallmark and the most common presenting symptom (Fig. 5.6). On examination the discharging sinus is generally fixed to the underlying bone and at times multiple puckered scar marks of healed sinuses may be visible. Irregular bony thickening and tenderness on deep palpation can be appreciated.

Radiological Examination

Sequestrum, the radiological hallmark of chronic osteomyelitis may indicate the diagnosis in some cases (Fig. 5.7).

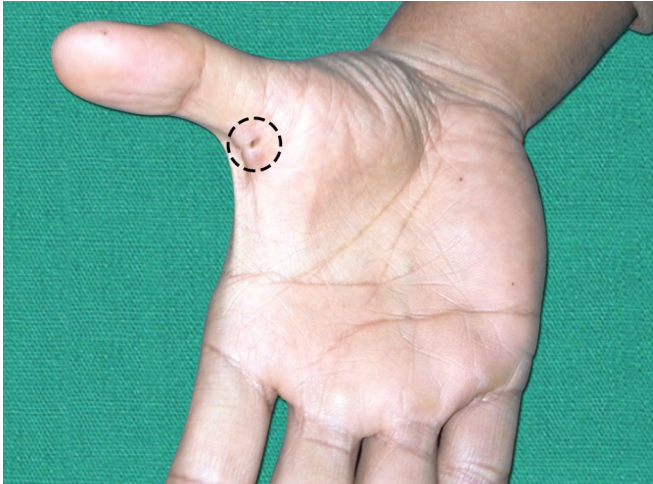


Fig. 5.6: Sinus in the web space of the hand (encircled).



Fig. 5.7: X-ray AP view of ankle with leg showing sequestrum in distal third of tibia.



Fig. 5.8: Moth eaten appearance.

Sequestrum appears radiodense than adjacent bone because of its avascularity as calcium is not resorbed from dead bone. Involucrum (also radiodense) is the reactive new bone present outside the infected granulation tissue. In late cases X-ray classically shows multiple lytic and sclerotic areas—the so called honey-combed pattern/moth eaten appearance (Fig. 5.8).

Diagnosis

The diagnosis is based on clinical, laboratory and imaging studies. The gold standard is biopsy and preferably the sample should also be cultured to isolate the organism and guide antibiotics. A sinogram (injecting radio-opaque dye in the sinus to delineate it) should be done to localize the source of pus.

Treatment

Surgery is the mainstay of treatment. Since the source of persistent infection is sequestrum surgery involves sequestrectomy, curettage of walls, creating the cavity into shape



Fig. 5.9: X-ray of tibia lateral view showing saucer shaped cavity (saucerization) after sequestrectomy and curettage in chronic osteomyelitis.

of a saucer (saucerization) and filling the cavity with antibiotic impregnated polymethylmethacrylate [PMMA (bone cement)] beads or bone grafts to eliminate dead space (Fig. 5.9). Excision of sinus tract should follow to complete all the steps. After surgery wound is usually closed over a continuous suction and irrigation system wherein irrigating fluid goes in via an inlet tube into the medullary cavity of bone and the same drains out after flushing the cavity via an outlet tube connected to a suction source.

Amputation may rarely be done in cases with chronic discharging sinuses with malignant change or infected nonunion with failed multiple previous surgeries.

An antibiotic cover is added to surgery but here iv antibiotics are given for all 6 weeks and then oral antibiotics for another 6 weeks.

Complications

- *Acute on chronic osteomyelitis:* Acute exacerbation is the most common complication of chronic osteomyelitis.

- *Growth disturbances and limb deformities:* Both shortening > limb lengthening (due to increased blood flow) may result.
- *Pathological fractures*
- Restricted joint movements leading to joint stiffness
- Amyloidosis
- Marjolin's ulcer i.e. squamous cell carcinoma in the sinus tract (rarely sarcoma of bone).

SCLEROTIC OSTEOMYELITIS OF GARRE

This is a nonsuppurative chronic or subacute osteomyelitis characterized by marked sclerosis (whitening of bone) and cortical thickening (Fig. 5.10). It is caused due to low-grade anaerobic infection and typically affects jaw more than diaphysis of tubular bone (mostly tibia). Clinically, patient may present with fever and pain worse at night but unlike chronic osteomyelitis there are no discharging sinuses. The bone is tender to deep palpation. Due to a fusiform osseous enlargement it is often confused with a bone tumor but the classical age and the X-ray picture are diagnostic. Treatment is largely supportive and broad spectrum antibiotics may be given.

MULTIFOCAL NON SUPPURATIVE OSTEOMYELITIS

This is a diagnosis that comprises of several different syndromes with certain features in common such as chronic skin lesions viz. pustular lesions of palms and soles (palmar-plantar pustulosis) and pustular psoriasis. It is more popularly known by the term SAPHO- synovitis, acne, pustulosis, hyperostosis and osteitis. Despite the name, there is no micro-organism which has been isolated and neither is a discharge present. Histology shows signs of subacute inflammation but the etiology still remains unknown.



Fig. 5.10: X-ray of leg AP and lateral views showing marked sclerosis and cortical thickening in Garre's osteomyelitis.

Few of the clinical syndromes included in this spectrum are:

Sternocostoclavicular hyperostosis: This presentation is seen mostly in men aged 40-50 years. Disease affection is predominantly in sternum and adjacent bones and the vertebral column. X-rays classically depict hyperostosis of the medial ends of the clavicles and sternum. Radio-scintigraphy also depicts increased activity around the sternoclavicular joints and also in affected vertebrae. There is no definite treatment but symptoms tend to fade away in long term follow up. Recurrent flares are common and eventually lead to ankylosis of the affected joints in some patients.

Subacute recurrent multifocal osteomyelitis: This presentation is seen mainly in children and adolescents. There are recurrent episodes of pain, swelling and tenderness around long bone metaphysis (most common site- the distal femur or the proximal/distal tibia), medial ends of clavicles or a vertebral segment. The involvement is mostly multifocal but may or may not be symmetrical. Radiographic changes include small, lytic lesions in the metaphysis with surrounding sclerosis. Clavicle is markedly thickened. Radio-scintigraphy shows increased activity around these lesions. Antibiotics have no role and treatment is generally palliative. Although the disease runs a protracted course, prognosis is good as lesions heal well without any sequelae.

HIGH-YIELD POINTS

- Most common site of osteomyelitis (acute and chronic both) in adults is vertebral bodies.
- Sequestra may not be seen in children (particularly infants) as they have loose periosteum that gets easily lifted and whole bone becomes sequestrum. In case small sequestra have formed then they get rapidly absorbed over time.
- Ideal timing of sequestrectomy is when three out of four cortices of involucrum are well formed.
- Sequestrum usually takes 2-3 months to separate from parent bone. It has an inner smooth surface and an outer rough surface. The outer surface is rough as the latter is being continuously eroded by infected granulation tissue. Another feature is that if this piece is placed in water it sinks and if it is examined on histopathology, one finds closed haversian system.
- *Osteomyelitis in HIV patients:* The disease in HIV patients also is mostly caused by *Staph aureus* although in one third cases the infection is polymicrobial. The pathology is absolutely similar with necrosis of bone and a periosteal reaction. However, involvement may at times be bilateral.
- *Salmonella osteomyelitis:* Salmonella infection is mostly seen in children with sickle cell disease. It occurs during the convalescent phase of the disease. Usual sites of involvement are diaphysis of long bones (most commonly tibia and forearm bones).



Figs. 5.11A to D: (A and B) Feathery sequestrum of tuberculosis (arrow). (C) X-ray showing ring sequestrum at site of insertion of external fixator pin in bone. (D) X-ray forearm AP view showing tubular sequestrum in ulna.

Sometimes involvement may be multifocal or bilateral symmetrical. The radiological hallmark is marked diaphyseal sclerosis.

- Cierny and Mader devised a classification system for chronic osteomyelitis based on anatomical status of lesion (medullary, superficial, diffuse) and physiological status of host (normal or immune-compromised).

Types of Sequestrum in Osteomyelitis

Types of Sequestra

Tubular sequestrum (Fig. 5.11D): Pyogenic osteomyelitis, Infants

Pencil like sequestrum: Infants

Ring sequestrum: At the end of amputation stumps (Fig. 5.11C), around pin tracts (of external fixator)

Conical/Annular sequestrum: Amputation stumps

Ivory sequestrum: Syphilis

Feathery sequestrum: Tuberculosis- in cavity (Figs. 5.11A and B), Syphilis

Coarse sandy sequestrum: Tuberculosis (outside cavity)

Rice grain sequestrum: Tuberculosis

Fine sandy sequestrum: Viral osteomyelitis, In metaphysis of tuberculosis osteomyelitis

Kissing sequestrum: Paradiscal tuberculosis spine

Black sequestrum: Actinomycosis, Fungal osteomyelitis

Colored sequestrum: Fungal osteomyelitis

Coralliform sequestrum: Perthes disease

Bombay sequestrum: On exposed surface of bone due to Hydrogen sulphide deposition

SEPTIC ARTHRITIS

INTRODUCTION

It is inflammation of the joint due to infection by micro-organisms.

PATHOGENESIS

Septic arthritis is more common in children, males more commonly affected than females. The possible routes of



Fig. 5.12: X-ray of septic knee in acute stage showing increased joint space.

infection are hematogenous (most common), open injuries, or infection through contagious sites like a nearby site of osteomyelitis. At times, even the umbilical cord sepsis in infants can travel to joints.

Infection begins with systemic bacteremia and once bacteria invade the joint, the synovium gets involved triggering an inflammatory cascade. Lysosomal enzymes are released by the macrophages that destroy the articular cartilage. Gradually the whole joint gets destroyed and bony trabeculae form that run across the articulating surfaces as the lesion heals leading to the bony ankylosis as end result.

ETIOLOGY

S. aureus is the most common causative organism in all age groups except in healthy, sexually active young adults where *Neisseria gonorrhoeae* is isolated in 75% of cases. *Streptococcus pyogenes* and *Pneumococcus* are others in the list.

HIGH-YIELD POINTS

- Coagulase negative *Staph* is more common after prosthetic joint surgery.
- Patients with systemic lupus erythematosus have increased risk of infection with *Salmonella*.
- Intravenous drug abusers have increased likelihood of *Pseudomonas* infection.
- Patients on TNF inhibitors have increased risk of Mycobacterial infection.
- *Pneumococcus* is more common in alcoholics and in patients with hemoglobinopathies.

CLINICAL PRESENTATION

The child is toxic with high-grade fever and presents with sudden onset pain, swelling and erythema around the affected joint. The child keeps the joint in position of



Fig. 5.13: X-ray showing bony ankylosis postseptic arthritis of knee.

maximum capacity of a joint also known as “position of ease”, which is flexion, abduction and external rotation for hip, flexion for knee and elbow and palmar flexion for wrist. If at all patient attempts to walk there is a painful limp with severe limitation of joint movements in all directions on examination.

The most common joint affected is knee followed by hip and then shoulder joint.

INVESTIGATIONS

Blood investigations reveal increased WBC counts with predominant neutrophilia.

Blood cultures may show causative organism in 60% cases.

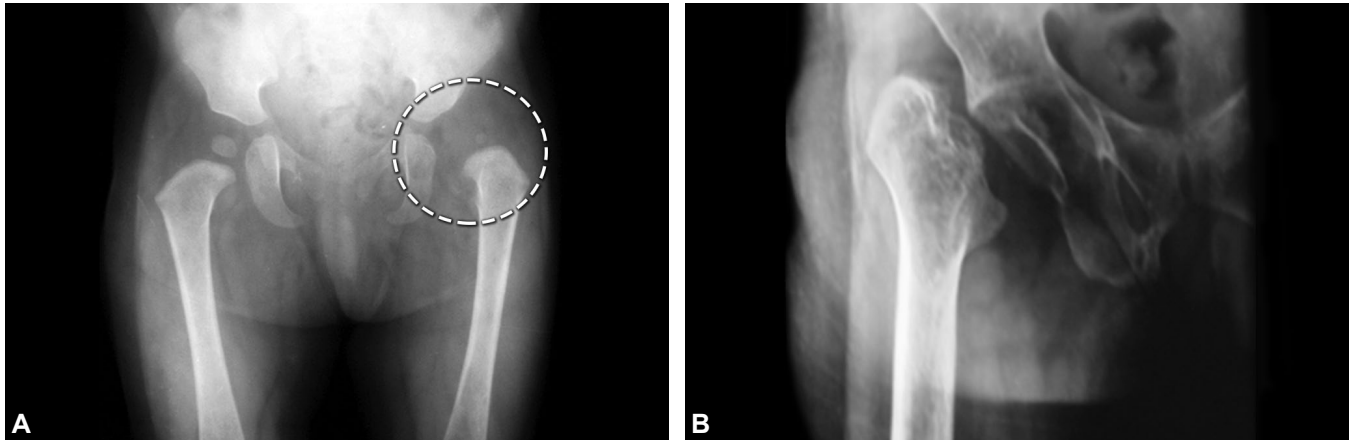
X-rays in early stages usually are normal. At times due to joint effusion one might appreciate an increased joint space on affected side in comparison to normal side (Fig. 5.12). As the infection progresses, there is joint space narrowing due to destruction of cartilage and in the end stage bony ankylosis of the joint may be seen (Fig. 5.13).

Ultrasonography is a useful investigation, especially in the deep-seated joints like the hip, as it can detect even small amount of collections. Fluid can be aspirated under ultrasound guidance and the aspirate analysis remains the most accurate diagnostic tool for concluding the diagnosis. If infected, total leukocyte count (TLC) is increased with neutrophilic leukocytosis while proteins increase and glucose level reduces in synovial fluid. Gram staining with culture sensitivity isolates the causative organism and guides the antibiotic treatment.

Differential diagnosis: Acute osteomyelitis, rheumatic arthritis, hemophilic arthritis and tubercular arthritis.

TREATMENT

Adequate drainage of pus from the joint (arthrotomy), IV antibiotic cover for 6 weeks and immobilization in functional position are the main principles in the management



Figs. 5.14A and B: (A) Tom Smith arthritis with destruction of head but normal looking acetabulum. (B) Sequelae of Tom Smith arthritis in an adult (see well-developed acetabulum).

of septic arthritis. If the aspirate is pus, arthrotomy is done as an emergency procedure and wound closed over a negative suction. Empirical antibiotics are started and tailored after the culture sensitivity report is received. In case there has already been significant destruction of the articular cartilage or a pathological dislocation, a thorough debridement of infected tissue is done and joint immobilized in optimum position to ensure maximum function in case the bony ankylosis is the end result.

COMPLICATIONS

- Septicemia in untreated cases
- Stiffness and deformity
- Secondary osteoarthritis
- Pathological dislocation.

Tom Smith arthritis: Tom Smith arthritis is the septic arthritis of the hip in infants. It can occur in neonatal period as a spread from umbilical sepsis.

In a child of less than 1 year of age, the head of the femur is cartilaginous which gets easily and rapidly destroyed by the bacteria. The onset is acute with rapid destruction of head of femur. On examination, the child walks with a limp, there is shortening of affected limb with attitude of external rotation and range of motion of hip is increased in all the directions. Telescopy at hip is positive.

X-ray shows complete absence of head and neck of femur (Figs. 5.14A and B). One needs to differentiate it

from developmental dysplasia of the hip (DDH). In Tom Smith arthritis, acetabulum is well developed.

Presentation in an adult: Many a times the initial diagnosis is missed and the child comes months or years later with a painless limp. The gait is unstable, trendelenburg type and affected leg is short. One has to differentiate it from DDH where the acetabulum is additionally abnormal.

HIGH-YIELD POINTS

- **Gonococcal arthritis:** *Neisseria gonorrhoeae* is the most common cause of septic arthritis in healthy, sexually active adults although a septic joint develops in even less than 3% of cases infected with *N. gonorrhoeae*. Joint infection generally manifests within 2 weeks of urethral discharge. Inflammation as a rule is restricted to subsynovial layers. Involvement can be polyarticular (although knee is most common joint involved) and associated with papular rash. Joint cultures are usually negative, but cultures from pharynx and urethra may be positive. Gonococcal arthritis has generally good prognosis if treated with appropriate antibiotics (drug of choice is penicillins) and drainage is usually not necessary.
- The most common joint affected in Brucellosis is Hip joint.
- Septic arthritis is the most common cause of bony ankylosis

MADURA FOOT

INTRODUCTION

Mycetoma (Madura foot) is a chronic granulomatous infection of skin and underlying tissues caused by bacteria (actinomycetes) or fungi (eumycetomas) that can extend

to the underlying bone. It is characterized by triad of tumefaction of the affected area, multiple sinus tracts and discharge of granules that contain the causative agent. The disease was first described in the Indian town of Madura in South India, and hence the name.

PATHOPHYSIOLOGY

Mycetoma typically presents in agricultural workers (affection of hands, shoulders and back—from carrying contaminated vegetation and other burdens), or in individuals who walk barefoot in dry and dusty conditions. The causative organism enters through sites of local trauma (e.g. cut on the hand, foot splinter). A neutrophilic response initially occurs, which may be followed by a granulomatous reaction. Spread occurs through skin facial planes and can involve the bone. Hematogenous or lymphatic spread is uncommon.

ETIOLOGY

Mycetoma may be caused by actinomycetes, which are considered as transitional forms between bacteria and fungi, or by true fungi (Eumycetes) where it is called “Eumycetoma”. Following are the common organisms involved:

Actinomycetes:

- *Actinomadura madurae*
- *Actinomadura pelletieri*
- *Streptomyces somaliensis*
- *Nocardia species*

Eumycetes:

- *Pseudallescheria boydii*
- *Madurella mycetomatis*

CLINICAL FEATURES

The disease is usually seen in field workers like farmers, and generally affects men between 20 years and 40 years. The disease is acquired by inoculation of grains of fungal spores from the soil through a breach in the skin.

The disease usually begins as a painless swelling or thickening of the skin and subcutaneous tissue. As the disease gradually progresses over months or years, the initial lesion enlarges and eventually becomes tumorous. The overlying skin may be smooth, depigmented or shiny.

Abscesses and sinus tracts develop over time and may contain a serosanguineous or seropurulent discharge, which may contain white-to-yellow or black granules. Granules are firm 0.2-mm to 5-mm aggregates of organized vegetative septate hyphae, which often are embedded in a matrix substance that contains sulphur. These sulphur

Box 5.2: Granules color in madura foot

RED- *Actinomadura pelletieri*

YELLOW- *Actinomadura madurae*, *Pseudallescheria boydii*

BLACK- *Exophiala jeanselmei*, *Madurella mycetomatis*

granules are usually macroscopic and are observed in the lesional tissue and in sinus tracts. The color of the granules is thought to be due to melanin, host protein and dark debris. The color is specific for a particular species (Box 5.2). Regional lymphadenitis secondary to bacterial superinfection of the lesion may be present.

DIFFERENTIAL DIAGNOSIS

The main differential diagnoses are chronic bacterial osteomyelitis, TB and other deep fungal infections such as blastomycosis or coccidioidomycosis.

INVESTIGATIONS

Microscopy and culture of exudates and skin biopsy for pathology are necessary to identify the causative organism.

Plain X-rays are used to assess for evidence of bone involvement. CT scan may be more sensitive in the early stages. MRI scans can provide a better assessment of the degree of bone and soft tissue involvement, and may be useful in evaluating the differential diagnosis of the swelling.

MANAGEMENT

Antifungal drugs like ketoconazole, voriconazole and itraconazole are generally employed in treating the infection. Actinomycetes usually respond well to medical treatment, but the eumycetes are generally resistant and may require surgical intervention. The latter includes a thorough debridement, followed by prolonged appropriate antibiotic therapy for several months. Amputation may be required in refractory cases.

HIGH-YIELD POINTS

- Most commonly actinomycosis involves orocervico-facial region.
- Overall, the most common site of actinomycosis is mandible.

SYPHILIS AND ORTHOPEDICS

INTRODUCTION

Syphilis is a sexually transmitted infection where the causative agent is a spirochaete *Treponema pallidum*.

The disease manifests not only in the host to which the organism is transmitted (Acquired syphilis) but also in the

fetus in case the transmission has occurred (Congenital syphilis). However, the manifestations are unique to each type.

ACQUIRED SYPHILIS

The course of disease passes through four phases:

1. *Primary stage*: 2–10 weeks after transmission a painless oval chancre develops at the site where the bacteria have entered the body (usually penis/vagina). Lesion mostly heals within 6 weeks without treatment.
2. *Secondary stage*: After around 3 months, disease enters secondary stage and a nonitching rash develops over palms and soles that usually heals in about another 6 weeks. During this stage the organism is spreading through the tissues of the host and the patient is highly contagious.
3. *Latent stage*: Duration varies from few years to decades. The patient is noninfectious with the bacteria lying inactive in lymph nodes and spleen. From here the disease may or may not progress to tertiary stage.
4. *Tertiary stage (Late syphilis)*: One-third of patients generally progress to this stage. The patient is noncontagious but the organism produces damage in various tissues of body. Invasion of the neural tissue is characteristic and referred to as “Tabes Dorsalis” (neurosyphilis).

Orthopedic Manifestations in Acquired Syphilis

Joints may be affected in secondary or tertiary stage of the disease. In secondary stage, there are transient polyarthralgias that generally involve large joints. In the tertiary stage, gummatous arthritis (synovial and osseous forms) is the characteristic manifestation. An indirect consequence that may occur in the tertiary stage “Charcot arthropathy” (Chapter 11) (tabes dorsalis).

CONGENITAL SYPHILIS

Transmission across the placenta causes syphilis in the fetus and the new born that presents as chronic osteitis, periosteitis and osteochondritis. Tibia is the most commonly affected bone.

Important orthopedic manifestations include:

- Frontal bossing/Olympian brow
- *Higoumenabi sign*: Bilateral enlargement of the sternal end of clavicle due to periostitis.
- *Saber shin*: Anterior bowing of mid-portion of tibia.
- *Parrot joints*: Syphilitic osteochondritis in children.
- *Clutton joints*: Painless, symmetrical synovitis most commonly involving knee in children near puberty.
- Bilateral symmetrical metaphyseal erosions most commonly seen in tibia.

LEPROSY AND ORTHOPEDICS (HANSEN'S DISEASE, 1873)

INTRODUCTION

Leprosy is a chronic granulomatous infection affecting multiple tissues like skin, peripheral nerves, testes, eyes and upper respiratory tract mucosa. It is caused by acid fast bacilli *Mycobacterium leprae*. The disease is only mildly contagious with infection being usually acquired by inhaling air borne droplets contaminated with bacteria on coming in close contact with affected individuals. Once the organism enters the body, it may take 3–5 years for the symptoms to appear but an incubation period of even up to 20 years has been reported.

PREVALENCE

Leprosy is one of the oldest known diseases of mankind. Although elimination of leprosy (i.e. a prevalence rate of leprosy less than 1 case per 10,000 persons at global level) was achieved in the year 2000, pockets of high endemicity still remain in some areas of many countries like Bangladesh, Brazil, China, Ethiopia, India, Indonesia, Myanmar, Nepal, Nigeria, Philippines, Sri Lanka, etc.

PATHOLOGY

Most people who are infected with the organism get rid of the infection by virtue of their immunity. However, in those where the immunity level is not appropriate, the organism produces the manifestations. Based upon the immune response mounted by the host, Ridley and Jopling classified the disease into “indeterminate”, “tuberculoid”, “borderline” and “lepromatous” subtypes.

The “indeterminate” type consists of first type of skin lesions (hypopigmented macules) that mostly heal spontaneously.

The “tuberculoid” form occurs in those who are able to mount up a reasonably good delayed type hypersensitivity (DTH) response. The granulomas are circumscribed and focal and have few scattered giant cells and lymphocytes. The disease in these cases is paucibacillary.

The “lepromatous” form is seen in those who are unable to mount effective cell-mediated immunity (CMI) against the infecting organism. Here the granulomas are diffuse and extensive and are loaded with bacilli (multibacillary).

The “borderline” types are intermediate forms that show some features from each of the above two forms.

ORTHOPEDIC MANIFESTATIONS

The orthopedic manifestations of the disease primarily span the following areas:

Skin Involvement

Hypopigmented skin patches with impaired sensibility are seen in all forms of “Leprosy”. Skin lesions in tuberculoid leprosy are well demarcated, few, hypopigmented, anesthetic macules while in lepromatous leprosy skin lesions are extensive, multiple, symmetrical with only some sensory impairment. Nodules may develop in advanced stage. Coarsening of facial skin and loss of eyebrow hair may produce the classical “leonine facies”. Nasal mucosal involvement may lead to destruction of nasal septum producing a nasal deformity.

Nerve Involvement

The nerve involvement is extensive in “Lepromatous leprosy” while in “tuberculoid” it is focal in distribution. However, clinical defects in nerve function appear early in tuberculoid leprosy while they are much later seen in lepromatous type.

Pattern of nerve involvement: Nerve trunks of the upper limb are involved more commonly than the nerves of lower limb. Overall, ulnar nerve is the most common nerve involved, followed by common peroneal nerve. Most common cranial nerve involved is facial nerve.

Nerve Involvement in Leprosy Occurs in Following Forms:

Nerve thickening: Peripheral nerve involvement is almost always a rule in leprosy. The affected nerves become chronically thickened due to hypertrophy of epineurium and perineurium, granuloma formation and endoneurial fibrosis. A thickened nerve may be strangulated by its own sheath or by the walls of a narrow passage that may be there in its course producing symptoms of nerve ischemia and compression.

Acute neuritis: The chronic course is often punctuated by acute episodes of neuritis due to the classic “Lepra” reactions that greatly increase the nerve damage. Type I reactions (Erythema Nodosum Leprosum) occur due to deposition of immune complexes and Type II (Reversal reactions) occur due to increase in cell mediated immunity (DTH).

Nerve abscesses: Occasionally nerve lesions in tuberculoid leprosy undergo caseation and liquefaction to form “cold abscess” that may break through the epineurium to present as a chronic collar stud abscess.

Clinical Presentation

The end result of nerve damage may bring the patient to the doctor with the following problems:

- *Muscle paralysis and joint deformities:* Damage to the affected nerves leads to paralysis and atrophy of the

muscles supplied. The end result may be joint deformities and contractures depending upon the nerve involved. For example, peroneal nerve involvement may end up in foot drop while ulnar nerve involvement may lead to claw hand deformity in hand.

- *Trophic ulceration:* Insensibility in area of affected nerve distribution predisposes to abnormal stresses of pressure especially on hands and feet. Thereby heads of first and fifth metatarsals, heel and sometimes the distal phalanges tend to develop trophic ulcers that are chronic in nature, resistant to healing and that progressively increase in size. Not uncommonly do these ulcers get secondarily infected.
- *Mutilations:* Neglect in treatment leads to mutilations of terminal extremities caused by recurrent trophic ulcers and sequestration of bone.

DIAGNOSIS

Diagnosis is established by taking a skin or nasal smear biopsy and demonstrating the acid fast bacilli.

WHO grading for orthopedic deformities is leprosy

Grade I: No sensory impairment/ No visible deformity

Grade II: Sensory impairment present but no visible deformity

Grade III: Both sensory impairment and visible deformity (i.e. claw hand) are present.

TREATMENT

Multidrug therapy: Drugs used to cure the condition include rifampicin, dapsone and clofazimine. The course and dosages depend upon whether leprosy is paucibacillary or multibacillary. Acute lepra reactions are generally managed with course of steroids and thalidomide. Kindly refer to medicine textbook for more information.

Surgical treatment: Indicated in following conditions:

- *Compression neuropathies:* Nerve decompression may be required in cases not responding to conservative treatment. The procedure involves tunnel release from which nerve is passing and incising epineurium over affected segment of nerve.
- *Nerve abscesses:* Abscesses likely to burst or those causing neurological deficit need to be drained.
- *Managing residual paralysis and trophic ulcerations:* These conditions are best prevented by early treatment. Insensate areas must be offered extra protection. Proper physiotherapy is must to prevent deformities. In case deformities result, then they can be managed by appropriate release operations and tendon transfers.

Few important tendon transfers:

- *For ulnar nerve palsy:* Omer’s transfer
- *For claw hand:* Zancolli Lasso procedure
- *For wrist drop (Radial nerve palsy):* Modified Jones transfer.

HIGH-YIELD POINTS

- *Cranial nerve involvement in leprosy:* Fifth and seventh nerves are involved.
- Patients undergoing surgery should not have had acute neuritis for at least 6 months prior to surgery.
- The first sign of the disease is the feeling of numbness or loss of sensation for temperature (heat)

followed by touch and pain which usually begins at the extremities.

- Lepre reactions occur in 30–50% of patients with leprosy. They may occur before, or more often, after the start of treatment and are induced by medicines, stress and surgical procedures.
- Lucio phenomenon is a cutaneous vasculitis in patients with lepromatous leprosy and tends to affect people who have not taken their medication regularly.

HAND INFECTIONS

INFECTIONS AROUND NAIL

Acute paronychia: Paronychia is the infection of soft tissue fold around the finger nail (eponychium) most commonly caused by *S. aureus* associated with poor nail hygiene. The patient presents with pain, redness and swelling around nail fold. Nail fold is extremely tender. Risk factors include diabetes, steroid therapy, chemotherapy, immunocompromised individuals, manual laborers and farmers.

Treatment: When there is no pus point visible, infection is controlled by oral or IV antibiotics. In late stages when there is abscess only on one side of the nail, incision and drainage is done (Fig. 5.15). If pus is extended to opposite side and under the nail, a second incision is made and proximal third of nail is removed.

Chronic paronychia: Seen in patients whose hands have prolonged exposure to water, which causes thickening of eponychium due to chronic inflammation and recurring infection. Organisms responsible are *S. pyogenes*, *S. epidermidis* and *C. albicans*.

Treatment: Eponychial marsupialization is to be done.

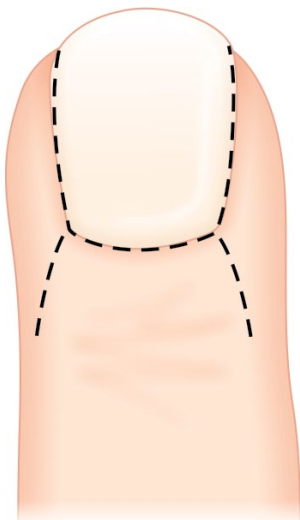


Fig. 5.15: Incision for draining a paronychium.

INFECTIONS IN THE HAND

Relevant Anatomy

Spaces of the Hand

The fascia and fascial septae in the hand form many spaces. The anatomy of these spaces is important because these spaces may get infected and infection from one space may reach other space. The important spaces of hand are:

- **Palmar spaces:**
 - Pulp space of fingers
 - Web space
- **Deep palmar space:**
 - Mid palmar space
 - Thenar space
- **Dorsal spaces:**
 - Dorsal subcutaneous space
 - Dorsal subaponeurotic space
- The forearm space of Parona.

Some important infections in hand:

Felon: A felon is the infection of the subcutaneous tissue of distal pulp of digit, the most common site being thumb followed by index finger. The distal pulp is divided into tiny compartments by strong fibrous septae that traverse from skin to bone, because of these septae any swelling in this space causes very pain due to increased pressure within the pulp (Fig. 5.16). Infection is generally caused by penetrating foreign body or pinprick for medical reasons (hematocrit or blood glucose estimation). *S. aureus* is the most common causative organism. Throbbing pain, swelling and redness of the terminal pulp are the presenting symptoms. Abscess formation may follow rapidly. Abscess can extend into underlying bone and may cause osteomyelitis of distal phalanx.

Treatment: Treatment consists of antibiotics and incision for drainage.

“Whitlow” is an infection of the pulp space of digit usually caused by Herpes simplex type I virus. The distinction between “felon” and “whitlow” is made primarily on the basis of history. Herpetic whitlow usually presents with a prodromal phase of 24–72 hours of burning pain prior to

the development of the classical skin changes. First there is erythema and swelling, then the formation of clear vesicles. The vesicles coalesce, often around the nail fold. The fluid within the vesicles is turbid but not frankly purulent. The pulp of the affected digit is not tense as in a felon. The disease persists over approximately 2 weeks and the same resolves over the next 1 week.

Web Space Infection (Collar Button Abscess)

Web space is the fat-filled triangular interdigital space at the level of metacarpophalangeal (MCP) joints. This infection usually seen in laborers, begins beneath palmar creases. Patient presents with redness swelling and tenderness over the web space (Fig. 5.17). Abscess, if undrained may spread through the lumbrical canal into the mid-palmar space. Treatment involves incision and drainage.

Deep Palmar Space (Mid-palmar and Thenar Space) Infections

Deep palmar space lies deep to the flexor tendons and their synovial sheaths. This space is divided into a mid-palmar

space (medially) and a thenar space (laterally) by a fascial membrane that passes obliquely from third metacarpal to fascia, dorsal to flexor tendons of index finger (Figs. 5.18A and B). Lateral to the thenar space lies thenar muscles and medial to mid-palmar space lies hypothenar muscles.

Mid-palmar Space

Triangular space is present under ulnar half of hollow of hand. Proximally, it extends up to the distal margin of flexor retinaculum and communicates with forearm space. Distally it extends up to distal palmar crease and communicates with fascial sheaths of third and fourth lumbrical muscles.

The space is bounded anteriorly by palmar aponeurosis and flexor tendons of third, fourth and fifth fingers and posteriorly by third, fourth and fifth metacarpals, medially by hypothenar septum and laterally by mid-palmar (oblique) septum.

Thenar Space

Triangular space is present under radial half of the hollow of hand. Proximally, it extends up to the distal margin of

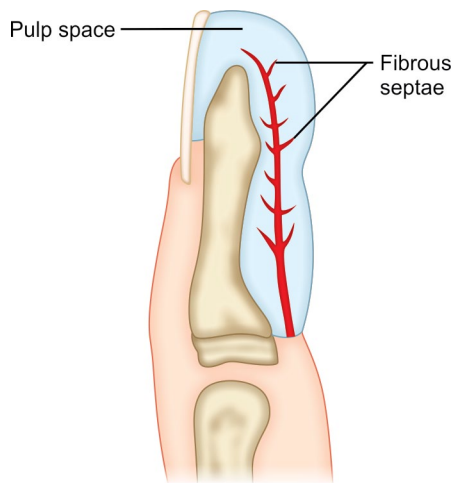
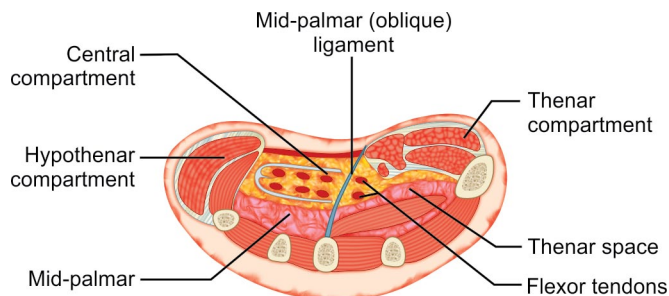


Fig. 5.16: Pulp space of digit.

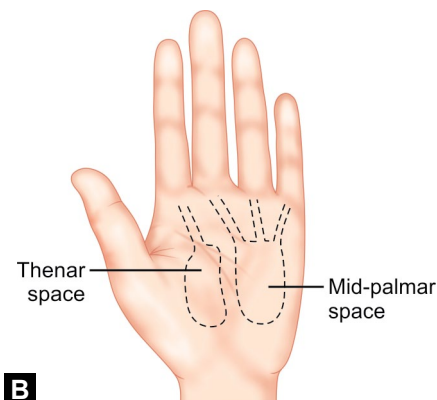


Fig. 5.17: Collar button abscess.



A

Figs. 5.18A and B: Deep palmar spaces of hand.



B

of flexor retinaculum and communicates with forearm space. Distally, it extends up to the proximal transverse palmar crease and communicates with subcutaneous web of thumb.

It is bounded anteriorly by palmar aponeurosis and posteriorly by first dorsal interosseous muscle, medially by mid-palmar septum and laterally by lateral palmar septum.

The infection in these spaces can be reached by penetrating wound, hematogenous route or infection from nearby site like web space infection or flexor tenosynovitis. There is pain, swelling and tenderness on the volar aspect of hand. A mid-palmar abscess can cause a systemic reaction, pain, tenderness, inability to move the long and ring fingers actively and swelling of hand and fingers. A thenar abscess causes similar symptoms but thumb web is more swollen.

Treatment: Incision and drainage under antibiotic cover. Transverse palmar incision is given between the two parallel flexion palmar creases for mid-palmar abscess. Thenar crease incision is given for thenar abscess (Fig. 5.19).

Dorsal Space Infections

Dorsal Subcutaneous Space

It lies deep to loose skin of dorsum of hand.

Dorsal Subaponeurotic Space

It lies deep to the dorsal aponeurosis of the hand. Infection of this space is usually caused by penetrating injuries to the dorsum of hand or local spread from other infection. Swelling, redness, and warmth over dorsum of hand, tenderness, painful finger extension and draining sinuses are usually seen.

Treatment: Incision and drainage along with antibiotics. Most dorsal abscesses are drained through a single longitudinal incision centered over the abscess. Large abscess may require two parallel incision, one over second metacarpal and other between fourth and fifth metacarpals.

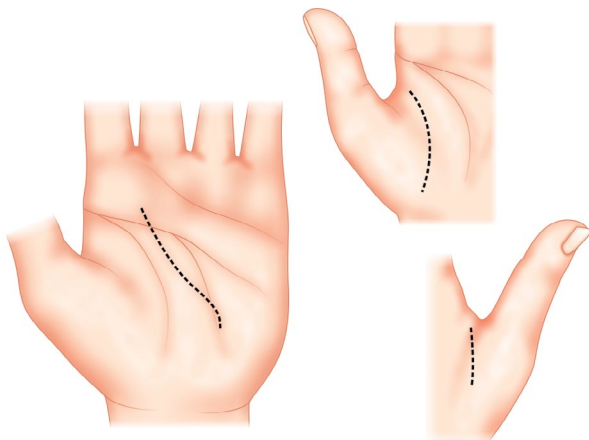


Fig. 5.19: Drainage of deep palmar abscesses.

Infections of the Forearm

Space of Parona

Rectangular space situated deep to the lower part of forearm just above the wrist. It is bordered by pronator quadratus dorsally, flexor pollicis longus laterally, the flexor carpi ulnaris medially and long flexor tendons on the palmar aspect. Inferiorly, it extends up to flexor retinaculum and communicates with the mid-palmar space and superiorly it may extend up to oblique origin of flexor digitorum superficialis.

Infections in this space generally are related to infections of the digital synovial sheaths, especially the ulnar bursa (*see below*).

ACUTE SUPPURATIVE TENOSYNOVITIS

Relevant Anatomy

The flexor tendons of the fingers are surrounded by their own synovial sheaths. The digital synovial sheaths of the second, third and fourth digits are independent and terminate proximally at the level of the MCP joints. The digital synovial sheath of the little finger continues proximally in the palm as the ulnar bursa while that of the thumb as radial bursa (Fig. 5.20A). The two bursas extend proximally for 2–3 cm above the wrist and communicate with each other and may communicate with forearm space of “Parona”.

Acute suppurative tenosynovitis is a purulent infection of the digital tendon sheaths. Although rare, this is the most serious hand infections as if left untreated, this infection can lead to destruction of the gliding surfaces in the sheath, necrosis of tendons, osteomyelitis and even amputation. Most commonly affected are the ring, middle and index fingers and *S. aureus* is the most common infecting organism. A history of penetrating injury is typical, by a sharp object like a needle, however, a few cases can occur as a result of hematogenous spread, usually caused by gonococcus.

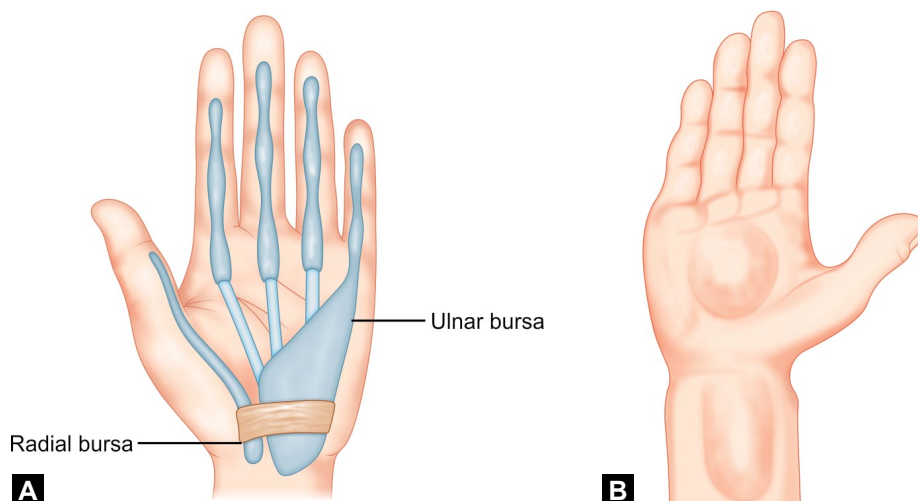
Clinical Features

The affected finger is grossly swollen and tender.

Kanavel described the four cardinal signs of flexor tenosynovitis: (1) fusiform swelling of the finger, (2) partially flexed posture of the digit, (3) tenderness over the entire flexor tendon sheath and (4) disproportionate pain on passive extension. The last sign is the most constant and typically the first being present in early cases.

Spread

Infections of the thumb can spread to radial and then to ulnar bursa while the infections of the little finger spread to involved the ulnar bursa primarily and then the forearm space of “Parona”. This results in an hour glass swelling



Figs. 5.20A and B: (A) Digital synovial sheaths. (B) Showing a compound palmar ganglion.

both proximal and distal to wrist (flexor retinaculum) and is called as “Compound Palmar ganglion” (Fig. 5.20B).

Treatment

An aggressive treatment is needed. Infections of the digital synovial sheaths are drained by two transverse incisions, one in DIP joint crease and the other in distal palmar crease. Ulnar bursa is approached by an incision along lateral margin of hypothenar eminence while the radial bursa is approached via incision along the medial margin of thenar eminence. A good antibiotic cover is added.

HIGH-YIELD POINTS

Spread of infections in hand:

- *Thenar space infection results from:* Index finger or thumb.
- *Mid-palmar space:* Middle and ring fingers
- *Infection of the thumb spreads to radial bursa*
- *Infection from little finger spreads to ulnar bursa.*
- Compound palmar ganglion is most commonly seen in Rheumatoid arthritis and Tuberculosis.

SKELETAL TUBERCULOSIS: INTRODUCTION

INTRODUCTION

Although the osteoarticular tuberculosis is disappearing in western countries but in developing countries it is still a major public health problem.

After lung and lymph node, the bone and joint is the third most common site of tuberculosis. Amongst skeletal system, spine is the most common site of involvement followed by hip and then by knee. Least common orthopedic site is bursa (out of which the trochanteric bursa is most commonly involved).

ETIOLOGY

The causative organism is *Mycobacterium tuberculosis*. Infection is paucibacillary and is always secondary to lung infection. Tubercle bacilli reach to the bone via hematogenous route or by direct extension from a neighboring focus. Lesion starts from metaphysis in children and epiphysis in adults.

PATHOGENESIS

The organism on reaching the bone causes chronic granulomatous inflammatory response with central caseous necrosis. On the basis of pathology, the lesions may be of two types. The caseous exudative type has exudate, is more destructive with abscess formation. The granular dry type is less destructive and abscess formation is rare.

CLINICAL FEATURES

The disease affects all age groups and both genders equally. Patients present with mono articular or mono osseous involvement with insidious onset dull aching pain with constitutional symptoms like low-grade fever, weight loss, anorexia, night sweats and night cries. On examination, tenderness, muscle wasting, painful restriction of movements and regional lymph node enlargement may be seen.

INVESTIGATIONS

Hemoglobin level is low (normocytic normochromic anemia of chronic disease). TLC increases with lymphocytosis in differential count. ESR is elevated. Ziehl-Neelsen (ZN) staining/Biopsy may be done to confirm the diagnosis.

X-RAY FEATURES

In Tubercular arthritis localized osteoporosis is the first radiological sign of active disease. The articular margins and bony cortices become irregular and hazy with no periosteal reaction/new bone formation. Bony destruction in absence of periosteal new bone formation is pathognomonic of tuberculosis. The synovial fluid, thickened synovium and pericapsular tissues may cause a soft tissue swelling. With destruction of articular cartilage, the joint space is reduced. In later stages, there is bone destruction with collapse, subluxation/dislocation and deformity of the joint.

PRINCIPLES OF TREATMENT

Chemotherapy: Antitubercular therapy is the mainstay of treatment. Same drugs as per the directly observed treatment short (DOTS) regimen are used. However, there are subtle differences in administration. Firstly, daily dose therapy is given (c.f. alternate regimen in DOTS), owing to poor bone penetration of these drugs. Secondly, the duration ranges from 9 months to 18 months mostly.

Antituberculous therapy (ATT) is stopped once the ESR of patient returns to normal, radiograph shows signs of healing and clinically tenderness in affected area disappears.

Nutrition: High protein diet and exposure to fresh air and sunlight provide good resistance to fight with infection.

Rest and traction: The affected extremity should be kept in functional position during the period of pain to decrease pain and to avoid the deformity/contractures.

Physiotherapy: With start of ATT, the disease activity and pain is reduced, gradual mobilization exercises is started followed by strengthening exercises.

Surgical management: Following surgeries may be required in different patients depending upon clinical situation:

- **Cold abscess:** Resolve with chemotherapy only. For those that are peripherally palpable and for those that are causing symptoms (like a psoas abscess causing pseudo flexion deformity of hip), aspiration (by anti-gravity method) and instillation of streptomycin injection in the cavity is needed.
- **Curettage of lesion:** For tubercular osteomyelitis, lytic lesion in the bone is curetted and the sample is sent for biopsy.
- **Joint debridement:** For tubercular arthritis, joint debridement is done and material sent for biopsy. This is also known as "joint clearance surgery".
- **Synovectomy:** In case of synovial tuberculosis, synovectomy is done partial or total depending on the extent of involvement.

TUBERCULOSIS OF SPINE

Also known as "Pott's Disease", named after Percival Pott (1779)

INTRODUCTION

The spine is the most common site of skeletal tuberculosis. 50% of cases of spinal tuberculosis involve dorsal region followed by lumbar and then dorso-lumbar (D12-L1) region. Although people of extremes of age are mostly affected, the more common presentation is in the first 2 decades of life.

PATHOLOGY

Tuberculosis of spine is always secondary to lung lesion. Bacilli reach the spine via hematogenous route (arteries or Batson para vertebral plexus of veins).

Anatomical types of spinal lesions (Fig. 5.21):

- **Paradiscal:** The most common type and disk space narrowing is earliest finding. Contagious area of two adjacent vertebrae along with disk is affected. It is because, the lower half of one vertebra and the upper half of one below it with the intervening disk, develop from each pair of sclerotome and thus have a common blood supply (Fig. 5.22).

- **Central:** Body of a vertebra is affected. In this infection, the disk space is preserved (Fig. 5.23). The whole vertebrae collapse in later stages leading to a "concertina collapse".
- **Anterior:** Infection starts beneath anterior longitudinal ligament and involves anterior margin of vertebral body. Infection can spread up and down under anterior longitudinal ligament. The pus that accumulates in this area often on radiograph gives an appearance of an aneurysm of aorta, hence called the "Aneurysmal phenomena".
- **Posterior (Appendiceal):** Posterior involvement is rare and involves the pedicles, laminae, transverse process, facet joints and spinous process. Facet joints followed by spinous process are the least commonly involved structures in posterior type.

CLINICAL FEATURES

Back pain is the earliest and most common symptom. Patient usually presents with pain in mid back, stiffness, swelling, deformity, and/or paraparesis with constitutional

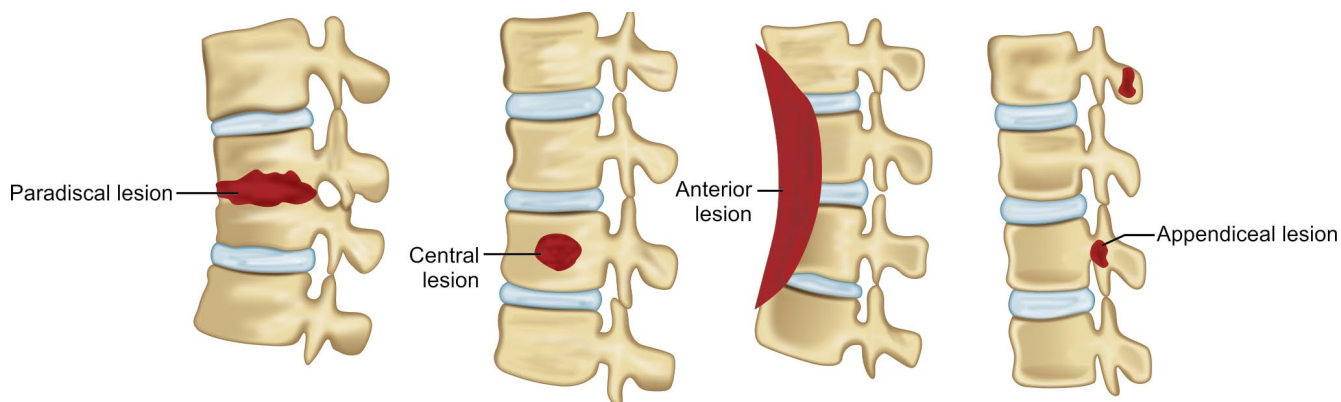


Fig. 5.21: Anatomical types of spinal lesions in TB spine.

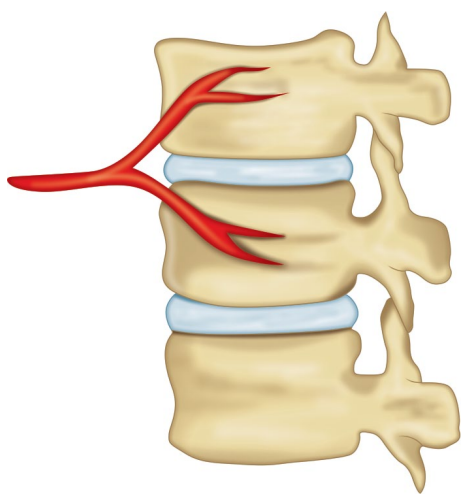


Fig. 5.22: Pattern of blood supply of a vertebra.

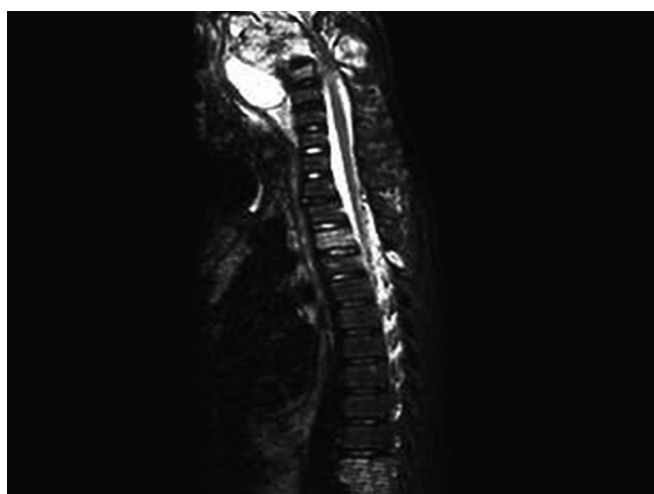


Fig. 5.23: MRI of dorsal spine (sagittal section) showing the involvement of vertebral body by tuberculosis (central TB).

symptoms like low-grade fever with evening rise of temperature, malaise, anorexia and weight loss. Pain is insidious onset, diffuse and dull aching in character. It may be radiating in nature if the disease process involves a nerve root.

On examination, the spine is stiff and painful on movement. In fact, the first clinical sign is paraspinal muscle spasm. Collapse of vertebral bodies leads to localized kyphotic deformity at the back causing prominent spinous process, which are tender to palpation (Fig. 5.24). Kyphus can be of three types: (1) knuckle (single vertebra involved), (2) angular kyphus (2 or 3 vertebra involved, gibbus was older term for same) or rounded kyphus (> 3 vertebra involved).

A cold abscess may be present far away from vertebral column along the fascial planes or course of neurovascular bundle. The usual sites are anterior/posterior triangle of neck, paraspinal region of back, along brachial plexus in axilla, along intercostal nerves in anterior/lateral chest wall, iliac fossa, psoas abscess, lumbar triangle (Fig. 5.25) and in upper part of thigh.

Past history or family history of tuberculosis should also raise the suspicion of the disease.



Fig. 5.24: Prominent spinous process at back (Knuckle, arrow).
Courtesy: Dr Matad Lokeshwaraiiah Chetan.

In late stages, if neglected, more and more vertebral body collapses and the necrotic caseous material herniates back and compresses the neural structures, the patient then may present with paraparesis (Fig. 5.26).



Fig. 5.25: Clinical picture showing cold abscess in tuberculosis tracked to lumbar triangle at the back.

NEUROLOGICAL COMPLICATION (POTT'S PARAPLEGIA)

Incidence of Pott's paraplegia is 10–30% and is commonly seen in disease of upper thoracic spine because of narrow canal space.

Causes of paraplegia can be grouped as shown in Table 5.1.

ORDER OF NEUROLOGICAL INVOLVEMENT

Rarely is paraplegia the presenting symptom. Motor system is almost always affected before the sensory system because diseased area in spine (i.e. vertebral body) lies anterior to the cord near the motor tracts (Fig. 5.28). The first neurological sign is ankle clonus followed by plantar extensor. Thereafter the patient develops mild spastic motor weakness manifesting as clumpsiness or incoordination of gait which ends in severe weakness to the extent where patient is unable to stand and is bed ridden. The sensations carried by lateral spinothalamic tract—pain, crude touch and temperature are affected first followed by sensations carried by dorsal column—vibration and proprioception. Lastly, there is paralysis of anal sphincter and bladder. In extremely severe cases, spasticity disappears and paralysis becomes flaccid.

Sudden onset paraplegia may be caused by ischemia of the cord due to thromboembolic phenomena, or cord transection due to pathological dislocation or rapid accumulated epidural abscess.

Stages of paraplegia:

Stage 1: Patient is unaware of neural deficit, physician detects plantar extensor and/or clonus.

Stage 2: Patient is aware of neural deficit, presents with complaints of clumsiness or incoordination while walking but is able to manage to walk with or without support.

Stage 3: Nonambulatory patient due to paraplegia in extension; sensory loss is less than 50%.



Fig. 5.26: Cord compression (arrow) in TB spine.

Table 5.1: Causes of paraplegia in tuberculosis (TB) spine

Extrinsic compression of cord

Inflammatory	Inflammatory edema
	Granulation tissue and pus (Most common cause)
Mechanical	Tubercular abscess
	Caseous tissue
	Tubercular debris
	Sequestra
	Canal stenosis
	Internal gibbus*
	Pathological dislocation of spine

Intrinsic pathology in cord

Vascular	Thrombosis or endarteritis of spinal vessels
Degenerative	Myelitis
	Syringomyelic changes
	Cord stretching due to severe deformity

Atypical causes: Spinal tumor syndrome** (Involvement of cord without osseous changes):

Extradural granuloma/Tuberculoma

**Internal Gibbus:* Collapse of vertebral body causes angulation of spine that leads to formation of a bony spur that may press on the anterior aspect of the spinal cord (Fig. 5.27).

***Spinal Tumor Syndrome:* See “differential diagnosis”.

Stage 4: Stage 3 + flexor spasms/paraplegia in flexion/flaccid paraplegia/sensory loss more than 50%/bladder-bowel involved.

Classification of paraplegia in TB spine (Griffith's classification)

Early onset paraplegia: It occurs during active phase of disease usually within 2 years of onset. It is caused due to

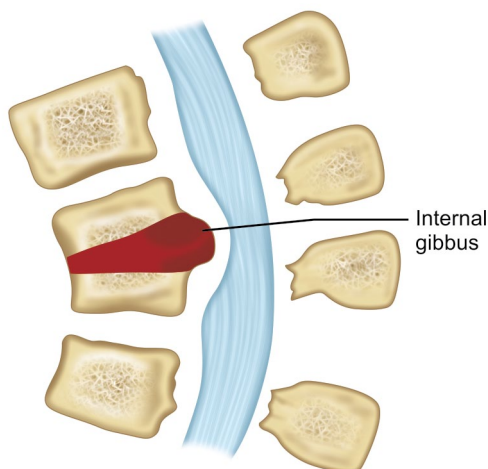


Fig. 5.27: Diagrammatic representation of internal gibbus.

inflammatory edema, granulation tissue, abscess, caseous tissue or ischemic lesion of cord.

Late onset paraplegia: It occurs after 2 years of the persistence of disease. It may be associated with recrudescence of the disease or due to mechanical pressure on cord. It is caused due to caseous tissue, tubercular debris, sequestra, internal gibbus, canal stenosis or severe kyphotic deformity.

DIAGNOSIS

Blood investigations show low hemoglobin, increased TLC and elevated ESR.

Radiological Features

The classic triad of TB spine is disk space reduction, lysis of the vertebra and paravertebral soft tissue abscesses (Fig. 5.29). Disk space reduction is the earliest finding, seen in commoner paradiskal type of tuberculosis. It is due to lack of nutrition or prolapse of nucleus pulposus into soft cancellous diseased body. Thereafter, the contiguous margins of the affected vertebrae get eroded. With further destruction of vertebral body, there is anterior wedging of vertebra leading to kyphotic deformity.

Paravertebral soft tissue shadow corresponding to site of affected vertebra indicates paravertebral abscess. In cervical spine tuberculosis, a retropharyngeal abscess may be seen on lateral view (Fig. 5.29). It is identified when space between pharynx and spine is more than 0.5 cm (if above cricoid cartilage) or more than 1.5 cm (if below cricoid cartilage). Psoas abscess is seen as soft tissue shadow on X-ray abdomen. In thoracic spine, paravertebral collection (Fig. 5.30) may either present as a fusiform/bird nest abscess (abscess with length greater than breadth) or a tense/globular abscess (abscess with width greater than length indicating pus under pressure). An abscess in dorsal spine may lead to a widened mediastinum.

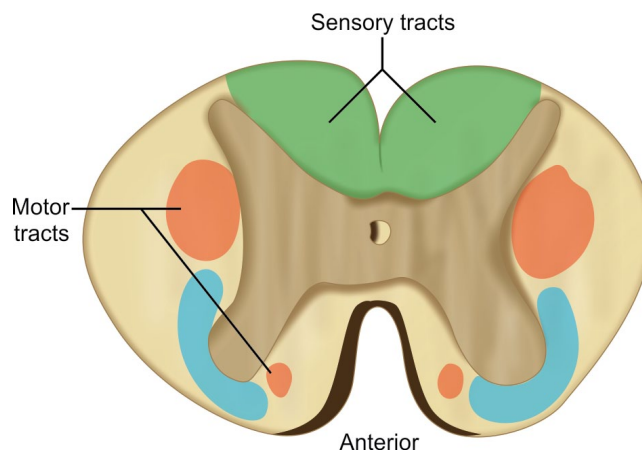


Fig. 5.28: Anterior compression of cord.

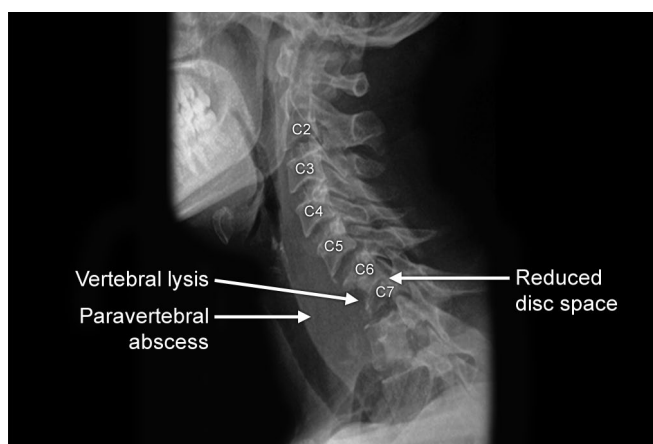


Fig. 5.29: X-ray of cervical spine lateral view showing the classic triad of tuberculosis.

Aneurysmal sign: Erosion of the anterior part of the body seen in anterior type of tuberculosis, sometimes also seen in cases of aneurysm of aorta.

Computed tomography scan is a useful tool in assessing the destructive lesions of vertebral body. Shape, extent and route of spread of cold abscess can be very well visualized on CT scan.

Magnetic resonance imaging is investigation of choice as it can evaluate the extent of cord compression (Fig. 5.31A). It is extremely useful in diagnosis of difficult and rare sites like craniovertebral or cervico dorsal region. It also shows the type and extent of paravertebral abscess.

Biopsy may be required in doubtful diagnosis. Infact, CT guided transpedicular vertebral biopsy is the gold standard for diagnosis of spinal tuberculosis.

DIFFERENTIAL DIAGNOSIS

Traumatic vertebral fracture: No constitutional symptoms, rather history of trauma may be there. X-ray shows the fracture with no paravertebral abscess.

Disk prolapse: Young age, history of lifting heavy weight and intact vertebral body on radiography with absent paravertebral shadow clinch the diagnosis.

Tumor (Fig. 5.31B): It is the most important differential especially in older individuals where metastasis is to be ruled out. Preservation of disk space and absence of paravertebral shadow provide the diagnosis. Mostly tumors tend to involve pedicles.

Ankylosing spondylitis: Patients may present with chronic back pain, however, absence of constitutional symptoms, characteristic age, presence of sacroillitis on X-ray and reduced chest expansion provide the diagnosis.

Spinal tumor syndrome (Figs. 5.32A and B): The name is a misnomer as it is not a tumor of spine. It refers to a condition when an extra dural mass (a granuloma over dura-mater/tuberculoma) compresses the cord. On X-ray, there are no osseous changes but patient may present with neurological deficit. MRI is the investigation of choice. Since vertebra is not eroded, surgical management involves

decompression via laminectomy unlike Pott's spine where laminectomy is contraindicated and anterolateral decompression is the treatment of choice.

TREATMENT

Chemotherapy—Anti-tubercular treatment (ATT) is started in all cases.

Bed rest and traction: Absolute bed rest is required for pain relief and to prevent further collapse of vertebra, pathological dislocation and neurological complication. In the treatment of cervical spine tuberculosis (if lesion seems unstable), skeletal traction by crutchfield tongs is used to put the diseased part at rest.

Mobilization: Gradual mobilization is encouraged with help of spinal brace as soon as the patient is comfortable (Fig. 5.33).

Treatment of abscess: Aspirated when palpable or symptomatic and 1 g of streptomycin is instilled.

Treatment of a case with paraplegia

All patients are initially started on antitubercular therapy as soon as the diagnosis is made and put on absolute bed rest.

Paraplegic care: A paraplegic patient is bed ridden and is vulnerable to numerous complications associated with recumbency. These complications are bed sores (decubitus ulcer), hypostatic pneumonia, deep venous thrombosis, constipation, urinary tract infection due to foley's catheter, joint stiffness, osteoporosis, muscle atrophy and depression.

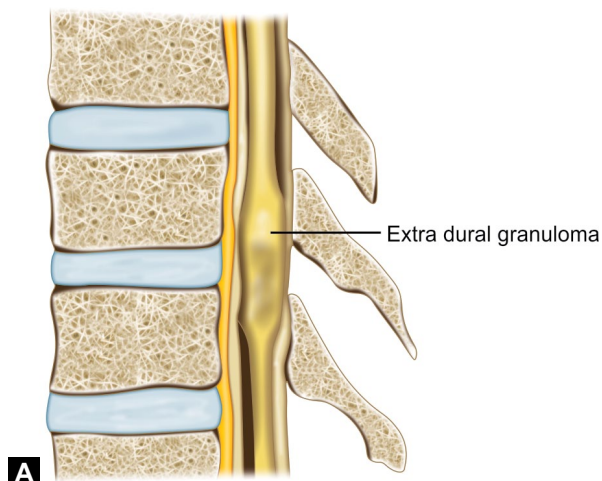
To prevent these complications, patient is encouraged to take frequent turns in bed specially 2 hour log rolling and application of talcum powder over the back to avoid bed sores. Air mattress is also used. Incentive spirometer and chest thumping (chest physiotherapy) is done to avoid chest complications. High fiber diet and bulk laxatives for constipation and bladder wash to prevent urinary tract infection are prescribed.



Fig. 5.30: Paravertebral abscess in TB thoracic spine.



Figs. 5.31A and B: (A) MRI of thoracic spine (sagittal section) showing loss of disk space and cord compression in tubercular affection of thoracic spine; (B) Tumor (Ewing sarcoma, arrow) of L5 vertebrae.



Figs. 5.32A and B: Spinal tumor syndrome. (A) Pictorial description (B) MRI thoracic spine (sagittal section) showing Extra dural granuloma.



Fig. 5.33: Mobilization in brace.

Operative treatment: Operative treatment is needed for those who do not respond to minimum 3 weeks of ATT. The indications for surgery are given in Box 5.3.

Operative Procedures

Costotransversectomy (Fig. 5.34A): removal of transverse processes and 6–8 cm of medial end of ribs attaching to diseased vertebrae. Minimum two and maximum four ribs can be removed.

Anterolateral decompression (Fig. 5.34B): most commonly performed procedure. Along with costotransversectomy, the diseased part of vertebra lying anterior and lateral to the cord is debrided and the cord is decompressed. In ALD, the structures removed are ribs, transverse process, pedicle and part of vertebral body. Spinous process and lamina are not removed because of risk of instability of spine.

Laminectomy: Removal of lamina in TB spine is contraindicated because TB usually involves anterior structures and removal of posterior structures is an unsound

Box 5.3: Indications of surgery

Absolute indications

- Paraparesis which do not show the signs of progressive recovery on conservative therapy.
- Paraparesis which develop during conservative treatment
- Paraparesis which becomes worse on conservative therapy
- Patients with recurrence of paraparesis.
- Patients of cervical spine tuberculosis having large prevertebral abscess causing dyspnea or difficulty in deglutition
- Grade 4 paraplegia.

Relative indications

- Paraplegia with onset in old age
- Painful paraplegia.

Rare indications

- Spinal tumor syndrome
- Cauda equina syndrome
- Posterior spinal disease.

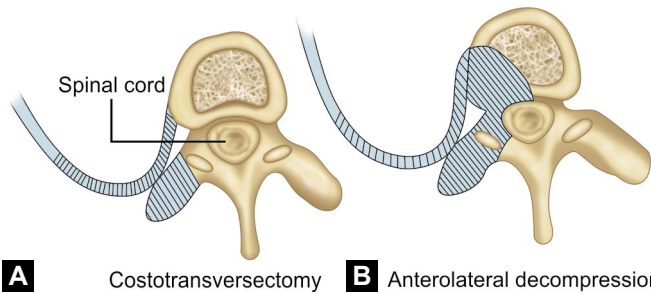
procedure and will further jeopardize stability of spine. However, laminectomy is indicated in cases of spinal tumor syndrome and posterior spinal disease.

Anterior decompression: It refers to going via anterior approach and removing the diseased vertebral body and caseous tissue to decompress the cord. Theoretically it is the best surgical procedure but since most orthopedic surgeons are unfamiliar with the approach, it is generally not preferred. It is mostly advocated in cases of cervical spine tuberculosis.

Prognostic factors: See Table 5.2.

HEALING OF DISEASE

As the disease heals, lytic focus gets surrounded by sclerotic bone. Even whole of vertebral body may become sclerotic (Ivory vertebra).



Figs. 5.34A and B: Surgery for Pott's spine (Shaded portion indicates the structures to be removed).

Table 5.2: Prognostic factors in tuberculosis (TB) spine*

Factors	Good	Bad
Age	young	old
Onset	early onset	late onset
Duration	shorter	longer
Progression	slow	rapid
Severity	stages 1 and 2	stages 3 and 4
General condition	good	poor
Vertebral disease	active	healed
Kyphosis	< 60°	> 60°
Cord status on MRI	normal	myelomalacic changes

* Tuberculosis of the skeletal system by Dr S M Tuli.

Earliest radiological sign of healing is sharpening of fuzzy paradiscal margins.

End result: Even though infection may be eliminated by chemotherapy, when several vertebrae have been damaged and disk space destroyed, the adjacent vertebrae undergo fusion resulting in bony ankylosis/bone block formation (Fig. 5.35). This is in contrast to other joints where TB leads to fibrous ankylosis, as in spine the area of contact between cancellous vertebral surfaces is high and in addition weight bearing induces bone formation.

HIGH-YIELD POINTS

- Tuberculosis is the most common cause of kyphosis in India.
- Tuberculosis is the most common opportunistic infection in HIV infected individuals.

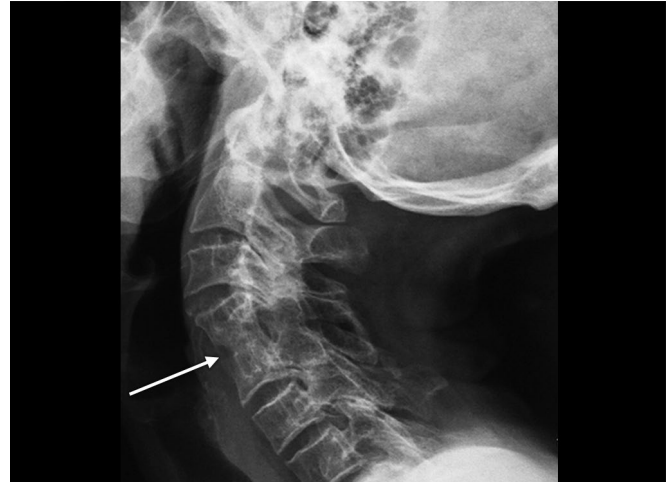


Fig. 5.35: Bony ankylosis (arrow) between C4 and C5 vertebrae.

- In 7% cases more than one level is involved in TB spine.
- Although disk space reduction is the earliest radiological sign of TB spine, the infection actually starts in the vertebral body adjacent to the disk, and it is later that the disk is secondarily destroyed.

Middle path regime (advocated By Dr S M Tuli, India): It is a general guide for treatment of TB spine and refers to “nonoperative treatment for all and operative in cases of failure of conservative therapy and complications”.

Hong Kong procedure (Radical anterior decompression and spinal fusion): It is a radical anterior debridement of spine followed by removal of diseased vertebral body and bone grafting in the area of the removed body. It helps in early healing of the disease and prevents also a deformity in better way, but needs appropriate facilities. It is usually done in cervical spine TB.

Prof. Rajshekharan (India) has described “spine at risk signs” (X-ray signs) in tuberculosis to caution against a progression of the tuberculous deformity. These include:

- Subluxation of the facet joint at the apex of the kyphus deformity
- Presence of retropulsion of the vertebra
- Posterior toppling of the vertebra
- Lateral translation of the vertebra

TUBERCULOSIS OF HIP

INTRODUCTION

Most common site of extraspinal TB is hip. The initial focus starts in acetabular roof (most common), epiphysis, metaphysis (area called as Babcock's triangle) or in greater trochanter. If the disease starts in acetabulum, the joint involvement is late and mild in severity. Rarely the disease may start in synovium and involve the bones later.

CLINICAL FEATURES

Mostly affected are children between the age of 5 years and 15 years. Pain, limp, deformity, stiffness, shortening and fullness around hip are the presenting symptoms. Constitutional symptoms like fever, weight loss, and loss of appetite are usually present. A child may wake up from sleep due to night cries. Rarely the patient may present

with palpable cold abscess, (femoral triangle, over medial, lateral or posterior part of thigh, ischioirectal fossa), discharging sinuses or pathological dislocation of hip if neglected.

Pain around the hip is insidious onset, gradually progressive and may be referred to medial aspect of knee.

Painful limp is the earliest and most common symptom. Patient walks with antalgic gait (decreased stance phase by putting little pressure for short time on affected limb). Muscle wasting of anterior thigh and gluteus maximus is seen.

On examination, tenderness may be present over anterior hip joint elicited 1–1.5 cm down and lateral to mid-inguinal point.

Deformity and movements: In sagittal plane, flexion deformity is present which is compensated by exaggerated lumbar lordosis (up to 30° of flexion deformity can be compensated). In coronal plane, any of adduction or abduction deformity may be seen. There may be global restriction of movements in all directions. In late stages, there is no movement possible (bony ankylosis).

STAGES OF TB HIP

The disease process progresses through the following clinical stages:

Stage 1 (Stage of tubercular synovitis): Due to synovitis, there is joint effusion and the joint is held in position of maximum capacity, i.e. flexion, abduction and external rotation causing apparent lengthening. On X-ray all that is visible is a widened joint space due to effusion and generalized osteopenia.

Stage 2 (Stage of early arthritis): With advancement of the disease process, there is destruction of articular cartilage. With spasm of flexors and adductors of hip, there is flexion, adduction and internal rotation deformity with apparent shortening. True shortening is also present due to

damage to articular cartilage but is less than 1 cm. X-ray shows decrease in joint space and osteopenia.

Stage 3 (Stage of late arthritis): With further destruction, clinical signs of flexion, adduction, internal rotation deformities and apparent shortening are exaggerated. True shortening is more than 1 cm. There is gross restriction of movements and muscle wasting. X-rays may show complete loss of joint space with destruction of head/acetabulum.

Stage 4 (Late arthritis with subluxation/dislocation): There are flexion adduction and internal rotation deformities with gross shortening. With destruction of acetabulum, femur head and ligaments, the upper end of femur may displace upwards and dorsally leaving the lower part of acetabulum empty but forming a false acetabulum higher up (wandering acetabulum, Fig. 5.36A). In some cases, the head and neck of femur gets smaller in size and contained in an enlarged acetabulum (mortar and pestle appearance, Fig. 5.36B). Severe destruction of capsule and acetabulum may eventually lead to pathological dislocation of femur head.

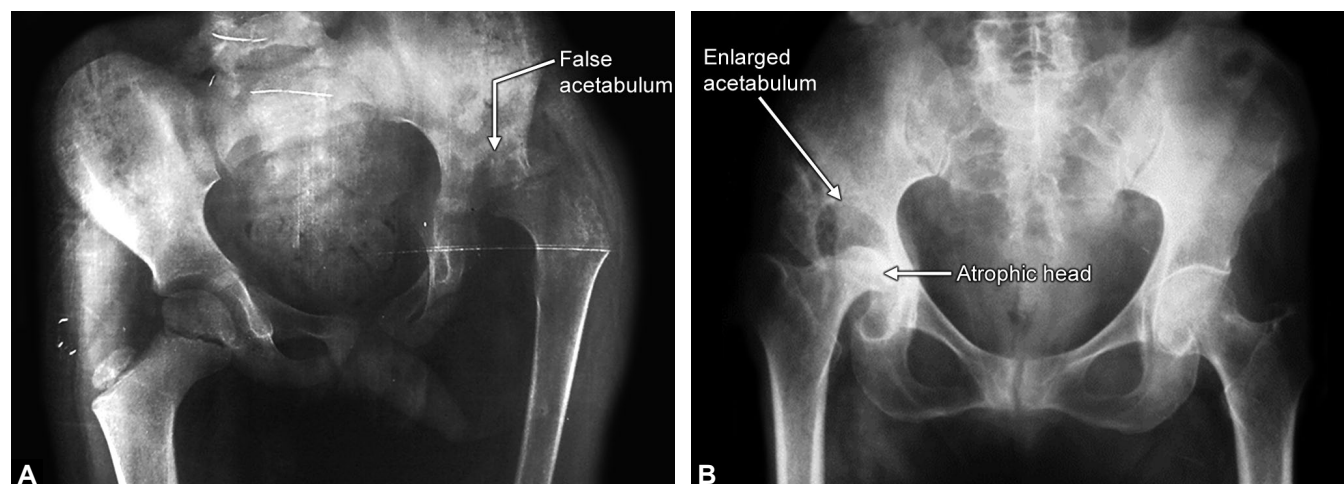
RADIOLOGICAL EXAMINATION (FIG. 5.37)

X-ray pelvis with bilateral hip AP view and hip lateral view is required. Reduction of joint space is the classical feature of tuberculosis that occurs because of destruction of cartilage. However, the earliest feature is juxta-articular osteopenia that is well appreciated when compared to opposite side. Lytic lesions may be seen in acetabular roof or femoral head.

DIFFERENTIAL DIAGNOSIS

In Children

Low-grade septic arthritis: Aspiration of pus and gram-stain and culture solves the query.



Figs. 5.36A and B: Tuberculosis of hip joint: (A) Wandering acetabulum and (B) Pestle and Mortar appearance. Courtesy: Dr Gaurav gupta.

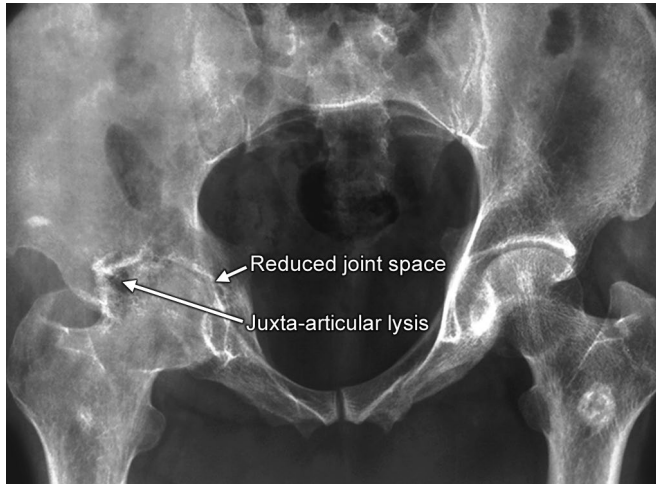


Fig. 5.37: X-ray pelvis with both hips AP view of patient with TB right hip.

Developmental dysplasia of the hip (DDH): Limp is painless, so are range of movements and telescoping is positive.

Congenital coxa vara: Children with this condition present with painless limp and restricted abduction and internal rotation. Fairbank's triangle may be visible in neck.

Perthes disease: It is the closest differential. It affects classically children in the age group 4–8 years. Symptoms are intermittent and child may present with painful limp. Clinically these patients have limited abduction and internal rotation while in TB, all range of motions are painful. MRI may be done where TB may show destruction of both acetabulum and femoral head while in Perthes disease, only the head is destroyed and there is no evidence of any collection.

In Adults

Monoarticular rheumatoid arthritis: Rare disease. Joint space is uniformly narrowed. RA factor or Anti-CCP may aid the diagnosis.

Osteoarthritis: Pain along with crepitus may be present. Rather than osteopenia on X-ray there is subchondral sclerosis. Constitutional symptoms are absent so is collection on MRI.

MANAGEMENT

Active Stage

Tuberculosis hip is said to be active when the hip is extremely painful with presence of constitutional symptoms. On examination, there is rise in local temperature, hip is tender, and range of motion is painful.

Nonoperative treatment: Patient is admitted and anti-tubercular therapy is started. The affected hip is put to rest

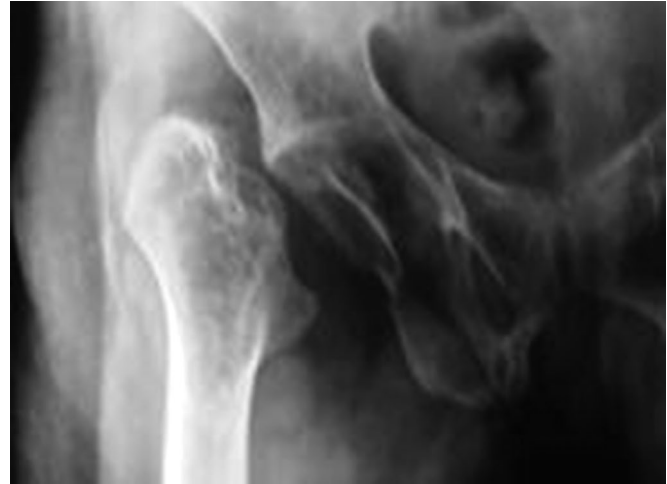


Fig. 5.38: X-ray pelvis with both hip joints AP view showing Girdlestone arthroplasty on right side.

by using skin or skeletal traction. Traction relieves spasm, reduces pain, prevent/correct deformity and prevent subluxation of hip. Abscess if present, is aspirated. When pain subsides, active assisted range of motion exercises are started.

Operative treatment: If there is no adequate response of conservative therapy, joint debridement (Wilkinson's joint clearance surgery) is done. In this, the joint is opened and pus, necrotic caseous tissue, debris, inflamed synovium, and other dead tissues are removed, joint is curetted and washed. Synovium and tissues are sent for histopathological examination.

Healed Stage

When patient presents in healing or healed stage, the disease has already eaten up the normal bone and patient presents mainly with deformity, instability and shortening with minimal pain. In such cases, the main aim is to provide painless hip with maximum useful functions.

Four options are present to tackle such situation:

1. *Corrective osteotomy:* Cases where hip is ankylosed in an unacceptable position, a subtrochanteric osteotomy will be helpful to correct the deformity.
2. *Girdlestone excisional arthroplasty (Fig. 5.38):* In this procedure, the head and neck of femur are excised. The dead necrotic tissues and granulation tissues are removed. Postoperatively, skeletal traction is given for 3 weeks followed by range of motion exercises of hip is started. It provides painless, mobile but unstable joint. Advantages are ability to squat and sit cross legged. Drawbacks are instability and shortening.
3. *Arthrodesis:* Classically, this operation is indicated in an adult presenting with unsound/painful ankylosis.

In this procedure, the hip joint is fused in functional position to provide painless, stable but fixed joint. Patient is unable to squat after arthrodesis.

4. *Total hip replacement (THR)*: Joint replacement after tuberculosis of hip is still a debate. Despite best of selection, reactivation of disease may occur. THR should be done after a long quiescent period of maintaining healed status under perioperative anti-tubercular treatment cover.

The end result of TB hip is fibrous ankylosis of the joint.

HIGH-YIELD POINTS

- Phemister triad of TB arthritis consists of juxtaarticular osteopenia, periarticular erosions and reduced joint space.
- *Shanmugasundaram classification of TB hip*: Based on prognostic value and also guides management. Classifies TB hip into six types: (1) normal, (2) traveling acetabulum, (3) dislocation hip, (4) Perthes type, (5) protrusio type and (6) atrophic type and Pestle and mortar type.

TUBERCULOSIS OF KNEE JOINT

INTRODUCTION

Knee is the third most common site for skeletal tuberculosis. Commonly affected patients are relatively older children and young adults.

PATHOLOGY

The origin of tuberculosis in knee can be:

- Synovial
- Osseous, involving articular surfaces
- Osseous but involving nonarticular parts of tibia or femur.

Somehow, most cases of TB knee start in synovium and tend to remain purely so for long time. The infection then spreads as a pannus under the articular cartilage, denuding the same and leading to reduction of joint space and arthritis. Eventually cold abscess may form that may track out as discharging sinuses. The end result generally is a fibrous ankylosis.

CLINICAL FEATURES

Most patients tend to present with pain and swelling in knee that is of long duration. There may be grossly visible muscle wasting in quadriceps muscle (especially vastus medialis). Sinuses either discharging or healed with puckering of skin may be noticed.

On examination, doughy thickening may be palpable in the suprapatellar region owing to synovial thickening. There is generally painful limitation of both flexion and extension. In advanced stages triple deformity results (due to spasm of iliotibial band, biceps femoris and hamstrings) where there is flexion, external rotation and posterior subluxation of tibia on femur.

DIAGNOSIS

Radiography: In initial stages radiographs show juxta-articular osteopenia, reduction of joint space and articular erosions. Late cases show the classical triple deformity.

Magnetic resonance imaging: It is needed in cases where radiographic findings are uncertain. MRI can demonstrate the pus collection, synovial thickening as well as osseous destruction.

Joint aspiration: It forms the cornerstone in cases where diagnosis remains a dilemma. Aspirated fluid can be sent for ZN staining and culture.

Biopsy: It remains the gold standard. Arthroscopic biopsy is generally preferred.

DIFFERENTIAL DIAGNOSIS

Important differentials include:

- Chronic recurrent traumatic synovitis
- Monoarticular rheumatoid arthritis
- Subacute septic arthritis
- Pigmented villonodular synovitis.

MANAGEMENT

The management is on same lines as TB hip. Gentle traction is applied and the joint is immobilized in Thomas splint. ATT is given. As the lesion enters healing phase, plaster cast is given and once lesion seems quiescent, range of motion is instituted. Surgical management in the form of synovectomy or an arthrodesis is generally required in nonresponders.

HIGH-YIELD POINT

Tuberculosis is the most common cause of monoarthritis in children.

TUBERCULOSIS OF OTHER JOINTS

INTRODUCTION

Almost any joint may be affected in tuberculosis including elbow, shoulder, ankle and wrist. Clinical features, diagnostic aspects and management principles remain the same as discussed above. Of particular interest are the following lesions:

Tuberculosis shoulder (Caries Sicca): This tends to be the granular dry type of lesion without any pus formation and

osseous destruction. However, range of motion is markedly restricted. The presentation is almost indistinguishable from frozen shoulder and must be kept as a possible differential in such patients.

Tuberculosis wrist joint: Abscess formation at this site may involve flexor tendon sheaths in the palm producing an hour glass swelling both above and below the flexor retinaculum, leading to formation of the characteristic compound palmar ganglion.

TUBERCULOUS OSTEOMYELITIS

Although tuberculosis mostly involves the epiphyseal area and joint, rarely shafts of long bones may be involved leading to tubercular osteomyelitis. Lesions are mostly multifocal and there is shear lysis without any attempt at new bone formation.

More common is rather tuberculous affection of short bones of hand and feet. The phalanges and metacarpals may be involved. Calcaneum is another common site. "Spina Ventosa" (Fig. 5.39) is the name given to "tubercular dactylitis" that involves the phalanges of the hand. The affected phalanx shows destruction with lot of new bone formation. The surrounding soft tissues may also markedly swell up and the patient presents with a painful spindle-shaped swelling of the affected finger.

HIGH-YIELD POINTS

- *Poncet's disease (Tubercular rheumatism)*: It describes a polyarthritis resembling rheumatoid arthritis occurring in patients with tuberculosis. On treating TB, polyarthritis also disappears.

- *Bacille Calmette-Guerin (BCG) osteomyelitis*: It is a rare complication that occurs a few months after BCG vaccine administration in children.



Fig. 5.39: X-ray of hand AP view showing spina ventosa of proximal phalanx of middle finger.

CHAPTER 6

Orthopedic Oncology



INTRODUCTION TO BONE TUMORS

INTRODUCTION AND CLASSIFICATION

Although bone malignancies form a small spectrum (approximately 1%) of all malignancies in the body, their clinical significance cannot be under rated. The diagnostic and management aspect can be badly challenging unless one has a meticulous knowledge on the subject.

Broadly speaking, the bone tumors are divided into tumor like lesions (Fibrous dysplasia/fibrous cortical defect (FCD), bone cysts), osteochondroma/exostosis (a lesion in between the tumor like lesions and true tumors) and the true tumors of the bone. The last ones are further subclassified into benign and malignant subtypes.

World Health Organization (WHO) has provided a relatively simpler way of classifying the true bone malignancies based on their origin, as shown in Table 6.1. However, the greatest majority of bone malignancies is actually formed by the metastasis that arise from other sites, the most common source being the breast in females and prostate in males (overall breast being the most common).

DIAGNOSTIC FUNDAMENTALS

Thorough history and good clinical examination are essentially the first step, imaging and biopsy play a pivotal role.

On plain radiography one must note:

The anatomical location viz. epiphysis, metaphysis or diaphysis (Fig. 6.1).

The margins: Well defined with a surrounding zone of reactive sclerosis in benign lesions, while the same are ill defined in malignant lesions.

The pattern of bone destruction (Figs. 6.2A to C):

- Geographic, seen in slow growing tumors where there is a narrow zone of transition between the normal and abnormal bone as seen in most benign lesions (Fig. 6.2A)

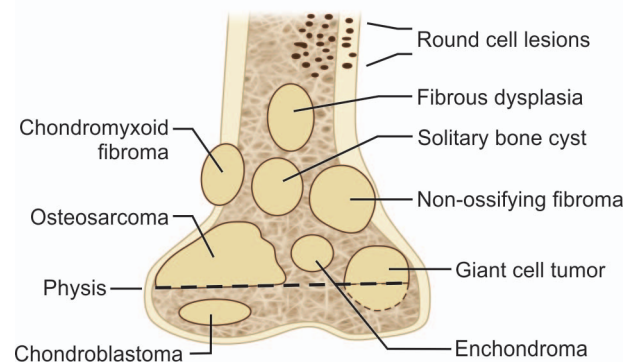
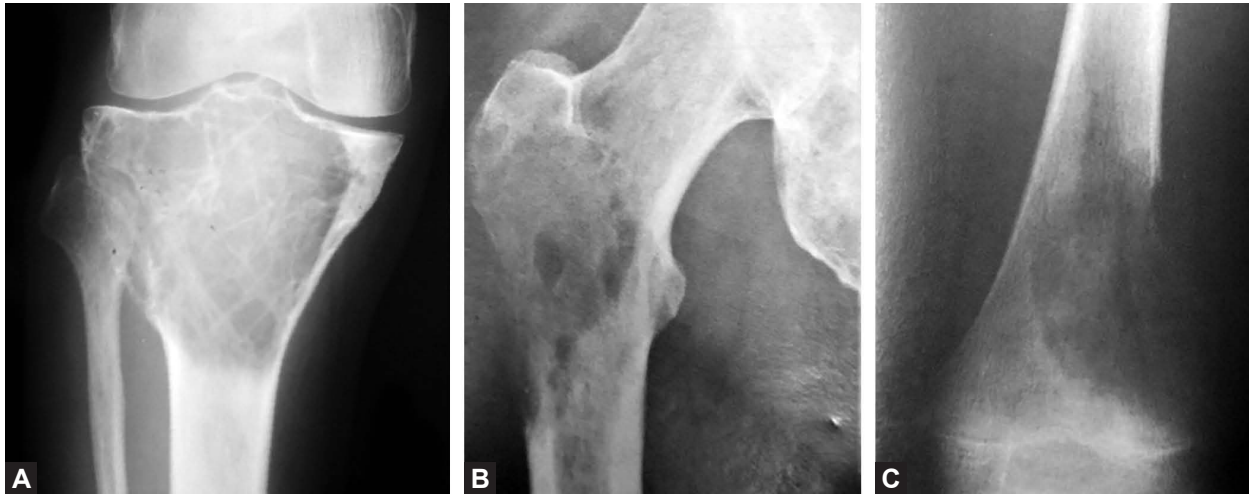


Fig. 6.1: Anatomical distribution of various bone tumors.

Table 6.1: Origin based classification of true bone tumors (Simplified WHO classification)

Types	Benign	Malignant
Bone forming tumors (arising from osteoblasts)	Osteoma Osteoid osteoma Osteoblastoma	Osteosarcoma
Cartilage forming tumors (arising from chondroblasts)	Enchondroma Chondroblastoma Chondromyxoid fibroma	Chondrosarcoma
Giant cell tumor (has osteoclast like cells, origin uncertain)	Osteoclastoma (Locally aggressive tumor)	
Marrow tumors		Ewing sarcoma, multiple myeloma (Plasma cells)
Vascular tumors	Hemangioma	Angiosarcoma
Other tumors		Chordoma Adamantinoma



Figs. 6.2A to C: Pattern of bone destruction (A) Geographic, (B) Moth eaten and (C) Permeative.

- Moth eaten, where there are multiple scattered lytic areas in bone like in Ewings and osteosarcoma (Fig. 6.2B).
- Permeative, seen in poorly demarcated lesions with wide zone of transition, as in high grade Ewings and chondrosarcomas (Fig. 6.2C).

Type of Periosteal Reaction

Solid: Cortical thickening as in osteoid osteoma

Lamellated: As in Ewing's sarcoma (Onion skinning)

Complex: As in osteosarcoma (Sunburst pattern)

Magnetic resonance imaging (MRI), CT and bone scan are vital add on investigations in indicated situations. The gold standard in making diagnosis of bone tumors is a biopsy (best taken from the peripheral margins as the center of tumor often is necrotic). Most surgeons today recommend MRI as a precursor investigation to appropriately localize the site for a biopsy, to see the soft tissue extensions of the tumor and thereby plan management in a better way.

STAGING OF BONE TUMORS

Enneking, the father of "Orthopedic Oncology", developed a rational system for staging the bone tumors that serves as a protocol for deciding surgical management and assessing prognosis (Tables 6.2 and 6.3). The system is based on histological grade (Low or high), anatomical location (T1-intracompartmental and T2-extracompartmental) and the presence of secondary metastasis (M).

Recently, American Joint Committee on cancer system has also provided a classification system that depends on grade, size (< 8 cm or > 8 cm) and presence of metastasis.

OPERATIVE MANAGEMENT

The operative management depends on the type of lesion—benign or malignant. Benign lesions are adequately treated with excision of the tumor, curettage of walls to remove any leftover tumor tissue, followed by filling the defect with bone graft/bone cement. Aggressive lesions generally

Table 6.2: Staging benign musculoskeletal tumors

Stage 1: Latent Lesion	<ul style="list-style-type: none"> • Intracapsular usually asymptomatic, incidental finding • Radiological features include: <ul style="list-style-type: none"> – A well-defined margin with a thick rim of reactive bone
Stage 2: Active Lesion	<ul style="list-style-type: none"> • Intracapsular, actively growing • Radiological features: <ul style="list-style-type: none"> – Well-defined margins with only a thin rim of reactive bone
Stage 3: Aggressive Lesion	<ul style="list-style-type: none"> • Extracapsular, aggressive nature • Radiological features: <ul style="list-style-type: none"> – Tumor has broken through the reactive bone and possibly the cortex

Table 6.3: Staging malignant musculoskeletal tumors

Stage	Grade	Site	Metastasis
IA	Low	Intracompartment (T1)	No
IB	Low	Extracompartment (T2)	No
IIA	High	Intracompartment (T1)	No
IIB	High	Extracompartment (T2)	No
III	Low/high	Any	Present (regional/distant)

need an extended curettage where an additional agent like phenol, hydrogen peroxide, liquid nitrogen or bone cement is used to promote killing of tumor cells. Frankly malignant lesions mostly need adequate surgical clearance. Based on the amount of tumor removed, the surgical margins can be classified as:

Intralesional: The plane of dissection lies within the tumor tissue.

Marginal excision: Plane of excision is through the pseudocapsule.

Wide excision: Plane of excision includes a cuff on normal tissue.

Radical excision: Involves removing the entire compartment containing the tumor.

HIGH-YIELD POINTS

- Cryotherapy is a type of extended curettage where liquid nitrogen is used to kill the left over tumor cells by freezing effect. Liquid nitrogen has been postulated to give least recurrence rate although it is debatable.

Cryotherapy also increases risk of fracture due to necrosis of surrounding tissues (side effect of freezing)

- In the following tumors/conditions multiple lesions are seen in bone: Histiocytosis, enchondroma, osteochondroma, fibrous dysplasia, multiple myeloma, metastases, hemangioma, hyperparathyroidism (Brown's tumors).

TUMOR LIKE CONDITIONS

FIBROUS DYSPLASIA

The term “fibrous dysplasia” refers to a benign nonfamilial disorder where a part of normal cancellous bone is replaced by flecks of fibrous tissue and woven (immature) bone. Affected individuals are generally in the age group of 5–30 years. It's generally a metaphyseal lesion that extends into the diaphysis. Most common site of affection are craniofacial bones and femur. Disease may be monostotic when affecting a single bone or may be polyostotic when a number of bones are affected. Monostotic form is 6 times more common than polyostotic form. Patients generally present with pain, deformity or a pathological fracture.

Important Radiological Signs

Diagnostic of fibrous dysplasia is a multiloculated translucent lesion expanding the cortex of the bone, classically demonstrating the so called “Ground Glass Appearance (Fig. 6.3)”.

In some cases the lesion is surrounded by a sclerotic rim. This is referred to as the Rind sign (Fig. 6.4).

In neglected cases, the proximal femoral lesion develops micro fractures as the patient continues to bear weight, leading to the medial wall collapse, eventually ending up with a femur that becomes hook shaped—The Shephard Crook Deformity (Fig. 6.5).



Fig. 6.3: Fibrous dysplasia of neck of femur showing ground glass appearance.

Diagnosis is confirmed on biopsy that shows the well-recognized “Chinese Letter Pattern”. Once the diagnosis is affirmed, treatment generally involves excisional curettage with bone grafting, as in most benign lesions.

HIGH-YIELD POINTS

- *McCune Albright syndrome:* It refers to the triad of polyostotic fibrous dysplasia, precocious puberty and skin pigmentation in the form of Cafe-au-lait spots. These spots are hallmarks of neurofibromatosis but in NF, these are smooth margined (Coast of California) in contrast to the irregular margins (Coast of Maine) these spots have when found in McCune Albright syndrome. 90% of patients of McCune Albright syndrome have craniofacial involvement.
- *Mazabraud syndrome:* Includes polyostotic fibrous dysplasia with intramural myxomas.
- Most common non skeleton manifestation of fibrous dysplasia is cafe-au-lait spots.

FIBROUS CORTICAL DEFECT (FCD)/ NONOSSIFYING FIBROMA (NOF)

Most authors consider it to be a smaller version of fibrous dysplasia only. FCD is a small eccentric metaphyseal lytic lesion with sclerotic margins (Fig. 6.6), most commonly found in the lower femur, where a nest of fibrous tissue persists in the bone for a variable time before finally ossifying. Nonossifying fibroma (NOF) is larger, lobulated well circumscribed geographic lesion with sclerotic margins (Fig. 6.7).

People generally affected with FCD are in the age group of 2–20 years, it's rare outside this age group. In fact, it's estimated to occur in approximately 35% of children. Mostly, it's an incidental finding and as it ossifies, it disappears with age. The importance of this condition lies in the fact, that it is the most common reported lesion (not tumor) of the bones.

OSTEOFIBROUS DYSPLASIA

Osteofibrous dysplasia (ossifying fibroma of long bones, also known as Campanacci disease) usually affects patients in their first 2 decades of life. The diaphysis of the tibia



Fig. 6.4: Rind sign in fibrous dysplasia of neck of femur.



Fig. 6.5: Shepherd crook deformity.



Fig. 6.6: Fibrous cortical defect.



Fig. 6.7: Nonossifying fibroma of distal femur.

followed by fibula is the most frequently affected location, tibia is often bowed anterolaterally and the radiographs show eccentric intracortical osteolysis with expansion of the cortex (Figs. 6.8A and B). Management involves observation as some lesions regress spontaneously while most do not progress after puberty. Surgical management is aimed at preventing pathological fracture and/or correcting deformity.

BONE CYST

A bone cyst refers to a cavity in the bones. Two varieties of cysts may be encountered as described below.

Simple/Unicameral Bone Cyst (Fig. 6.9)

It is the only “true” cyst of the bones as most other lesions that appear cystic are actually osteolytic. Although



Figs. 6.8A and B: X-ray leg AP and lateral views showing osteofibrous dysplasia.

the exact pathogenesis is unclear, some believe it as a defect of growth plate development while others suggest it is due to venous obstruction to drainage of interstitial fluid. The resulting pressure changes due to blockage of interstitial fluid drainage lead to cyst formation within the bone. Pathologically, the cyst wall is generally lined by a thin fibrous membrane (< 1 mm thick) and the contents comprise yellowish/straw-colored serous fluid. It usually occurs during the first 2 decades of life (more in 4–10 years of age group) with a 2:1 male to female preponderance.

Most commonly affected site includes the metaphysis of proximal humerus followed by the distal femur and the proximal tibia. Although initially they start as metaphyseal lesions, with time they move closer to the diaphysis. Unicameral cyst is classified as active when within 1 cm of the physis and latent when they are closer towards the diaphysis. The cyst generally is asymptomatic but as many as two-thirds of patients may present with a pathological fracture after a trivial trauma.

X-ray would usually show up an aseptic lytic lesion in the metaphyseal area of a long bone. The lesion is

centrally placed and symmetrically expansile, but almost never penetrates the cortex. Diagnostic of the SBC is the “Fallen fragment/leaf sign (Fig. 6.10)”. A small fragment of cortex sometimes breaks and the piece settles to the most dependent part of the cyst, confirming its empty cystic nature. However, in some cases the broken fragment does not fall as it remains attached to the periosteum but it folds inwards. This is called as “Trap door sign”.

Treatment involves one or two attempts of aspiration and intralesional corticosteroid injections. If they fail to stimulate healing then one has to opt for excisional curettage with bone grafting. However, one may note that if there occurs a pathological fracture, only treatment of the fracture is needed as fracture in cyst has been shown to stimulate healing of the cyst.

Aneurysmal Bone Cyst (Figs. 6.11A and B)

Aneurysmal bone cysts (ABCs) are benign but locally destructive, blood filled reactive lesions of the bone. Although a wider age group may be affected, most commonly

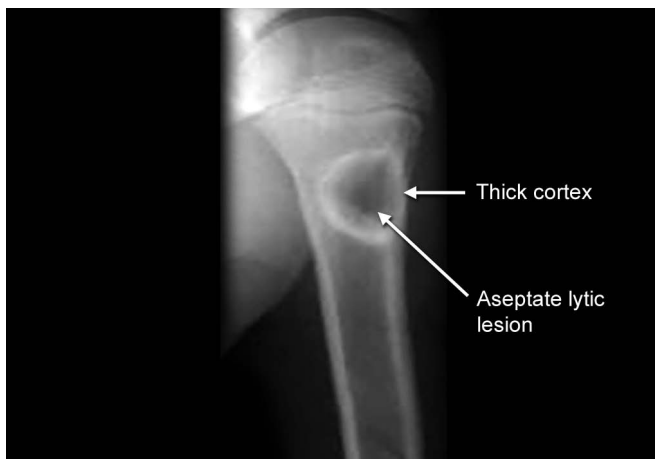


Fig. 6.9: Simple bone cyst (SBC) of proximal humerus metaphysis.

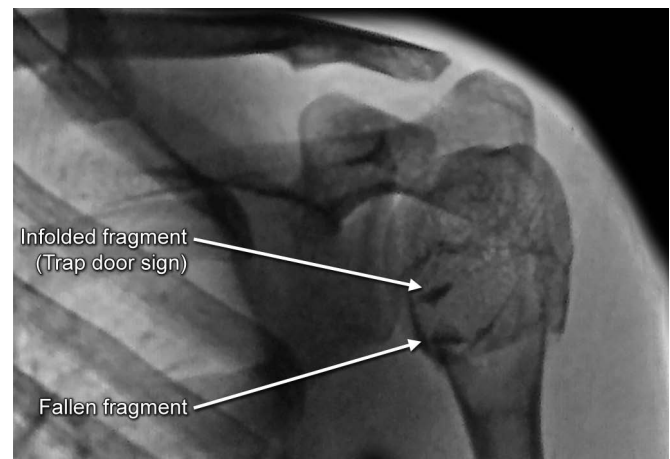


Fig. 6.10: Simple bone cyst (SBC) of proximal humerus showing fallen fragments in cyst cavity and an infolded fragment (Trap door).



Figs. 6.11A and B: (A) Aneurysmal bone cyst (ABC) of proximal humerus. (B) A large aneurysmal bony cyst of distal femur.

Table 6.4: Simple bone cyst (SBC) versus aneurysmal bone cyst (ABC)

Features	SBC	ABC
Sex	Male preponderance	Slight female preponderance
Location	Central to start	Eccentric lesion initially
X-ray appearance	Aseptate	Multiloculated
Expansion	Symmetrically expansile	Asymmetrical/ballooning expansion
Overlying cortex	Normal	Thinned
Aspiration	Straw-colored fluid	Hemorrhagic fluid
Treatment	Excisional curettage with bone grafting	Extended curettage

they are seen in patients younger than 20 years of age, with a slight female preponderance. Most common sites include metaphysis of femur followed by tibia and then humerus. Vertebral lesions involving the posterior elements are common (approximately 20%).

The clinical course is much rapid and often mimics a malignancy. Radiographs reveal an eccentric lytic lesion, often multiloculated, that elevates the periosteum but remains contained by a thin shell of cortical bone, signifying its asymmetrical expansion and ballooning nature.

Differentiating it from SBC is important (Table 6.4) and MRI often helps. MRI in ABC classically shows intralesional septations and double density fluid levels.

Treatment has to be more aggressive and involves an extended curettage where after curettage tumor cavity is treated with agents like liquid nitrogen, phenol, hydrogen peroxide or bone cement to kill the leftover tumor cells. Despite it the recurrence rate is high (approximately 10–20%) especially in patients younger than 15 years, centrally located lesions and in cases where there is incomplete removal of cyst contents. Recurrences can be treated in the same way as primary lesions but with greater care.

HIGH-YIELD POINT

A solid variant of ABC is often referred to as a giant cell reparative granuloma.

OSTEOCHONDROMA (EXOSTOSIS)

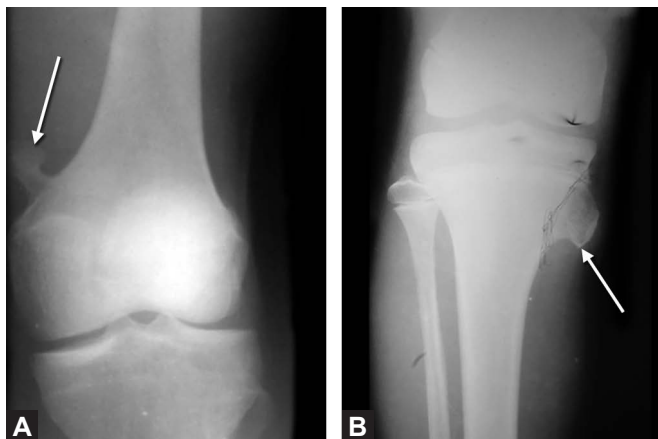
Osteochondroma/Exostosis is an aberration at the growth plate where a few cells at the periphery of the plate rather than growing up and down, start growing centrifugally to form a separate lump at one side. It originates at the physis/growth plate, but with bone growth the tumor gets “left behind” and comes to lie at the metaphysis and sometimes even diaphysis. Even though it’s the most common benign tumor of bone, it’s generally not considered to be a true neoplasm as the growth often ceases once the skeletal maturity is reached. Being developmental lesions, they generally become evident before the individual reaches 20 years of age, with most lesions found near the rapid skeletal growth. Although they can involve any bone developed by enchondral ossification, most common site

includes distal femur followed by proximal tibia and then proximal humerus, which show that the lesion is common around the growing ends of long bones. Next common site is the iliac crest.

The lesion usually comprises of a pedunculated bony mass (Fig. 6.12A), often in form of a stalk (can rarely be sessile, Fig. 6.12B), produced by progressive endochondral ossification of a growing cartilaginous cap. Although most lesions are solitary, multiple lesions (approximately 5%) do occur. In fact, “hereditary multiple exostosis (HME)” (syn. Diaphyseal aclasia, Fig. 6.13) is an autosomal dominant condition with variable penetrance. These patients have mutations in one of the two genes: *EXT1* (Chromosome 8) or *EXT2* (Chromosome 11). The striking feature of the disease apart from the presence of multiple osteochondromas is the presence of growth anomalies such as abnormal tubulation of bones producing broad metaphysis and sometimes causing bowing of radius and shortening of ulna (Masada syndrome, Fig. 6.14).

Clinically most lesions are asymptomatic and discovered incidentally. Sometimes they cause mechanical symptoms by irritating the surrounding structures (e.g. Bursitis over the tip of osteochondroma) or rarely become painful due to a pathological fracture of the osteochondroma itself (not of bone). False aneurysms of the neighboring vessels and neuropathies also have been reported.

Plain radiographs are generally sufficient to make the diagnosis. The projecting part of the lesion has cortical and cancellous components, both of which are continuous with the corresponding components of the parent bone (c.f. Myositis ossificans where this continuation is absent). The lesion is covered with a cartilaginous cap that is often not visible on an X-ray, unless calcification in the cap may be seen. CT is sometimes needed to confirm the diagnosis. Thickness of the cartilage cap more than 2 cm (Fig. 6.15) is often indicative of malignancy (mostly chondrosarcoma arises). However, malignant degeneration is exceedingly rare (only 1% for solitary osteochondroma but 5% for HME). If at all it occurs, the previously quiescent lesion in the adult may show signs of rapid growth causing mechanical symptoms or the patient may start complaining of pain in a previously painless swelling or one may find ulceration of the overlying skin or involvement of the adjacent lymph nodes.



Figs. 6.12A and B: X-ray knee AP and lateral views showing pedunculated and sessile osteochondromas (arrows).



Fig. 6.13: X-ray knee AP and lateral views showing multiple exostosis.



Fig. 6.14: Forearm deformities of MHE—metaphyseal broadening and shortening of ulna with radial bowing and radial head dislocation.



Fig. 6.15: Chondrosarcomatous change in osteochondroma.

Treatment is observation for most small sized lesions while problematic lesions should undergo an extraperiosteal excision (excising overlying periosteum to avoid leaving any abnormal cartilage cells).

HIGH-YIELD POINTS

- *Subungual exostosis:* A variant of osteochondroma that generally involves the distal phalanx of the great toe. Excision is indicated when elevation of the nail produces pain.
- *Bizarre parosteal osteochondromatous proliferation (Nora's lesion):* It is a benign condition affecting

patients in 2nd or 3rd decade of life. The lesion is an exophytic outgrowth from the cortical surface of bone consisting of elements of bone, cartilage and fibrous tissue. It is mostly seen in the phalanges and metacarpals of the hand (> feet). Classical X-ray picture and biopsy may provide the diagnosis. Excision is needed but recurrence rate is high.

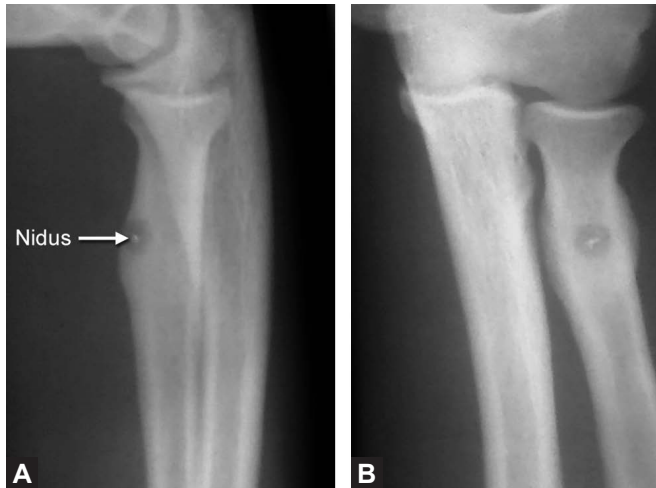
- If a chondrosarcoma occurs in exostosis, prognosis after excision of chondrosarcoma is excellent.
- An important differential to rule out in exostosis is Trevor's disease (refer to Chapter 9 for details).

BENIGN BONE TUMORS

OSTEOMA

Osteoma is a benign slow growing osteogenic lesion, characterized by the proliferation of compact or cancellous

bone, almost exclusively found in the head and neck region (skull being the most common site). Central, peripheral and extraskeletal are the three variants of osteoma. Paranasal sinuses are the favorite locations of peripheral



Figs. 6.16A and B: Osteoid osteoma of radial tuberosity (with nidus in center).

osteoma of the craniofacial region; frontal and ethmoidal sinuses being the common ones. Although, peripheral osteomas are usually benign, innocuous lesions, their size and prominent location on the visible parts of the face makes the surgical intervention necessary.

OSTEOID OSTEOMA

It is a benign bone forming lesion considered to be the most common true benign tumor of the bone. With slight male preponderance, it's usually seen in 2nd or 3rd decades of life. The lesion is diaphyseal generally, sometimes metaphyseal, with most lesions affecting the femur greater than tibia. It is also known to occur in vertebrae (7–20% incidence) where it mostly affects the posterior elements.

Clinically, patients typically present with pain that is worse at night. Possible cause seems to be the elevated levels of prostaglandins and cyclooxygenase that have been demonstrated in the lesions. This fact explains the dramatic and diagnostic relief provided by Aspirin [non-steroidal anti-inflammatory drugs (NSAIDs)] in patients with this tumor.

X-ray is usually diagnostic (Figs. 6.16A and B). Typical lesion consists of a radiolucent nidus surrounded by a thick rim of dense sclerotic bone. CT scan is the investigation of choice to identify the nidus, the size of which is generally less than 1.5 cm. Biopsy is not needed but may show immature bony trabeculae with a fibrovascular stroma that is rimmed by prominent osteoblasts.

The malignancy potential of the lesion is almost nil so most patients are given a trial of anti-inflammatory medications initially. If the symptoms are controlled, the treatment is continued and most lesions show spontaneous healing in 3–4 years. Surgical management involves removal of the entire nidus mostly done by a special technique called as “burr down technique”. In this manner a



Fig. 6.17: Osteoblastoma in tibial diaphysis (arrow).

minimal amount of surrounding sclerotic bone is removed thereby minimizing the subsequent risk of pathological fracture.

HIGH-YIELD POINTS

- Tc-99 scintigraphy reveals increased uptake in the nidus and may be used to confirm the diagnosis.
- Osteoid osteoma is the most common primary benign tumor of the spine.

OSTEOBLASTOMA

It is a rare bone forming benign neoplasm that occurs in 10–30 years old individuals with a 3:1 male preponderance. 30–50% of the lesions are located in the spine with most involving the posterior elements of the vertebrae. In the long bones, the lesion is mostly in diaphysis, can be in metaphysis but is never in epiphysis. Pain is the most common symptom and may be similar in nature to osteoid osteoma.

Unlike osteoid osteoma, X-rays usually reveal a mineralized nidus (sclerotic lesion) surrounded by a radiolucent halo with hardly any rim of reactive sclerosis (Fig. 6.17). If sclerosis occurs then one has to differentiate it from osteoid osteoma by going for a CT scan. The differentiation is then based on the size of the nidus which in these cases is usually larger than 1.5 cm.

Microscopically the lesion resembles osteoid osteoma but as far as the clinical behavior is concerned, the lesion is much more aggressive than osteoid osteoma. Treatment consists of extended curettage with bone grafting.

CHONDROMA (ENCHONDROMA)

They are benign neoplasms of hyaline cartilage. Since they usually lie inside the medullary canal, they are often



Fig. 6.18: Enchondroma in metaphysis of proximal phalanx middle finger (arrow).

referred to as “enchondromas”. Very rarely they arise from the surface of the bone in which cases they are referred to as “juxtacortical chondromas”. Any age group can be involved (more so in 2nd decade). Most common site is the hand and feet bones (particularly phalanges), although any bone formed in cartilage can be involved. Radiographs classically show an expansile radiolucent lesion in the metaphysis of bone with wisps of calcification (stippled calcification) giving a septate appearance (Fig. 6.18). One has to differentiate it from ABC or tubercular dactylitis (Spina ventosa, i.e. tuberculosis of phalanges).

Most lesions are solitary but at times can be multiple. Multiple enchondromatosis is referred to as Ollier’s disease (Fig. 6.19) (nonhereditary disorder) and if along with multiple enchondromas there are multiple cavernous hemangiomas and phleboliths, then the condition is called as Maffucci syndrome (Hereditary disorder).

Treatment is generally advised for enlarging lesions and consists of excisional curettage and bone grafting.

HIGH-YIELD POINTS

- Enchondromas are the most common bone tumors of the hand bones.
- Most common malignant bone tumor of hand is chondrosarcoma.
- Most common malignant tumor of hand is squamous cell carcinoma.
- Malignant transformation to chondrosarcoma occurs in less than 2% of solitary cases, 25% cases in Ollier’s disease (by age 40 years) and in almost 100% cases in Maffucci syndrome.
- Computed tomography is best investigation to evaluate endosteal erosion that can signify a chondrosarcoma.

CHONDROBLASTOMA

Chondroblastoma are epiphyseal lesions mainly seen in distal femur followed by proximal humerus and then proximal



Fig. 6.19: X-ray hand AP and oblique views showing multiple enchondromatosis.

tibia, in 10–25 years of age group with a 2:1 male preponderance. At times, the lesion may be seen in an apophysis like greater tuberosity or greater trochanter. Since they are epiphyseal lesions, most patients complain of progressive pain that often mimics an intra-articular pathology like chronic synovitis.

Radiological findings are characteristic with the X-ray showing a well circumscribed eccentric epiphyseal lytic lesion with a rim of sclerosis (Fig. 6.20). 30–50% exhibit matrix calcification on CT evaluation.

Differential is giant cell tumor (GCT) in older individuals. GCT would not have a rim of sclerosis or intralesional calcification and might have a soft tissue component.

Biopsy confirms the diagnosis and demonstrates dystrophic calcification surrounding individual cells the so called “chicken wire appearance”. Multinucleate giant cells are abundant.

Treatment is excisional curettage with bone grafting.

HIGH-YIELD POINTS

- Histological grading is of no prognostic significance in chondroblastoma.
- Since this lesion was described by the famous scientist Codman (in 1931), it’s also called as Codman’s tumor.

CHONDROMYXOID FIBROMA

Chondromyxoid fibroma is a benign cartilage tumor that also has myxoid and fibrous elements. Most lesions occur in patients 10–30 years old. Chondromyxoid fibroma rarely is included in the differential diagnosis of a lesion, unless the lesion is in the proximal tibial metaphysis, which remains its most common location.

Radiographically, it’s usually a well-circumscribed lesion with a rim of sclerosis in the metaphysis of a long bone and may have a bubbly appearance mimicking a nonossifying fibroma (Fig. 6.21). In contrast to other



Fig. 6.20: Chondroblastoma (arrow) of distal femur.

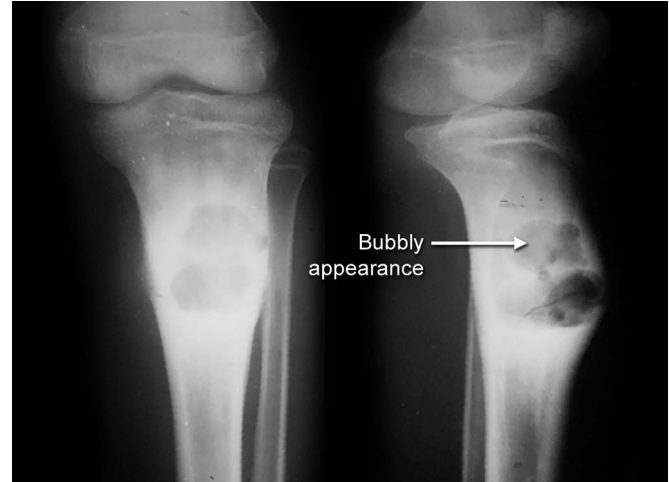


Fig. 6.21: Chondromyxoid fibroma of proximal tibia.



Fig. 6.22: Giant cell tumor (arrow) of proximal tibia.



Fig. 6.23: X-ray knee AP and lateral views showing the classical soap bubble appearance of expanding GCT.

cartilaginous lesions, radiographic evidence of intraleisional calcification usually is absent.

Microscopically, chondromyxoid fibroma appears lobulated. The center of the lobules contains loose myxoid tissue and the periphery contains a more cellular fibrous tissue. The background often appears chondroid, although distinct areas of hyaline cartilage are rare. Microscopic calcification may be present.

Treatment consists of resection or extended curettage with bone grafting. Sarcomatous change is rare.

GIANT CELL TUMOR (GCT) (OSTEOCLASTOMA)

Giant cell tumor is a locally aggressive tumor, the origin of which is uncertain. Since it is composed of giant cells on microscopy, mistaken as osteoclasts, it's also referred to as osteoclastoma. The characteristic age group of affection is 20–40 years with a slight female preponderance. Although

classically categorized as an epiphyseal lesion, in adults it spans across both the epiphysis and metaphysis. However, in adolescents it's primarily limited to metaphysis being confined proximally by the growth plate. One theory suggests that these lesions originate in the metaphysis and later extend into the epiphysis on closure of the growth plate. The most common sites of occurrence include distal femur followed by proximal tibia and then distal radius.

Clinically patients usually present with progressive pain. In 10–30% cases pathological fractures are evident at presentation. On examination, the clinician can elicit “egg shell cracking” sound on tapping the lesion.

Radiographic appearance is characteristic (Fig. 6.22). An eccentric expansile lytic lesion is located in the epiphyseal-metaphyseal area usually abutting the subchondral bone (the so called “Soap Bubble appearance, Fig. 6.23”). Initially GCT is covered by a thin shell of reactive bone but with expansion it may break through the cortex; however, intra-articular extension following a break in subchondral

bone is very rare. Matrix calcification is not seen in GCT. MRI clearly defines the extent of lesion within bone and in soft tissue. The lesion is dark in T1-weighted images and bright in T2-weighted images.

Microscopically, the tumor is composed of many multinucleated (having 40–60 nuclei per cell) giant cells lying in a sea of mononuclear stromal cells (Fig. 6.24). The nuclei of mononuclear cells are identical to the nuclei of the giant cells, a feature that helps to distinguish GCT from other tumors that may contain giant cells. It should be noted that these osteoclast like giant cells are reactive and benign in nature. Mononuclear mesenchymal stromal cells having mitotic activity are the neoplastic component of tumor. Campanacci grading system for GCTs is based on the radiographic appearance of the tumors.

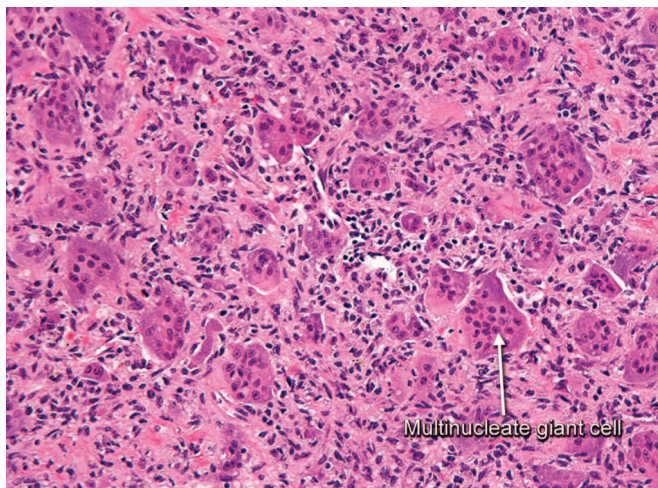


Fig. 6.24: Microscopic picture of giant cell tumor.

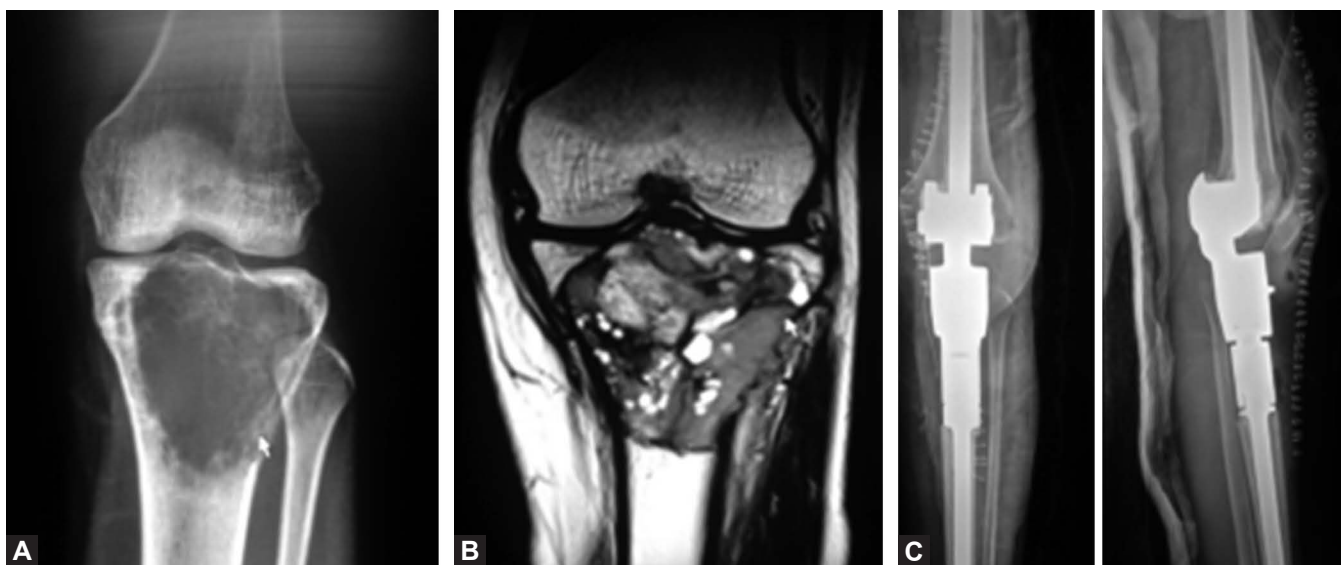
A grade 1 lesion (latent) has a well-defined margin and an intact cortex.

A grade 2 lesion (active) has a relatively well-defined margin but no radiopaque rim, and the cortex is thinned and moderately expanded.

A grade 3 lesion (aggressive) has indistinct borders and cortical destruction.

Treatment is extended curettage with bone grafting/ bone cement. Cementing is generally preferred as cement provides immediate stability aiding quicker rehabilitation and allows easier detection of recurrence than a bone graft. The lesions around knee that abut the subchondral bone sometimes require excision with reconstruction or arthrodesis of the joint. Excision of tumor and reconstruction arthroplasty is preferred over arthrodesis now a days. For aggressive Campanacci grade III GCT with extensive tumor wide excision and joint reconstruction using megaprosthesis is done (Figs. 6.25A to C). For GCT of distal end radius treatment of choice is excision of tumor and reconstruction with fibular grafting. Chemotherapy has limited success and irradiation should be reserved for symptomatic inoperable cases. Recently bisphosphonates have been postulated to prevent recurrence. Reported recurrence rate is 5–15%. Treatment of recurrent lesions is same as primary lesions provided biopsy demonstrates them to be benign.

Although these tumors typically are benign or more appropriately locally aggressive, pulmonary metastasis can occur in approximately 3% of patients. Both recurrences and pulmonary metastasis usually occur within 3 years but have been reported even after 20 years. Most common malignancy in GCT is osteosarcoma followed by malignant fibrous histiocytoma and fibrosarcoma.



Figs. 6.25A to C: (A) Aggressive GCT of proximal tibia (B) MRI showing intra-articular extension and (C) joint reconstruction after excision of tumor using megaprosthesis.

Courtesy: Dr Shailendra singh Thakur: Custom prosthetic reconstruction of proximal tibial GCT, Journal of Mahatma Gandhi Institute of Medical Sciences, September 2014 [Vol 19] Issue 2).

HIGH-YIELD POINTS

- Giant cell tumors represent less than 5% of neoplasms of bone. Less than 5% are multicentric and less than 5% show pulmonary metastasis.
- The “Es” of GCT:
 - E—Occurs during epiphyseal closure (20–40 years)
 - E—Epiphyseal eccentric lytic lesion (distal femur > proximal tibia)
 - E—Expansile lesion (causes expansion of the overlying cortex giving soap bubble appearance on X-ray)
 - E—Egg shell cracking sound on tapping the lesion is heard
 - E—Extended curettage with bone grafting is the treatment
- In spine most commonly GCT occurs in vertebral body of sacrum followed by lumbar and then thoracic vertebrae.
- Giant cell tumor is a pulsatile bone tumor. Other pulsatile bone tumors include telangiectatic variant of osteosarcoma, ABC and metastasis from follicular carcinoma thyroid and renal cell carcinoma.
- *Giant cell tumor variants*: These are those lesions which resemble GCT on microscopic examination because of presence of giant cells on microscopy. The lesions include:
 - A—ABC and SBC
 - B—Brown’s tumor of hyperparathyroidism
 - C—Chondroblastoma and Chondromyxoid fibroma
 - D—Desmoplastic fibroma
 - E—Epulis (Giant cell reparative granuloma)
 - F—Fibrous dysplasia and non-ossifying fibroma
 - G—Giant cell rich osteosarcoma
 - H—Benign fibrous histiocytoma.
- ABC is the closest GCT variant and non-ossifying fibroma is the most common GCT variant.

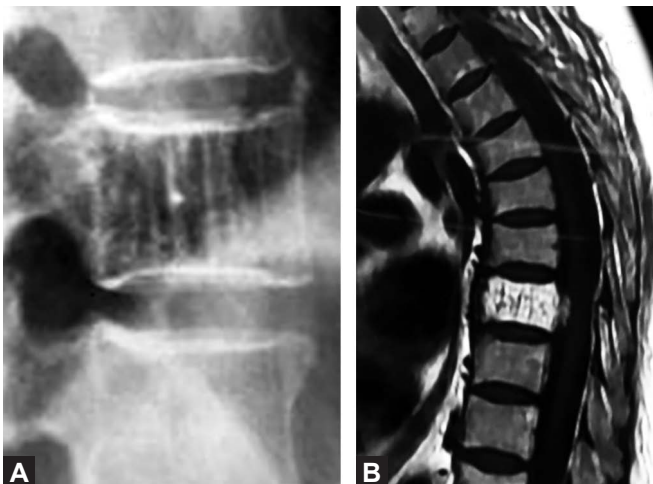
- Mostly malignancies appearing in GCTs are secondary malignancies following radiation and primary malignant transformation is rare.
- In spine most common site for GCT is vertebral body of sacrum followed by lumbar vertebrae.
- Giant cell tumor of tendon sheath/Giant-cell synovium/Localized nodular tenosynovitis, is a firm lesion, measuring 1–3 cm in diameter, and is most commonly attached to the tendons of the hands and wrist, with a predilection for the flexor surfaces. These tumors (mostly seen in 20–30 years of age) are typically painless but can cause cortical erosion. Surgical excision is commonly needed, but the tumors tend to recur.

HEMANGIOMA

This common benign lesion is appropriately a hamartoma in bone being composed of masses of vascular channels (capillary, venous, cavernous). Most common age group is the 5th decade of life with a female preponderance. Most common site of occurrence is vertebrae (T4–L4) followed by skull. In fact, it is estimated to be present in approximately 10% of population in the form of asymptomatic spinal lesions that at times are discovered incidentally.

Radiographic features are characteristic and biopsy is almost never required. On X-ray (Figs. 6.26A and B) vertebra shows vertically oriented trabeculae giving the classic “jailhouse appearance” or the so called “Corduroy appearance”. On cross sectional images on CT scan, the pattern is called as “Polka Dot pattern (Fig. 6.27)”. The lesions are characteristically bright in both T1 and T2 images of MRI.

Treatment is necessary mostly for symptomatic lesions. Selective arterial embolization or low dose radiation are generally the preferred modes. Recently, vertebroplasty (page 327) has been advocated as another modality of treatment with promising results.



Figs. 6.26A and B: (A) X-ray and (B) MRI of thoracic spine showing classical corduroy appearance of vertebral hemangioma.

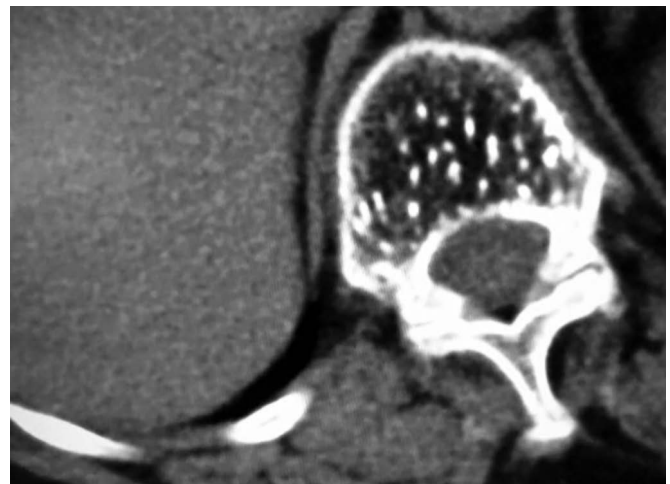


Fig. 6.27: Axial CT scan cut showing the characteristic Polka Dot pattern.

MALIGNANT BONE TUMORS

CHORDOMA

This rare malignant neoplasm arises from notochord remnant. It is the second most common primary malignancy in spine (after multiple myeloma) and is the most common primary malignancy of the sacrum with a peak incidence in 5th to 7th decade of life. Greater than 50% arise in the sacrococcygeal area (below S3 level) while more than 30% arise at the base of the skull. The most common presenting complaint for sacrococcygeal tumors is low back pain while larger masses may present with neurological involvement.

Bone destruction is the radiographic hallmark of the lesion. The lesions virtually arise from the midline. Often they are missed on AP X-rays due to overlying gas shadows. They are usually more easily appreciated on lateral view of sacrum.

Microscopically, they consist of lobules of cells separated by fibrous bands. The cells contain abundant vacuolated cytoplasm (physaliferous cells—pathognomic).

The primary treatment is surgical resection with wide margins even if it creates a neurological deficit. Effort should be to protect S2, S3 nerve roots to avoid bladder, bowel function. Radiation may benefit nonresectable cases. Chemotherapy is of no proven benefit.

HIGH-YIELD POINTS

- A more distal location for sacral lesions is associated with a better prognosis.
- In adults remnant of notochord is nucleus pulposus.

CHONDROSARCOMA

This malignant bone tumor arising from the cartilage cells is the third most common primary malignant bone

tumor (most common—Multiple Myeloma, second most common—Osteosarcoma) or the second most common primary nonhematological malignancy of the bone. Peak incidence occurs in 4th to 6th decades of life (it is the most common primary malignant tumor of the bone in people above 40 years of age) with a slight male preponderance. Lesions may arise de novo or in a preexisting tumor like an enchondroma or osteochondroma. Most common site is pelvis > proximal femur, the tumor having predilection for flat bones. It is also most common malignant chest wall tumor. Although malignant, patients generally present with a slowly enlarging mass and a dull aching pain.

Radiographically, the tumors are characterized by metaphyseal radiolucent lesions with cortical erosions and rarely a soft tissue mass. There is abundant matrix calcification, the so called “mottled/pop-corn like/comma shaped calcification (Figs. 6.28A and B)”. Biopsy demonstrates malignant cells with abundant cartilaginous matrix.

Treatment in most cases is wide/radical excision (excision of whole compartment that contains the tumor) or at times an amputation is needed. There is no role of chemotherapy and radiotherapy is only palliative. Since cartilage is avascular, it survives transplantation easily and hence recurrences are common. Metastasis is mostly hematogenous and most frequently to lungs. The prognosis for patients with chondrosarcoma depends mostly on the size, grade and location of the lesion.

HIGH-YIELD POINTS

- There is no osteoid production in chondrosarcoma. If at all even minimal amount of osteoid is found, then the diagnosis is chondroblastic osteosarcoma (a variant of osteosarcoma)—a tumor with a different prognosis and treatment.



Figs. 6.28A and B: Chondrosarcoma of (A) calcaneum and (B) proximal humerus showing popcorn calcification (arrow) (Fig. 6.28B is reproduced with permission from “The Radiology assistant”).

- Less common histological subtypes of conventional chondrosarcoma include dedifferentiated chondrosarcoma, clear cell chondrosarcoma, and mesenchymal chondrosarcoma. Clear cell type (low grade) has tendency to occur in epiphysis and can have giant cells on biopsy (giant cell variant). Mesenchymal variety (high-grade variant) has cellular portions that often have a hemangiopericytomatous pattern of growth with “staghorn-like” vessels.

OSTEOSARCOMA

Osteosarcoma is a highly malignant tumor characterized by the production of osteoid by the tumor cells. It is the second most common primary malignancy of bone but the most common nonhematological primary malignancy of bone. Area with high rate of bone growth are more commonly affected with most common sites being metaphyseal areas of distal femur followed by proximal tibia and then proximal humerus. Classically, it has a bimodal age distribution with a primary variety (conventional osteosarcoma) that arises *de novo* and predominates in the 2nd decade of life and a secondary variety that arises in premalignant lesions (Table 6.5) and spans the 40–60 years of age group. Overall, males are more commonly affected than females. Although the tumor is present in association with hereditary forms of retinoblastoma, Rothmund-Thomson syndrome and Li-Fraumeni syndrome, genetic factors rarely have been shown to play a role.

Table 6.5: Premalignant lesions associated with secondary osteosarcoma

Premalignant lesions associated with Secondary osteosarcoma	Fibrous dysplasia
	Paget's disease
	Postirradiation
	Osteochondromatosis (multiple)
	Bone infarction

Clinically, patients mostly report progressive pain as first symptom that results from micro-infarctions as the invasive tumor cells weaken the involved bone. Night pains may be present in 25% of these people. Later on swelling may be evident with overlying skin appearing warm and tender and dilated veins crossing the swelling (Figs. 6.29A and B).

Plain radiographs are valuable to make the diagnosis. Primary/Conventional osteosarcoma is characterized by a permeative lytic lesion with ill-defined borders with evidence of bone formation. Periosteal reaction may take the form of Codman's triangle (Fig. 6.30), a triangular area of subperiosteal new bone at the tumor host cortex junction at the ends of the tumor or may appear as the classical Sun ray appearance (Fig. 6.31), which is due to calcification along the Sharpey's fibers that attach the periosteum to the bone cortex. Often the tumor breaks through the cortex and forms a soft tissue mass. MRI is best to know the soft tissue extent but to detect “skip lesions,” bone scan is the preferred investigation.

Microscopically, the lesion is characterized by variable amount of osteoid production by the atypical spindle-shaped tumor cells. Based on the amount of osteoid production, the tumors are subclassified as being osteoblastic (lot of new bone formation), chondroblastic (Cartilage formation predominates), fibroblastic (where fibroblasts predominate) and telangiectatic/osteolytic (with areas of tumor necrosis and blood filled spaces) types. The latter has highly malignant looking cells and resembles an ABC to a great extent.

Treatment of osteosarcoma has evolved considerably over the past few years. In older times radical excision or mostly an amputation was the preferred treatment modality but with the advent of effective chemotherapy regimens the current trend is to go for “Limb Salvage Surgery.” Chemotherapeutic drugs are administered as per the “T-10” protocol (Table 6.6) and tumor is excised taking a safe margin (preferable > 10 cm). In majority of cases micrometastasis already would have occurred by



Figs. 6.29A and B: Massive swelling and dilated veins due to osteosarcoma of (A) distal femur and (B) distal humerus.



Fig. 6.30: Codman's triangle in osteosarcoma distal femur.



Fig. 6.31: Sun ray appearance in osteosarcoma distal femur. Courtesy: Dr Gaurav gupta.

Table 6.6: Chemotherapy for osteosarcoma	
T-10 protocol for osteosarcoma	High-dose methotrexate
	Vincristine
	BCD: bleomycin, cyclophosphamide, dactinomycin
	Doxorubicin
In patients not responding to methotrexate, cisplatin is used as substitute	

the time of the diagnosis and adjuvant chemotherapy is even effective in controlling them. Lung is the most common site for metastasis that generally reaches the organ via hematogenous route (lymphatic spread is extremely rare). Radiotherapy has no role as it is a highly radio resistant tumor. Immunotherapy is a recently introduced modality where a portion of tumor is implanted into a sarcoma survivor and is removed after a few days. The sensitized lymphocytes from the survivors are then infused into the patient and these lymphocytes then selectively destroy the tumor cells.

With today's multiple-agent chemotherapy regimens and appropriate surgical treatment, most series report long-term survival of 60–75%. The most important prognostic factor at the time of diagnosis is the tumor stage. Patients with pulmonary metastasis at diagnosis have a poorer prognosis as do patients with skip lesions. The next most important prognostic feature is the grade of the lesion. Size and location are also important variables; most proximal tumors are larger at the time of diagnosis than distal tumors and have a bad prognosis. Paget osteosarcomas continue to have a poor prognosis, with less than 15% long-term survival. Radiation-associated osteosarcomas also have been regarded as having a poor prognosis. Age and gender are not associated.

Parosteal/Juxtacortical osteosarcoma (a less common variant of conventional osteosarcoma): This is a slow

growing variant that arises in the region of periosteum, in relation to the cortex of the bone, usually the distal femur. People in the age group of 20–35 years are generally affected. Treatment is wide excision with reconstruction using a prosthesis. Overall prognosis is much better than conventional osteosarcoma.

HIGH-YIELD POINTS

- Osteosarcoma is the most common primary tumor of bone causing pulmonary metastasis (micrometastasis being present in 90% of cases and detectable in 15–20%).
- The most common factors associated with secondary osteosarcomas include Paget's disease and previous radiation therapy. The incidence of osteosarcoma in Paget's disease is approximately 1% and higher (5–10%) for patients with advanced polyostotic disease.
- Osteosarcoma is the most radio resistant tumor and the most common radiation induced tumor. Radiation-associated osteosarcoma occurs in approximately 1% of patients who have been treated with greater than 2,500 cGy and can occur in unusual locations, such as the skull, spine, clavicle, ribs, scapula, and pelvis. The time to onset of the secondary osteosarcoma averages 10–15 years after radiation exposure but may occur 3 years to several decades after treatment.
- Serum alkaline phosphatase levels in this tumor are often raised but rather than diagnostic significance, they are important to monitor follow up or recurrence.
- Recently, FBJ murine virus has been implicated in the pathogenesis of osteosarcoma.

ADAMANTINOMA/AMELOBLASTOMA

This locally invasive low-grade malignant tumor arises from ameloblasts which are enamel forming cells present

in the mandible. Posterior part of mandible (in the area of the molar teeth) is overall the most common site. An aberrant nest of specialized cells similar in histology to ameloblasts has been found to be present under the skin over bones in subcutaneous location, giving rise to adamantinoma of long bones. Tibia (85% cases) followed by fibula is the most common site for adamantinoma of long bones. The tumor generally affects individuals in their 2nd to 3rd decade of life. Pain is the most common symptom with which most patients report to the clinician. The tumor is typically slow growing in nature.

X-ray classically shows multiple demarcated radiolucent lesions in tibial diaphysis, separated by areas of dense sclerotic bone (Fig. 6.32). The picture is quite similar to osteofibrous dysplasia (Campanacci disease) and some workers consider Adamantinoma to be a malignant variant of the same.

Microscopic examination shows islands of epithelial cells in a fibrous stroma. Nuclear atypia is minimal.

Treatment is wide resection with adequate margins. The tumor is chemo and radio resistant. Local recurrences may occur in up to 25% cases and may need an amputation. Due to slow growing nature, recurrences have been reported to occur quite late (some up to 20 years). Metastasis generally goes to lungs and inguinal lymph nodes.

HIGH-YIELD POINTS

- Immunohistochemical stains viz. cytokeratins and vimentins stain positive in adamantinoma.
- Most common tumor of jaw is squamous cell carcinoma of oral mucosa. Adamantinoma is the most common bone tumor of jaw.

EWING SARCOMA

Ewing sarcoma (named after James Ewing, who first described it in 1921), is the third most common nonhematologic primary malignancy of bone, but it is the second most

common (after osteosarcoma) in patients younger than 30 years of age and the most common in patients younger than 10 years of age. Classically it affects children in the age group of 5–15 years with those in their 2nd decade being more commonly affected. There is slight male preponderance. Most common bones affected include Pelvis and Femur (diaphysis). The tumor also is commonly found in diaphysis (often extending into metaphysis) of humerus, tibia and the flat bones like the vertebrae, ribs and scapula. Multicentric lesions have also been reported.

Pain is the universal complaint but often there is delay in diagnosis as the clinical picture may closely resemble acute osteomyelitis with the child having complaints of intermittent fever with raised leukocyte count, erythrocyte sedimentation rate (ESR), C-reactive protein (CRP) and anemia. Often a needle aspirate of Ewing may grossly resemble pus further complicating the matter. X-ray in acute osteomyelitis would show a metaphyseal lesion with well-defined cloacae and a relatively smooth periosteal reaction and may reveal a sequestrum. However, in Ewing sarcoma, X-ray classically shows a permeative lytic lesion (moth eaten appearance) in the diaphysis of a long bone surrounded by a lamellated periosteal reaction (Onion peel appearance, Fig. 6.33). Skip lesions are not reported but at times almost the entire bone may be involved. MRI is generally required to know the full extent of the lesion.

Microscopic picture is classical with multiple small round blue cells with very scanty intercellular matrix, at times showing pseudorosette formations, a pattern attributed to the group of primitive neuroectodermal tumors (PNET) (Fig. 6.34). In fact, the cells stain positive for S-100 and neuron-specific enolase, show neural elements on electron microscopy, are positive for *MIC-2* gene and also demonstrate the t(11;22) seen in the PNET group. One has to opt for tumor markers to reach the specific diagnosis. Ewing sarcoma is CD-99 positive and usually is periodic acid-schiff (PAS) positive (owing to intracellular glycogen) but reticulin negative. In contrast, lymphomas (another PNET group tumor) are PAS negative and reticulin positive; additionally they stain positive for leukocyte common antigen (CD 45).

Treatment concepts of Ewing sarcoma have immensely changed over the past few years. The success of chemotherapy (VDCA regime—vincristine, doxorubicin, cyclophosphamide and actinomycin D) has emerged as a game changer and both adjuvant and neoadjuvant chemotherapy are extensively used to treat the lesion as well as the distant metastasis that might have been undetectable. Also this tumor is very radiosensitive. In fact, the tumor is said to melt on radiotherapy. So the patients who have a resectable lesion, where resection with wide margins would not cause a functional deficit are offered surgery followed by radiotherapy (60 Gy) while for most other lesions the multiagent chemotherapy remains the mainstay.

Metastatic deposits are not uncommon and occur primarily to lungs (50%) and to bones (25%). Prognosis



Fig. 6.32: X-ray leg lateral view showing adamantinoma (arrow).



Fig. 6.33: Ewing sarcoma of proximal ulna showing lamellated periosteal reaction.

depends on a number of factors. The most unfavorable prognostic factor in Ewing's sarcoma is the presence of distant metastasis at diagnosis. Other unfavorable prognostic factors include an age older than 10 years, a size larger than 8 cm, more central lesions (as in the pelvis or spine) and poor response to chemotherapy. The histological grade is of no prognostic significance, as all Ewing's sarcomas are of high grade. Fever, anemia, and elevated white blood cell (WBC) count, ESR, and lactate dehydrogenase (LDH) values have been reported to indicate more extensive disease and a poorer prognosis. The presence of t(11;22) (present in 90% cases of Ewing sarcoma) however, does not seem to affect the clinical course.

HIGH-YIELD POINTS

- Ewing sarcoma is the most chemosensitive and most radiosensitive malignant bone tumor.
- Ewing sarcoma (> osteosarcoma) is the most common tumor showing bone to bone metastasis, hence mandating a bone scan to detect the metastasis.
- The *MIC-2* gene detection (by monoclonal antibodies) is significant for the screening purposes while the most specific diagnostic measure involves the demonstration of t(11;22) by a reverse transcription polymerase chain reaction (RT-PCR) method.
- Although classified under the PNET group, as per the latest hypothesis, the tumor actually has a mesenchymal origin. The sarcoma arises from medullary cavity (marrow) but the t(11;22) (*EWSR1-ETS* family gene fusions) changes the developmental pattern of these cells and makes the tumor express the ectodermal markers.

MULTIPLE MYELOMA (KAHLER'S DISEASE)

Plasma cell dyscrasias comprise a group of disorders characterized by neoplastic proliferation of single clone of

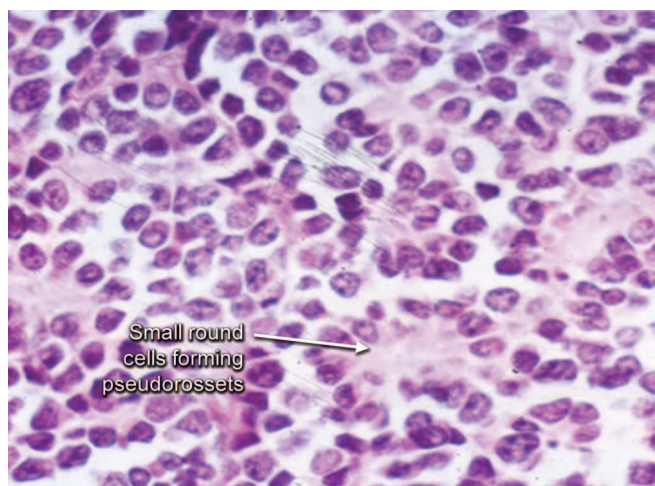


Fig. 6.34: Microscopic picture of Ewing sarcoma.

plasma cells in the bone marrow, which then produces excess of monoclonal immunoglobulins leading to a constellation of clinical signs and symptoms. The presentation is most commonly a multisystem disorder called Multiple Myeloma (MM), but in about 5% cases they may present as an isolated bony lesion termed as solitary plasmacytoma. A third rare form of presentation is an osteosclerotic myeloma.

Epidemiology

Multiple myeloma is the most common primary malignancy of bone. It is diagnosed in adults over 40 years of age (median age at diagnosis 65 years) being nearly twice as common in males as in females.

Etiology

Exact etiology is still to be elucidated. Mutations of chromosome 14 and deletions on chromosome 13 are found in many cases and portend a poor prognosis. Few other factors that have been purported to play a role in causation are radiation exposure, pesticide (Dioxin) exposure and infection with HHV-8 and HIV. Why some patients develop MM and others plasmacytoma is also not completely understood. It might be related to differences in cellular adhesion molecules or chemokine receptor expression profiles of the malignant plasma cells.

Pathogenesis

The proliferation of abnormal plasma cells results in overproduction of heavy chains in the form of monoclonal IgG (most common), IgA or IgM and light chains (kappa and lambda—commonly called the Bence Jones proteins). These proteins aggregate to increase viscosity of blood or overload the renal tubules culminating in renal failure or over a longer period lead to amyloidosis. Additionally, the abnormal plasma cells lead to bone destruction by

humoral mechanisms (overproduction of RANKL, IL 6 and MIP 1 alpha).

Clinical Features

The most common presentation of MM is generalized bone pain in an elderly patient. Pathological fractures are common and may be the presenting feature in other patients. Features indicating end organ damage may include anemia (due to replacement of marrow by abnormal plasma cells) or hypercalcemia and uremia due to renal failure. Hyperviscosity may lead to neural ischemia manifesting as paraesthesias and areas of sensory loss. Amyloidosis may develop in some patients causing macroglossia, skin lesions and peripalpebral purpuras.

Imaging

Punched out lesions without a reactive zone/sclerotic zone with a sharp zone of transition to normal bone, are found throughout the skeleton (Figs. 6.35A and B). Common sites of involvement (in order of frequency) are spine (commonest), pelvis, ribs, upper extremities, face, skull, femur and sternum.

Bone scan is usually negative (cold spot) because of lack of osteoblastic overactivity. Screening tool of choice is a skeletal survey. MRI and CT are not routinely done but may be helpful tools in defining skeletal lesions or when a decompression of a spinal lesion is to be planned.

Diagnosis

In majority of cases the diagnosis is self-evident from the classical clinical picture and the radiological findings. However, considering the elderly age group, metastasis to bone remains an important differential to exclude. The same can be easily excluded by a blood or urine analysis. Patients with suspected multiple myeloma

should be investigated with screening tests which include paraproteins in serum and Bence Jones protein in urine.

In MM, on blood examination one would find low hemoglobin, raised serum calcium (due to marked osteolytic action of myeloma cells), increased uric acid (due to increased cell breakdown), elevated urea (in patients in renal failure), markedly increased ESR and a high total protein value but with reversal of A: G (Albumin: Globulin) ratio (due to increase in globulin fraction of proteins). Electrophoresis shows an increase in gamma fraction of globulin called the M-spike detectable in both blood and urine. Serum β_2 -microglobulin is a tumor marker, increase of which is a poor prognostic sign.

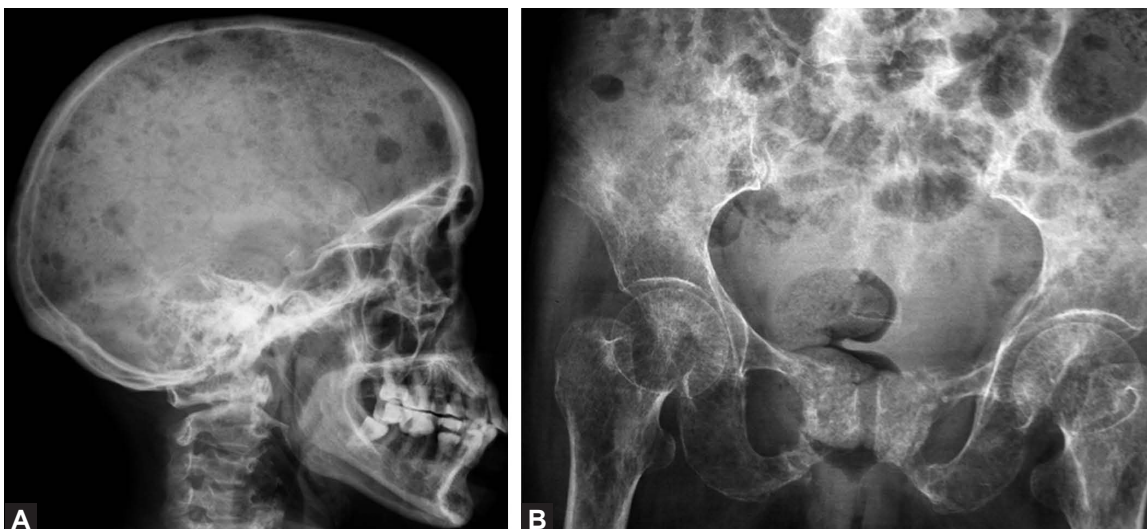
On urine examination one can also detect the presence of Bence Jones proteins by the heating method or by immuno-electrophoresis (more sensitive method).

On histological examination, the tumor cells have an eccentric nucleus with clumped nuclear chromatin arranged in a clock face pattern (Cart wheel appearance) and stain positive for CD 56 and CD 38 (while normal plasma cells don't). Hoffa's clear zone (clear zone near nucleus representing golgi apparatus) is characteristic in these cells. Amyloid collection on bone marrow biopsy in an old patient who is not on long term hemodialysis is a very strong indicator of underlying multiple myeloma.

Establishing finally the diagnosis of MM requires one major plus one minor, or three minor criteria as shown in Table 6.7.

Solitary plasmacytoma occurs as a single skeletal (or extraskeletal) lesion without fulfilling the above criteria and in the absence of other features of MM (i.e. anemia, hypercalcemia, renal insufficiency or multiple lytic bone lesions). It progresses to classic systemic form in more than 50% patients.

Osteosclerotic myeloma is rare and is characterized by POEMS (Polyneuropathy, Organomegaly, Endocrinopathy, M spike, Skin changes).



Figs. 6.35A and B: X-rays showing the classical lytic lesions of MM in skull and pelvis.

Table 6.7: Diagnostic criteria for multiple myeloma
Major criteria
<ul style="list-style-type: none">Biopsy confirmation of plasmacytoma>30% plasma cells on bone marrow biopsySerum IgG > 3.5g/dL, IgA > 2g/dLUrine IgA > 1g/24 hr or presence of Bence Jones proteins
Minor criteria
<ul style="list-style-type: none">10-30% plasma cells on bone marrow biopsySerum or urine protein levels below those listed for major criteriaMultiple lytic bone lesionsDecreased serum IgG levels

Treatment

Chemotherapy is the mainstay of treatment. Drugs used are Melphalan in combination with prednisolone. Other agents which may be used are cyclophosphamide, doxorubicin and thalidomide. Bisphosphonates are used to decrease bone pain and control hypercalcemia.

Autologous stem cell transplantation, although not curative (i.e. does not cause remission) improves overall survival by 2–3 years. It is an option in relatively young (<65 years) patients without comorbidities.

Orthopedic Management

Impending (Mirel’s score > 8) or actual pathological fractures may require long bone stabilization with intramedullary implants (to splint the entire length of bone). Peri-articular fractures are managed with joint replacements or megaprotheses. The tumor is radiosensitive so three weeks after surgery radiation is also added to the treatment regimen. Kyphoplasty or vertebroplasty is used for painful vertebral compression fractures.

Solitary plasmacytoma is treated mainly with radiotherapy only, with operative stabilization employed generally in cases of actual or impending pathological fracture.

Prognosis

The overall prognosis for MM is bad, however, patients with solitary plasmacytomas tend to have a better prognosis.

HIGH-YIELD POINTS

- The levels of alkaline phosphatase are not raised in multiple myeloma.
- Bence Jones proteins may be identifiable in urine in almost 50% of MM patients. These proteins precipitate when the sample is heated to 50°C and again dissolve when the sample is heated to 100°C.
- Unlike multiple myeloma, solitary bone plasmacytoma does not include the presence of abnormal plasma cells throughout the bone marrow.
- International myeloma working group diagnostic criteria of solitary plasmacytoma of bone, extramed-

ullary plasmacytoma, monoclonal gammopathy of undetermined significance and smoldering multiple myeloma (SMM)	
Diagnosis	Criteria
Solitary plasmacytoma of bone	No M-protein in serum and/or urine Single area of bone destruction due to monoclonal plasma cells Normal bone marrow (plasma cells < 1%) Normal skeletal survey No organ related or tissue impairment
Extramedullary plasmacytoma	No M-protein in serum and/or urine Extramedullary tumor of clonal plasma cells Normal bone marrow (plasma cells < 1%) Normal skeletal survey No organ related or tissue impairment
Monoclonal gammopathy of unknown significance (MGUS)	Serum monoclonal protein level < 3 g/dl Plasma cell count raised but < 10% in bone marrow Absence of end organ damage like anemia, hypercalcemia or renal failure. Normal skeletal survey
Smoldering multiple myeloma (SMM) or asymptomatic multiple myeloma	Serum monoclonal protein (IgG or IgA) level equal or more than 3g/dl and or bone marrow plasma cells > 10%, absence of end organ damage, such as anemia, hypercalcemia or renal failure and normal skeletal survey.
<ul style="list-style-type: none">The commonest site for an extramedullary myeloma is skin and subcutaneous tissues > liver. Over 80% of these arise in the region of head and neck, especially the upper respiratory tract.The most common site for a solitary plasmacytoma is spine.Multiple myeloma is one tumor which can have dural deposits without bone lesions.	

MISCELLANEOUS CONDITIONS OF CLINICAL INTEREST

“Bone island” (Fig. 6.36) is an unossified piece of cartilage in the bone. At times a person may have multiple bone islands scattered in whole body, a condition called as “osteopoikilosis” (see Chapter 9 for details).

Pigmented villonodular synovitis: Pigmented villonodular synovitis (PVNS) is a rare benign disease of the synovial membrane which is characterised by hypervascular neoplastic proliferation of the synovium with deposition of macrophages, multinucleated giant cells and hemosiderin. Knee joint is most commonly involved joint. On arthroscopy typical brownish pigmentation of synovium is seen due to deposition of hemosiderin pigment. Two varieties have been described, diffuse variety and localized nodular variety. Chances of recurrence are higher in diffuse variety. Low dose external beam radiotherapy and arthroscopic/open synovectomy have been tried with varying



Fig. 6.36: Bone island in proximal tibia (calcified).

success for the treatment. Malignant transformation has been reported but very rare.

Gorham's disease (Disappearing bones/Massive osteolysis): This is a disease of unknown etiology characterized by progressive disappearance of bones in the body (Fig. 6.37). Shoulder and pelvis are most common sites although any bone may be affected. The medical treatment includes radiation therapy, bisphosphonates (inhibit osteoclastic function) and α -2b interferon. Surgical options include resection of the lesion and reconstruction using bone grafts/prostheses. In most cases, bone grafts tend to undergo resorption and are hardly helpful.

Cortical desmoid: A cortical desmoid is an irregularity in the posteromedial aspect of the distal femoral metaphysis that occurs as a reaction to muscle stress exerted by the adductor magnus, mostly in 10–15 years old boys. Clinical symptoms include soft tissue swelling and pain. Radiographs and MRI reveal erosion of the cortex with a sclerotic base. A biopsy is not warranted. Treatment usually consists of observation only.

Glomus tumor: Glomus tumor is a benign neoplasm arising from a neuromyoarterial apparatus called the glomus body. Glomus bodies are arterio-venous shunts, involved in thermoregulation of extremity, by regulating blood flow to the extremity. The most common site of occurrence of this tumor is the subungual area of the fingers, although any area may be affected. Classical feature is pin point tenderness on touching the lesion that produces a bluish discoloration below the nail (Fig. 6.38). Treatment involves complete surgical excision.

METASTASIS TO BONE

After lung and liver, skeletal system is the third common site to receive secondary metastatic deposits from a primary site. In fact, metastasis to bone are so common that metastatic carcinomas not only constitute the most common cause for destructive bone lesion in adults, they also are the most common tumors of the bone.



Fig. 6.37: X-ray of a patient with Gorham's disease showing disappearing forearm bones.



Fig. 6.38: Glomus tumor (arrow) of toe nail showing bluish discoloration.

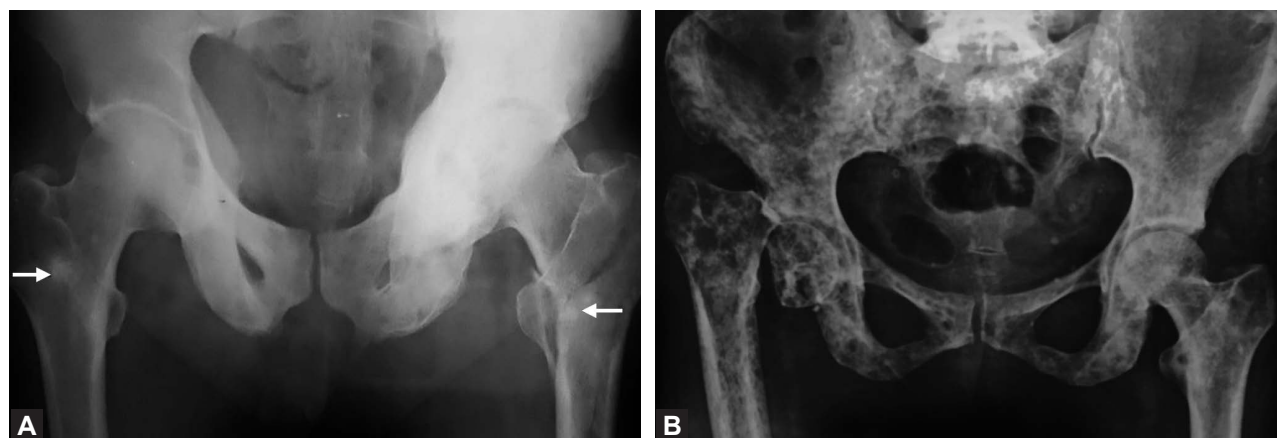
Sites

Metastasis can reach the bone from a number of primary sites that include the breast, lung, prostate, kidney, thyroid etc. Overall, the commonest site for a primary tumor that metastasizes to bone is the breast carcinoma. Table 6.8 given below is depicting common sites for primary in case of bony metastasis in some special situations.

Metastasis most commonly involve the axial skeleton (spine followed by pelvis then ribs and then skull) and thoracic segment of spine is the most commonly involved site. Not uncommon is the involvement of the proximal ends of humerus and femur, due to predominance of the red bone marrow. However, metastasis distal to the knee and elbow are very rare and generally tend to arise from lung (most common) and tibia is the most common affected bone in these cases.

Table 6.8: Common primary sites for bone metastasis

In males: Prostate followed by lung
In females: Breast followed by lung
In children: Neuroblastoma
Overall: Breast followed by prostate and then lung



Figs. 6.39A and B: (A) X-ray pelvis with both hips AP view showing osteoblastic metastasis (arrows) from carcinoma prostate and pathological intertrochanteric fracture left femur; (B) X-ray pelvis with both hips AP view showing osteolytic metastasis from lung carcinoma with pathological fracture neck of right femur.

Table 6.9: Primaries causing osteoblastic (sclerotic) and osteolytic bone metastasis

Osteoblastic (Fig. 6.39A)—Prostate, seminoma, carcinoids, medulloblastoma

Osteolytic (Fig. 6.39B)—Kidney, thyroid, lung

Mixed—Breast (more commonly lytic)

Mode of Spread

Hematogenous spread has been documented as the commonest mode of bone involvement. Vertebra is a cancellous bone highly rich in red marrow and hence the commonest site of affection.

Pathophysiology of Bone Metastasis

Once the metastatic deposits reach the bone, they can produce either an osteoblastic or an osteolytic lesion (Table 6.9). Tumor cells in some cancers (prostate) produce some signaling molecules that stimulate bone formation by increasing osteoblast activity. They include transforming growth factor- β (TGF- β), bone morphogenetic proteins (BMPs), and endothelin-1. Whereas in other metastatic cancers like breast cancer, tumor cells secrete parathyroid hormone related protein (PTHrP) and IL-6, which are powerful mediators of osteoclast activation and participate in osteolysis by stimulating the production of receptor activator of nuclear factor- κ B ligand (RANKL) by osteoblasts and stromal cells.

Clinical Presentation

Mostly these patients are old aged and present to the orthopedic surgeon with a clinically silent primary site but with either bone pain or a pathological fracture. In all elderly patients presenting with generalized bone pain, a detailed skeletal survey with radiographs of all suspected areas is of utmost importance to prevent missing a metastasis. In case where radiographs fail to detect the lesions,

bone scan is a useful tool and it can especially pick up skip lesions. It is the investigation of choice for detecting osteoblastic metastasis while for osteolytic lesions FDG-PET scan can be employed. In fact, PET CT can detect any tumor cell activity. MRI is more useful in primary bone tumors to find their soft tissue extent.

Not uncommon for these patients is to present with a pathological fracture. Femoral neck is the most common site of pathological fracture in such patients and these pathological fractures classically tend to produce transverse fracture lines on radiographs.

Locating the Primary Site

A challenge in these patients is to locate the primary site. A detailed history, meticulous general physical examination and a case tailored investigation profile are necessary to appropriately locate the primary site from where the secondary deposits originated. Serum alkaline phosphatase levels may be elevated in cases with bone destruction but attempted reparative osteoblastic reaction while in cases of massive destruction, the urine hydroxyproline levels may go up. Thus evaluation of markers of bone formation and resorption (page 9), can help in making diagnosis in these patients. Tumor specific markers can also be employed to rule out suspected primary sites, e.g. serum acid phosphatase levels to rule out a prostatic carcinoma. Occasionally it is difficult to detect the primary despite extensive skeletal survey and lab investigations. In such cases biopsy examination of the lesion may be necessary to reveal the primary.

Management

Treatment in these cases is dictated by two important factors: the source of the primary site and the general condition of the patient.

In cases where general condition of patient is good and there is solitary metastatic deposit with a located primary, the

primary lesion is treated first and the metastatic area excised. In inaccessible areas, radiotherapy or chemotherapy may be employed depending on the source of metastasis. Multiple secondaries with an unknown or even a known primary are better managed with palliative chemotherapy or radiotherapy to provide some pain relief. Bisphosphonates inhibit the osteoclast mediated bone resorption by inducing osteoclast apoptosis, inhibiting osteoclast maturation and decreasing their activity and hold an important place in medicinal treatment of bony metastasis. Both Bisphosphonates and radiotherapy are especially useful in affecting pain relief and halting the progression of bone destruction in metastatic bone cancer.

Metastatic pathological fractures often fail to unite and require internal fixation with intramedullary rod or long plate with addition of bone cement to fill the defect. Joint arthroplasty is a favorable option for lesions near the joint. For involvement of larger areas of bone, often replacement of whole bone with tumor prosthesis (megaprosthesis) may be required.

HIGH-YIELD POINTS

- Most common site for metastasis to bone is breast, but from primary bone tumors metastasis most commonly involve the lung.
- Bone is the primary site of metastases in 40%–75% cases of breast cancer.
- Bone to bone metastasis are seen in Ewing sarcoma and osteosarcoma (Ewing sarcoma > Osteosarcoma).
- About 70% of cases with bony metastases are detected radiographically and 85% of them show lytic changes.
- Metastasis from follicular carcinoma thyroid and renal cell carcinoma are pulsatile. Most pulsatile tumors are metastasis followed by ABC and GCT.
- Sarcomas of soft tissue origin rarely metastasize to bone, however, the following ones may- Angiosarcoma, Liposarcoma, Rhabdomyosarcoma and Synovial cell sarcoma.
- Radionuclide therapy is a recent addition in treatment for palliative pain relief from metastatic bone disease. Commonly used agents are Phosphorus-32 Orthophosphate and Strontium-89 Chloride.

SOFT TISSUE SARCOMAS

INTRODUCTION

Soft tissue sarcomas are rare tumors. They account for nearly 1% of all malignancies. Based on the location and tissue of origin, following types are recognized:

- Smooth muscle: Leiomyosarcoma
- Skeletal muscle: Rhabdomyosarcoma
- Fat: Liposarcoma
- Blood vessels: Angiosarcoma
- Fibrous tissue: Fibrosarcoma
- Fibrohistiocytic: Malignant fibrous histiocytoma (MFH)
- Lymph vessels: Lymphosarcoma
- Uncertain origin: Synovial sarcoma, epithelioid sarcoma.

Soft tissue sarcomas overall are more common in males, and mostly occur in adult population. These most commonly arise in the extremities (60%), with lower extremities being involved three times as often as upper extremity. General indicators of poor prognosis include size greater than 5 cm, location below deep fascia, and high-grade lesions, proximal extremity location (as opposed to distal extremity). Stage followed by presence of metastasis triumphs all factors. Soft tissue sarcomas most commonly metastasize to lungs. Diagnosis is confirmed on biopsy.

MALIGNANT FIBROUS HISTIOCYTOMA (MFH)

It is the most common soft tissue sarcoma in adults. It is interesting to note that the most common radiation-induced soft tissue sarcoma is also MFH (whereas osteosarcoma is overall the most common radiation-induced sarcoma).

Its most common location is thigh where it commonly presents as a deep-seated painless mass, gradually increasing in size. Rarely, it may arise from the bone also. Occasional systemic features include fever and hypoglycemia. Lesions appear hypointense on T1 and hyperintense on T2-weighted MRI. Tumor pathology is heterogeneous with predominantly storiform or cartwheel arrangement (irregularly whorled pattern) of histiocytic cells (Fig. 6.40) with occasional giant cells. Due to its pleomorphic nature, it has been recently reclassified as pleomorphic undifferentiated sarcoma.

Management includes wide resection and radiation (preoperative or postoperative). Tumors not amenable to resection demand a more aggressive surgery in the form of amputation. Chemotherapy may also be added but its role is not clear at present.

Metastasis to lungs and lymph nodes is common. Prognosis mainly depends on histological grade of tumor (atypia, mitotic figures, etc.).

LIPOSARCOMA

It is the second most common soft tissue sarcoma in adults. Presentation is similar to MFH. Behavior depends on histological type. Well-differentiated type occurs in limbs, rarely metastasizes and has an excellent survival rate, whereas the dedifferentiated type is more aggressive and commonly occurs in abdomen or groin region. Another rare type is myxoid type, which tends to occur in relatively younger age group and has a predilection for the retroperitoneum. Well-differentiated type is treated with resection alone, whereas other types require surgery, radiotherapy and occasionally chemotherapy.

SYNOVIAL CELL SARCOMA

Synovial cell sarcoma is a soft tissue tumor that does not have synovial origin despite its name. It is a rare but aggressive tumor that arises in vicinity of bursa, tendon sheaths or joint capsules where there are multipotent stem cell rests that differentiate into mesenchymal as well as epithelial structures, hence a “biphasic tumor”. The tumor is most commonly located around the knee. It is also the most common soft tissue sarcoma of foot. It is characterized by t(11;18). Wide excision is the treatment of choice and radiotherapy also is effective.

FIBROSARCOMA

Very rare entity; in fact, it has become a diagnosis of exclusion. The characteristic microscopic appearance of fibrosarcoma consists of spindle cells arranged in a herringbone pattern (Fig. 6.41). The typical presentation is a 5- to 10-cm, slow-growing, painless mass in the deep soft tissues of the lower extremity in adults aged 30–50 years old.

EPITHELIOID SARCOMA

It is the most common soft tissue sarcoma of hand. It may be confused with a benign granuloma clinically and histologically. Metastasis to lymph nodes is relatively common. Treatment is by wide resection or amputation (if non-resectable).

RHABDOMYOSARCOMA

It is the most common soft tissue sarcoma in children. Most common locations are head and neck, genitourinary and retroperitoneum. Only 15% occur in extremities.

Histologically, three types are there:

1. Embryonal type is most common and consists of round and spindle cells in a myxoid stroma. Visible cross-striations may be seen. Sarcoma botryoides is its variant, which occurs in hollow mucosa-lined organs (vagina, bladder).
2. Alveolar rhabdomyosarcoma commonly occurs in extremities. It consists of septa which divide clusters of cells (similar to alveolar architecture of lung).

3. Pleomorphic rhabdomyosarcoma is rare and consists of large eosinophilic polygonal cells. Multinucleated giant cells are prominent and the typical strap- and racquet-shaped cells are also seen.

Rhabdomyosarcoma frequently has a rapid and aggressive clinical course. Metastases occur in the lungs, lymph nodes and bone marrow. Treatment consists of wide resection and multiagent chemotherapy.

HIGH-YIELD POINTS

- Most common soft tissue sarcoma in adults: Malignant fibrous histiocytoma followed by liposarcoma
- Most common soft tissue sarcoma in young adults: Synovial cell sarcoma
- Most common soft tissue sarcoma in children: Rhabdomyosarcoma
- Most common site of rhabdomyosarcoma: Genitourinary followed by extremities.
- Most common soft tissue sarcoma of foot is Synovial cell sarcoma
- Most common soft tissue sarcoma of the hand/upper extremity: Epithelioid sarcoma
- Most common malignant tumor of hand is squamous cell carcinoma.
- Most common malignant bone tumor of hand is Chondrosarcoma
- Most common soft tissue mass in hand is ganglion while the commonest benign tumor of hand is Enchondroma.
- Most important prognostic factor in soft tissue sarcomas: Histological grade
- Most common radiation-induced soft tissue sarcoma: Malignant fibrous histiocytoma. Otherwise, most common radiation-induced sarcoma: Osteosarcoma
- Sarcomas metastasizing via lymphatic system (mnemonic “ME Loves CARS”):
M: Malignant fibrous histiocytoma
E: Epithelial sarcoma
L: Lymphosarcoma
C: Clear cell sarcoma
A: Angiosarcoma
R: Rhabdomyosarcoma
S: Synovial cell sarcoma

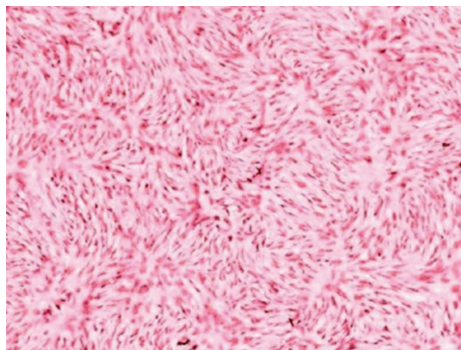


Fig. 6.40: Storiform or whorled appearance of histiocytic cells.

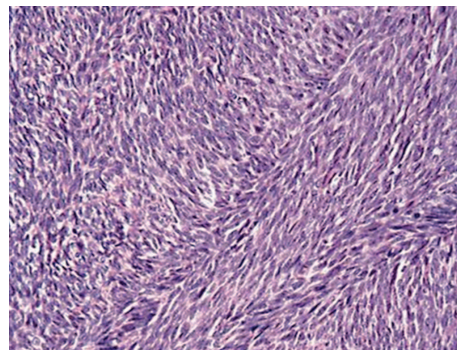


Fig. 6.41: Herringbone pattern in fibrosarcoma.

EOSINOPHILIC GRANULOMA AND LANGERHAN CELL HISTIOCYTOSIS

Eosinophilic Granuloma (EG) is a part of spectrum of disease Langerhan's cell histiocytosis, formerly called as Histiocytosis X.

Langerhan's cell histiocytosis is a disease of unknown etiology characterized by accumulation in body of large number of abnormal histiocytes, that actually start damaging the body itself. It can present in three forms:

1. Letterer-Siwe disease (10% cases)—a fulminant systemic disease that occurs in children under 3 years age and is rapidly fatal.
2. Hand-Schuller-Christian disease (10-20% cases)—a chronic disseminated that occurs in older patients and exhibits the well-known triad of diabetes insipidus, exophthalmos and skull lesions.
3. Eosinophilic Granuloma/Pulmonary histiocytosis-X (60-80% of all cases)—the most benign form of the three clinical variants. It is basically a solitary non-neoplastic proliferation of histiocytes that mostly produces a lesion in the lungs or bones. It is seen mostly in 5-10 years old children and sometimes in young adults, with a male to female ratio of 2:1.

EOSINOPHILIC GRANULOMA OF BONE

EG may occur in the bone as either a solitary lesion of bone destruction (more common) or as multiple lesions in the skeleton. Although any bone can be involved; the more common sites include the skull (most common site), mandible, spine, ribs and the long bones. The patients are usually children that present with localized pain, tenderness, swelling, fever, elevated ESR and leukocytosis. The radiographic picture is non-specific and varies with the site of involvement. The skull may have a lesion with sharp, punched out borders that are uneven across the inner and outer table causing a "bevelled edge" that gives them the characteristic double contour (Fig. 6.42). In spine lesions appear in the vertebral body and bone destruction may lead to collapse of the whole vertebra leading to classical picture of vertebra plana (Fig. 6.43). In long bones, EG is found in the diaphysis or metaphysis mostly in the center of the medullary

cavity. The lesion is generally surrounded by a good periosteal reaction and may expand to cause endosteal scalloping. Bone scan is not much useful in delineating these lesions and MRI is more commonly employed. Biopsy remains the gold standard for confirmation. Under the microscope, EG consists of sheets of Langerhan's cells that are derived from the mononuclear cells and dendritic line precursors found in the bone marrow. These cells when seen under the electron microscope demonstrate racket shaped cytoplasmic inclusion bodies called Birbeck's granules. Additionally, on immunohistochemistry, the cells stain positive for S-100, CD-1a and Neuron specific enolase.

Although almost always symptomatic, the lesions mostly regress spontaneously in about 6 months to 2 years. At times, the biopsy may incite the regression. So treatment is mostly not required. The lesions are also highly radiosensitive and excision and curettage is employed only for resistant cases. Chemotherapy is limited to systemic form of the disease. Overall prognosis is very good.

HIGH-YIELD POINTS

- Lung involvement occurs in 20% of the patients with EG and in an older group (age, 20–40 years).
- In 50–75% of the patients, the disease is monostotic and skull involvement is seen in 50% of these patients.
- Punched out lesions in the skull may be seen in Multiple myeloma as well as Eosinophilic Granuloma. They can be differentiated by the fact that in EG, the lesions have a double contour (due to bevelled edge) as there is uneven destruction of the inner and outer table of the skull.
- Important causes of Vertebra Plana:
 - Eosinophilic granuloma (most common cause of vertebra plana)
 - Ewing sarcoma
 - Lymphoma/Leukemia
 - Gaucher's disease
 - Aneurysmal bone cyst
 - Infection—Tubercular or pyogenic spondylitis



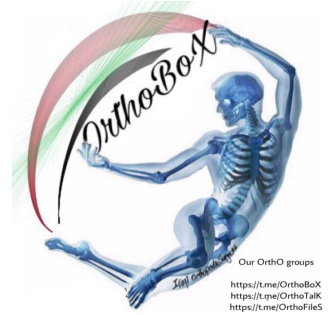
Fig 6.42: Eosinophilic granuloma lesion in skull depicting the classical double contour pattern.
Courtesy: Dr. Utkarsh.



Fig 6.43: X-ray of spine AP view showing vertebra plana (Flat vertebra) at T10 level.

CHAPTER 7

Pediatric Orthopedics



FOOT DEFORMITIES

CONGENITAL TALIPES EQUINOVARUS (CTEV)

(Clubfoot)

(Latin: tali-ankle; pes-foot; equino-horse like)

Relevant Anatomy

The ankle joint is a hinge joint allowing motion in one plane, i.e. plantar flexion and dorsiflexion. This joint is formed by tibia on top and dome of talus below. Now, the talus rests on top of calcaneum and the two tarsals articulate at the subtalar (talo calcaneal joint), which accounts for the inversion (syn. Varus) and eversion (syn. Valgus) motions of the foot (Fig. 7.1A). The talus that sits on top of calcaneus is rotated inwards/medially and articulates in front with navicular while the calcaneum is rotated laterally/outwards and articulates with the cuboid (Fig. 7.1B).

For descriptive purposes, foot is divided into three parts (Fig. 7.1B):

1. *Forefoot*: Metatarsals and phalanges.
2. *Midfoot*: Cuboid, navicular and three cuneiforms.
3. *Hindfoot*: Talus and calcaneum.

Lisfranc joint: Joint between forefoot and midfoot.

Chopart joint (Midtarsal): Joint between midfoot and hindfoot, i.e. calcaneocuboid and talonavicular joints.

Important ligamentous structures in the foot (Fig. 7.2):

Important Ligaments Around the Ankle and the Foot (Fig. 7.2)

Deltoid Ligament

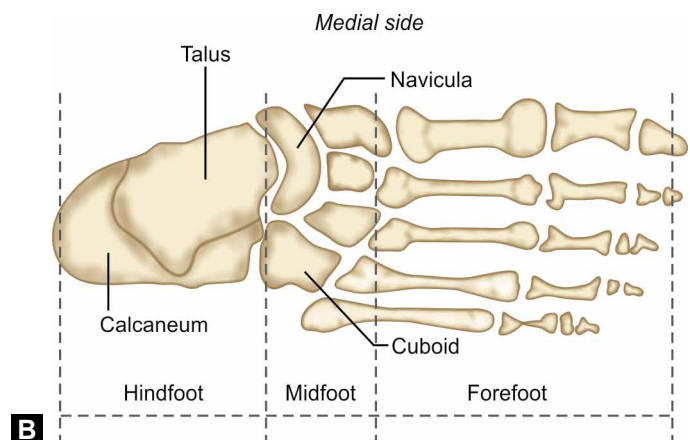
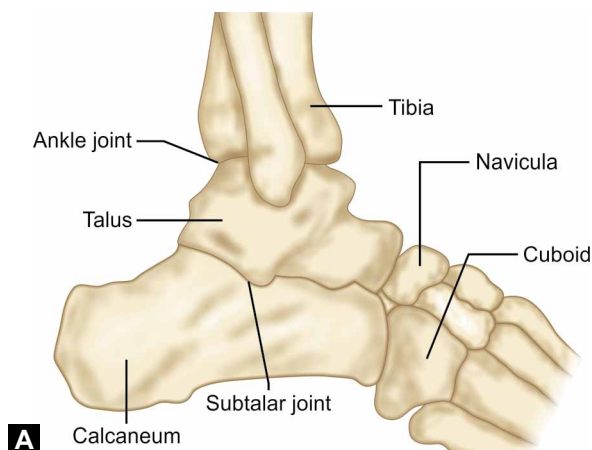
Medial collateral ligament of the foot attaching medial malleolus to multiple tarsals (navicular, calcaneum and talus). It consists of superficial and deep parts.

Spring Ligament

Plantar calcaneonavicular ligament, which is a thick band of fibers connecting sustentaculum tali of calcaneum to the plantar aspect of navicular. It supports the head of talus.

Bifurcate Y Ligament

Originates from calcaneum and then divides distally in a Y-shaped manner to give two slips, medially to navicular and laterally to cuboid.



Figs. 7.1A and B: Normal anatomy around foot and ankle.

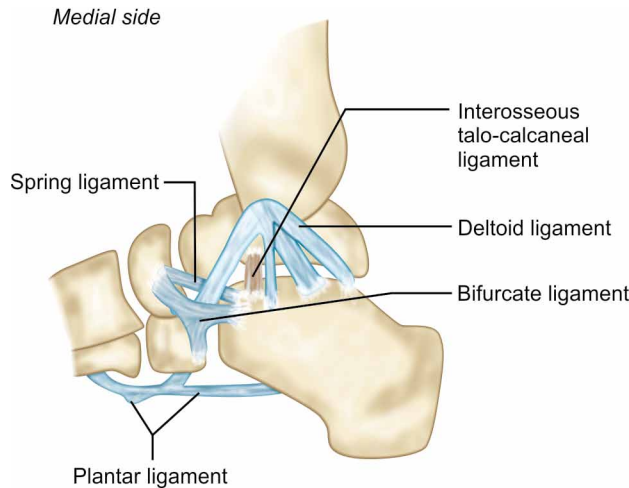


Fig. 7.2: Ligaments of foot.

Interosseous Talocalcaneal Ligaments

Thick and strong ligament binding the talus and calcaneum together.

Plantar Fascia

Thick aponeurosis, which originates at the calcaneal tuberosity and runs towards heads of metatarsals.

Ossification of Foot Bones

At birth talus, calcaneum and cuboid are ossified but the navicular and cuneiforms are cartilaginous. The metatarsals and phalanges are also ossified at birth. The navicular ossifies between 2 years and 5 years and the cuneiform between 6 months and 3 years.

Understanding the Condition

Congenital talipes equinovarus or club foot is basically a deformity of the foot wherein the foot is plantar flexed and turned/rotated inwards such that the patient bears weight on the lateral border of the foot (Fig. 7.3). The deformity is mostly idiopathic but can result due to a number of secondary causes.

This anomaly comprises of four basic deformities in the foot (Table 7.1)—(1) the ankle is fixed in equinus, (2) the subtalar joint in varus (inversion), (3) the midfoot has cavus (a prominent medial longitudinal arch) and (4) the metatarsals are adducted towards the midline. An additional component is internal tibia torsion (the distal tibia is inherently rotated medially).

Incidence

- It is the most common congenital anomaly of foot affecting 1 in 1,000 live births.
- Males are affected nearly twice as often as females.
- Deformity is bilateral in nearly 50% of the cases.



Fig. 7.3: Clinical photograph of a patient with CTEV.

Table 7.1: Basic deformities in the foot

Deformity	Joints affected	Zone of foot
Equinus	Ankle (Tibiotalar)	Hindfoot
Varus/Inversion	Subtalar (Talocalcaneal)	
Cavus and supination	Intertarsal joints	Midfoot
Adduction	Tarsometatarsal joints	Forefoot
Internal tibia torsion	Distal tibia	

- There is a high concordance rate among monozygotic twins.

Pathogenesis

The primary problem in CTEV that fixes the foot in the above-mentioned deformed position is the fact that all structures lying on the posteromedial side of the lower leg and foot (structures below knee level involved) are contracted. Some workers believe that these patients have genetic abnormalities and hence defective bones leading to articular malalignments that cause secondary contracture of the soft tissues while the other school of thought is that these patients may primarily have a soft tissue contracture and the bones may get secondarily deformed. Anyhow, the crux is that these patients have articular malalignments that get firmly fixed by capsular, ligamentous and musculo-tendinous contractures on posteromedial aspect of the foot.

Although the exact cause still remains to be elucidated a number of theories exist that try to explain the origin of the deformity:

- Arrest in fetal development of foot (foot goes through a stage resembling clubfoot during normal development).
- *Myofibroblastic theory*: fibrotic contractile tissue present on posteromedial aspect of foot.
- Primary germplasm defect in the cartilaginous talus (bony deformity being primary cause, with soft tissue contractures occurring secondarily).

- **Multifactorial:** most probable theory. Genetic association has been shown which accounts for familial clustering of cases. *PITX1* gene has been recently linked to CTEV.

Pathoanatomy

Following abnormalities in various structures of foot have been observed in patients who have CTEV:

Deformities in bones of foot:

- Talus is the most deformed bone. Head and neck are small, plantarflexed (equinus) and medially deviated relative to body. Deformed talus with a subluxated talo-navicular joint is the most important pathology and is central to the origin of deformity in CTEV.
- Calcaneum is in varus and is internally rotated.
- Navicular is subluxated medially at talonavicular joint and is wedge shaped.
- Cuboid is also subluxated medially.

Following muscles, ligaments and capsular structures at posteromedial aspect of foot (present behind medial malleolus) are shortened and contracted:

- **Muscles/Tendons:** Tibialis posterior, flexor digitorum longus (FDL), flexor hallucis longus (FHL) and Tendo achilles.
- **Capsule/Ligaments:** Deltoid ligament, spring ligament, bifurcate Y ligament, interosseous ligament, posteromedial capsule of ankle, subtalar and talonavicular joints and plantar fascia.

Overall, foot size is small with absent deep creases over lateral border of foot and exaggerated deep creases over medial border of foot. Lateral border of foot is convex and long, medial border is concave and short. As these children begin to walk the weight is borne by the lateral side of the foot and callosities and bursae develop on the lateral border.

Types of Clubfoot

Based on whether the deformity was present since birth or was it acquired after birth, CTEV is divided into primary and secondary types respectively with syndromic type being a third but rare variant.

1. **Primary (Congenital clubfoot):** Cases where clubfoot may be present since birth include:
 - Idiopathic (most common type)
 - Neurogenic—Spina bifida
 - Dysplastic—Arthrogryposis multiplex congenita (AMC).
2. **Secondary (Acquired clubfoot):** In some diseases a muscle imbalance may result, causing contracture of the posteromedial foot structures leading to a secondary CTEV anytime during life.
 - Paralytic (Poliomyelitis)
 - Post-traumatic—contracted scar on posteromedial aspect
 - Postinfective
 - Spastic (Cerebral palsy).

Table 7.2: Difference between primary and secondary clubfoot

Feature	Primary clubfoot	Secondary clubfoot
Time of diagnosis	Presence since birth	Develops after birth
Bilaterality	More often bilateral (60%)	More often unilateral
Foot appearance and creases	Chubby short foot, creases present	Atrophic skin with absent creases
Heel size	Small	Relatively normal
Foot size	Clearly smaller when compared to a normal foot	Normal or somewhat small
Neurological examination	Normal	Motor/sensory loss present
Prognosis	Good	Poor

Differences between primary and secondary clubfoot are given in Table 7.2.

3. **Syndromic:** Patients with following syndromes may have CTEV—AMC, Down's syndrome, Streeter's dysplasia (constriction bands form around fingers), Larson syndrome, Freeman-Sheldon syndrome, Mobius syndrome, Pierre Robin syndrome, Prune belly syndrome and Fetal alcohol syndrome.

Diagnosis

Congenital talipes equinovarus is by and large a spot diagnosis. The crux is identifying the classical deformities that have been mentioned above.

Equinus (Figs. 7.4A and B): Identified by dorsiflexing the foot. If equinus is present foot cannot be dorsiflexed beyond neutral. Normally in a new born, tissues are so pliable that the forefoot can be dorsiflexed to an extent to touch even the front of tibia.

Varus (Fig. 7.5A): Looking from behind, a line through center of calf should cut the heel in the middle in normal feet, but in varus it passes through lateral part of heel.

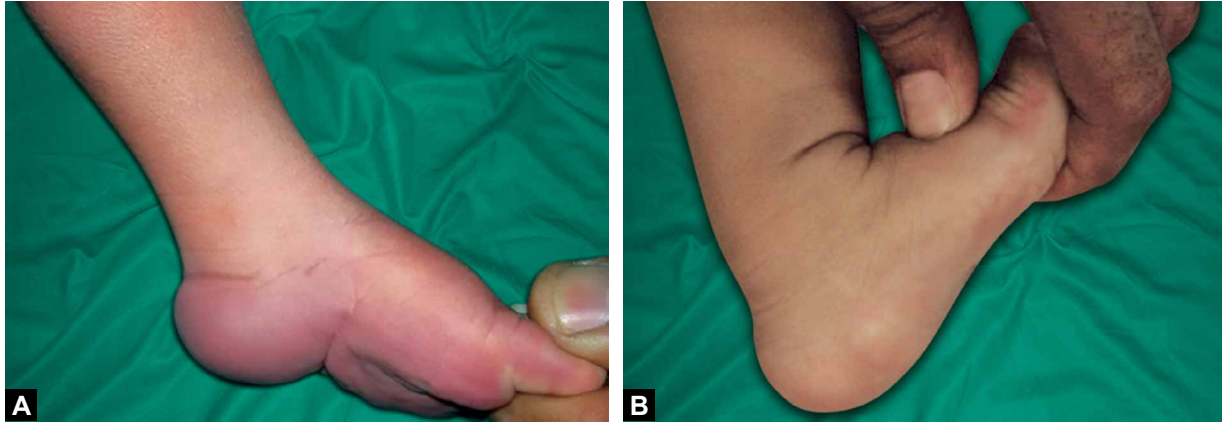
Cavus (Fig. 7.5B): Exaggerated medial longitudinal arch is easily detectable, especially in unilateral cases upon comparing to opposite side.

Adducted metatarsals (Figs. 7.6A and B): Looking from behind normally only the great toe should be visible medially, but if forefoot is adducted, more toes are seen medially (too many toes sign) and none visible laterally.

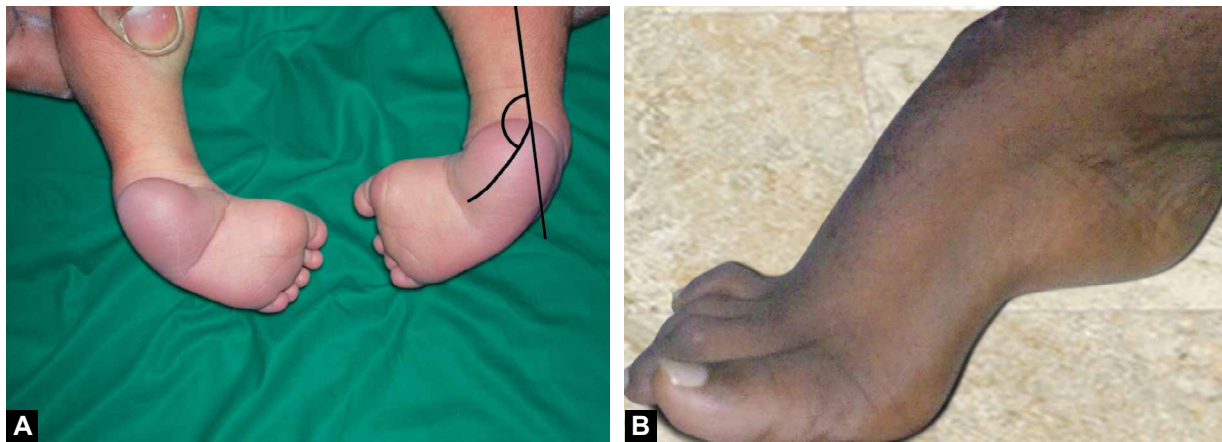
Best views to assess these deformities are varus from back, equinus from side, forefoot adduction from front.

Once the deformities have been recognized, one can enquire if the condition is congenital (primary clubfoot) or acquired (secondary clubfoot) and then go on to look for the cause by taking appropriate history.

Radiographic assessment: Routinely it is not necessary but is useful to confirm the diagnosis especially in relapsed or recurrent cases. Some important parameters evaluated include:



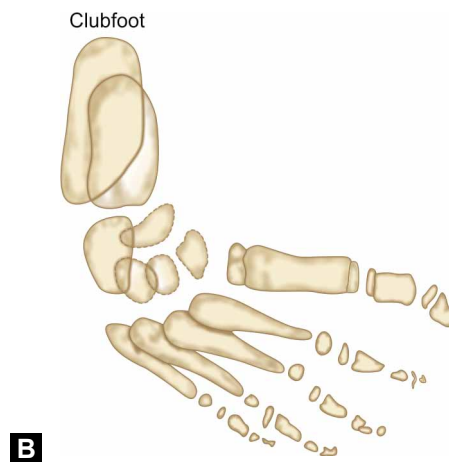
Figs. 7.4A and B: (A) Equinus at ankle joint (B) Normal dorsiflexion at ankle joint.
 Courtesy: Dr. Gaurav Gupta (JN medical college, AMU).



Figs. 7.5A and B: (A) Varus at subtalar joint. (B) Cavus.

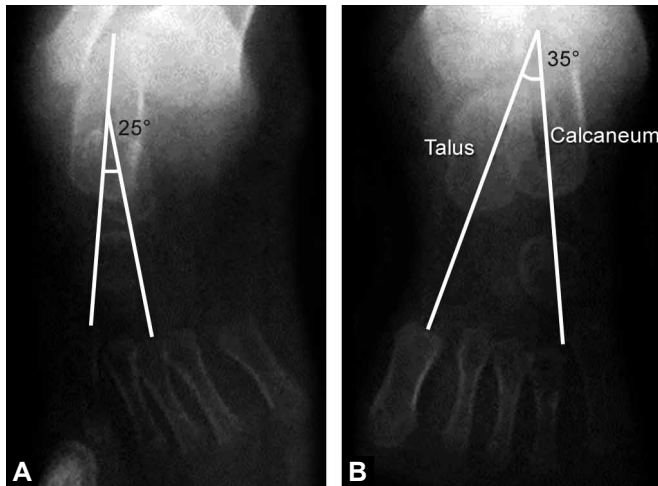


Figs. 7.6A and B: Adduction of metatarsals.



- *Talocalcaneal angle (Kite's angle on AP view) (Figs. 7.7A and B):* Angle between long axis of talus and calcaneum. Normal value is 35°–55° on AP view. A value of less than 25 degree is confirmatory for clubfoot.
- *Talus first metatarsal angle (Meary's angle) (Fig. 7.8):* Angle between the long axis of talus and first metatarsal in weight bearing lateral view. Normally, this angle

- is zero degree. Becomes greater than 5 degree (convex upwards) in clubfoot. It measures cavus deformity.
- *Tibio calcaneal angle (Fig. 7.9):* Angle between the long axis of tibia and calcaneum in stress lateral view. Normal value is 10°–40° in stress lateral view. Increases in clubfoot (>90°). It is a measure of heel equinus.



Figs. 7.7A and B: Talo calcaneal (Kite's) angle in CTEV and a normal patient.

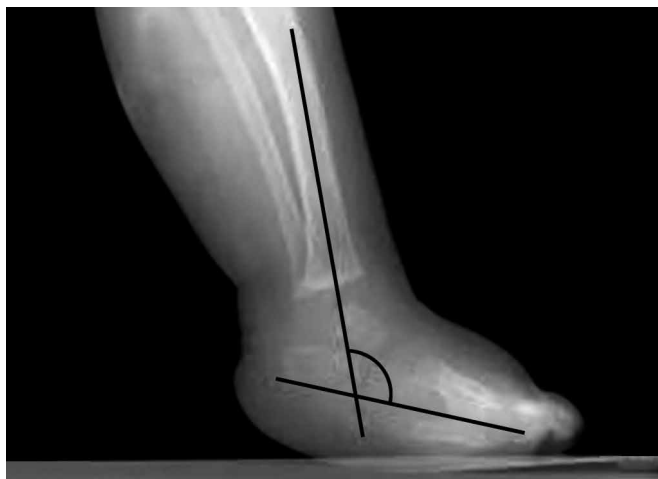


Fig. 7.9: Tibio calcaneal angle.

Classifications (Scoring Systems for Grading the Severity of Deformity)

- **Dimeglio classification:** Primarily based on degree of reducibility of deformities (equinus, varus, forefoot adduction, derotation of calcaneopedal block).
- **Pirani classification (more commonly used):** Three variables for midfoot (curvature of lateral border, severity of medial crease, palpation of talar head to assess its uncovering) and three variables for hindfoot (emptiness of heel, severity of posterior crease and rigidity of equinus) are assessed. Each has score of 0, 0.5 or 1 depending on severity. Maximum score is 6 (worse).

Treatment

Treatment should be started immediately after birth. Early in life the soft tissues of the infant are very pliable and the deformity can be corrected by conservative means

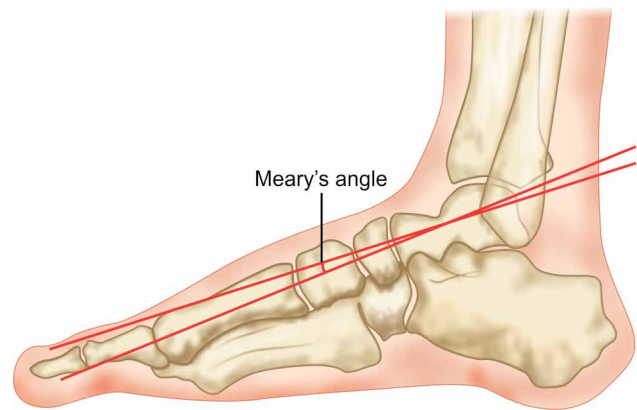


Fig. 7.8: Meary's angle.

only. However, as the child grows, the deformity becomes more and more fixed and surgical management becomes necessary and more so if a particular age is crossed then even the results with surgery are not very encouraging. So, the dictum is to start the treatment just as the lanugo is shed off.

Treatment of CTEV is dictated by the age of the patient.

Age less than 1–2 years: Serial manipulation and casting is the treatment of choice. This consists of manipulating the foot of the child and applying a corrective plaster every week when the child comes to attend the OPD clinic. After a few plasters the deformity is corrected in most cases and then the correction is maintained by specific orthosis.

Three philosophies of conservative gradual correction of deformity are there:

1. **Ponseti method (Figs. 7.10A to C) (method of choice now with a success rate of > 95%):** This procedure consists of manipulating the foot for 1–3 minutes into corrected position, followed by holding the correction in an above knee cast (applied with knees flexed to 90°). After 7 days, cast is removed, foot re-manipulated, and re-casted for another week in successively more corrected position. Usually 5 to 7 casts are sufficient and deformity gets corrected. The order of correction is very important. It can be remembered by the pneumatic "CAVE". Cavus is corrected in the first cast by supinating the forefoot and dorsiflexing the first metatarsal. Forefoot must never be pronated as it will increase the cavus deformity. Adduction and varus are then corrected simultaneously in the subsequent casts by abducting the forefoot in supination with counter pressure being applied at talar head. Lastly, equinus is corrected, by dorsiflexing the fully abducted foot. In case dorsiflexion is difficult beyond neutral then a percutaneous tenotomy of Tendo Achilles is done to achieve adequate dorsiflexion.

Caution: It is important to follow the above-mentioned order. When an attempt is made to correct equinus before adduction and varus are fully corrected, the



Figs. 7.10A to C: Ponseti technique (A) Cavus correction, (B) Varus and abduction corrected and (C) equinus correction.

equinus gets corrected at the midfoot area (midfoot breaks) rather than at the ankle and the plantar surface of the foot becomes convex. This is referred to as Rocker bottom foot.

2. **Kite's method:** Oldest devised method, but not used nowadays. Sequence of correction was forefoot adduction, followed by heel varus, and lastly equinus. Cavus was not addressed. Kite followed a strict sequence of correction, proceeding to the next deformity only when first one is fully corrected. This is biomechanically incorrect as all joints in foot are kinematically interlinked (Kinematic Coupling, i.e. movement at one joint will automatically result in movement in surrounding joints also). This method is lengthy (may take up to 2 years for correction) and success rate is also around 70–75% only. The biggest mistake made by Kite (Kite's error) was that he abducted the foot by using cuboid as the fulcrum rather than talar head as in Ponseti's method, which is biomechanically more sound.
3. **French physiotherapy method (Functional method) (Bensahel):** Used mainly in Europe. Consists of progressive passive manipulations, active muscle work, taping (special stretchable tapes to hold corrected foot positions) and splinting (not casting).

Once the desired correction has been achieved, the same has to be maintained over next few years by applying a foot abduction orthosis. Options available include

Dennis Brown Splint or CTEV shoes. CTEV shoes (Figs. 7.11A and B) are special shoes that have a straight inner border (to prevent adduction of metatarsals), no heel (to avoid equinus recurrence) and raised outer border (to make foot go into eversion). Dennis brown splint (Fig. 7.12) is rather dynamic in action. It has a pair of shoes mounted on a steel bar. The shoes rotate outwards whenever the child kicks thereby causing more and more abduction. Mostly, a Dennis Brown splint is preferred but as the child approaches the walking age, CTEV shoes are opted for. The orthosis has to be applied for 23 hours a day (i.e. full time) for 3 months and during sleep till 2–4 years of age.

Age 2–5 years: Posteromedial soft tissue release (PMSTR). Once the child has crossed the age of 1–2 years, the soft tissues are no longer that pliable that they can be stretched by plaster alone. Surgery is often required in these children to correct the deformity and this involves releasing the tight structures present on the posteromedial side of the foot (behind the medial malleolus). Surgery is best delayed till walking age (9–12 months), so that the walking child can easily maintain correction and also the foot is easier to operate upon.

Posteromedial soft tissue release: Two commonly done procedures for PMSTR are Turco's release via medial hockey stick or J shaped incision and a modified McKay extended release by a transverse incision.



Figs. 7.11A and B: Congenital talipes equinovarus (CTEV) shoes.

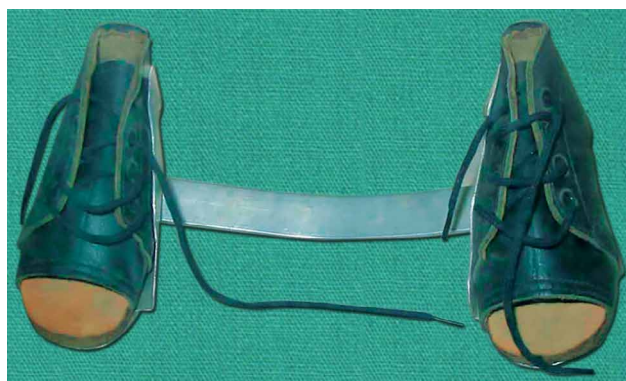
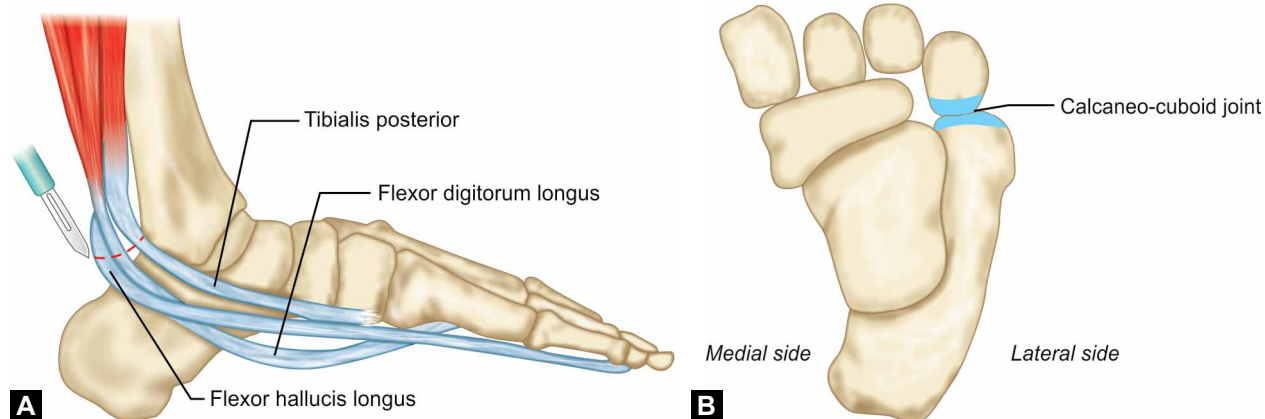


Fig. 7.12: Dennis Brown splint.



Figs. 7.13A and B: Posteromedial soft tissue release (PMSTR) and Dillwyn-Evans procedure

The structures cut in PMSTR (Fig. 7.13A) include—Tibialis posterior, FHL, FDL and Tendo Achilles (lengthened by tenotomy).

Age more than 5–10 years: Bony osteotomy is often required in addition to PMSTR. (Classically Dillwyn-Evans procedure)

The principle behind bony osteotomies is to shorten the lateral column as these patients have a long lateral border and a short medial foot border.

Dillwyn-Evans procedure (Fig. 7.13.B): It involves resection and fusion of calcaneocuboid joint on the lateral aspect of the foot. The growth on lateral side stops, medial side continues to grow and foot gradually corrects over time.

Lichtblau's procedure (Fig. 7.14): It involves lateral closing wedge osteotomy of anterior end of calcaneum. An advantage of this procedure is that it avoids hindfoot stiffness, which may occur after Dillwyn-Evans procedure.

Age more than 10 years: Triple arthrodesis



Fig. 7.14: Litchblau's procedure

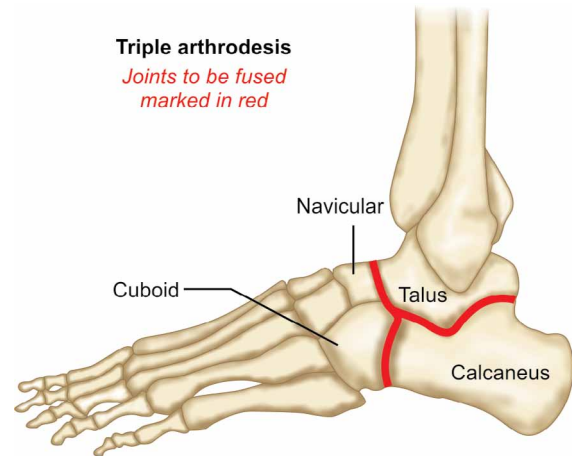
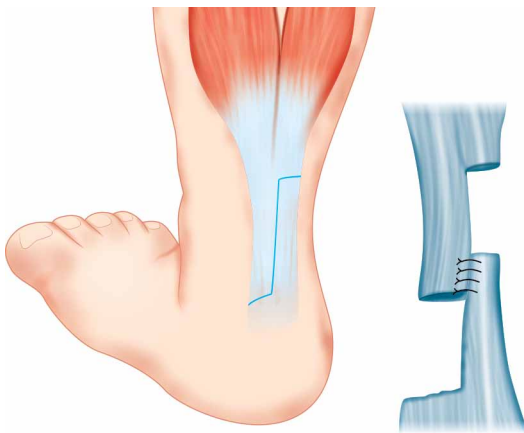
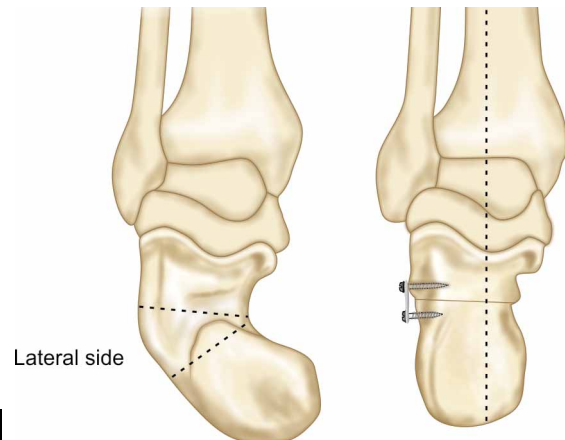


Fig. 7.15: Triple arthrodesis.



A



B

Figs. 7.16A and B: Tendo Achilles (TA) lengthening and Dwyer's osteotomy.

Triple arthrodesis (Fig. 7.15): Fusion of talonavicular, talocalcaneal and calcaneocuboid joints after taking out adequate wedges to correct the deformity. It results in a stiff but cosmetically better foot. It is performed after skeletal maturity (inadequate fusion occurs if performed before skeletal maturity and also growth of foot will be affected).

Recurrence

The most common deformity to recur is equinus followed by varus. In case there is recurrence then following procedures may help in controlling a recurrence.

For Equinus: Tendo Achilles (TA) lengthening (Fig. 7.16A) and Lambrinudi arthrodesis (for fixed equinus that is not correctable passively).

For isolated heel varus: Dwyer osteotomy (Fig. 7.16B); Calcaneal osteotomy (medial opening wedge osteotomy) for correcting heel varus.

HIGH-YIELD POINTS

- Congenital talipes equinovarus is basically a dysplasia of all tissues and structures “below the knee” (i.e. excluding the knee).

- **Master knot of Henry:** It is a tough fibrous tissue encasing the crossing of FDL and FHL at plantar aspect of foot. It must be released during PMSTR.
- **Supination:** Combination of varus of hindfoot, plantar flexion at ankle and adduction of forefoot.
- **Pronation:** Combination of valgus of hindfoot, Dorsi-flexion at ankle and abduction of forefoot.
- **Neglected clubfoot**—Which is not treated till 2 years of age.
- **Relapsed/recurrent clubfoot:** Deformity corrected initially, but one or more components recurred.
- **Resistant clubfoot:** Not corrected or partially corrected despite correctly using the Ponseti technique.
- **Atypical/Complex clubfoot:** This term refers to a very rigid club foot. These feet are short and chubby with underdeveloped calf muscles and are characterized by severe cavus and marked equinus (due to hyperflexed metatarsals) that tend to produce a single deep transverse crease in the middle of the sole. Often these are not identified in the beginning of the treatment but recognized when the Ponseti casting commences. Although the medial soft tissues stretch



Fig. 7.17: Pes cavus.

up, cavus and equinus show great resistance. In such patients the Ponseti technique needs to be modified a little bit. The aim should be to achieve 20–40° of abduction (rather than routine 70° as it may lead to exaggerated flexion of metatarsals) while a dorsiflexion of 5° usually suffices as the latter spontaneously improves after a few months.

- Fulcrum of correction:
 - Kite's method—Calcaneocuboid joint
 - Ponseti method—Talar head.
- Most common complication of Triple arthrodesis—Talonavicular pseudoarthrosis.
- Joint not fused in triple arthrodesis—Ankle (tibiotalar).
- Most common cause of failure of conservative treatment/relapse is noncompliance with bracing.
- Congenital talipes equinovarus is associated with hypoplasia or absence of anterior tibial artery (dorsalis pedis) in many children.
- *Rocker bottom foot (convex plantar surface of foot)*: It is also seen in congenital vertical talus.
- *Joshi's external stabilization system (JESS)*: Indigenous external fixation system developed by Dr B B Joshi based on the principle of "fractional distraction", where the shortened posteromedial side of the foot is distracted. It is used for correction of relapsed, resistant and neglected clubfoot.

PES CAVUS AND PES PLANUS

Relevant anatomy

Since the foot has to act as a pliable platform to support body weight, it is an arched structure. There are two longitudinal (medial and lateral) and two transverse (anterior and posterior) arches. Both the longitudinal arches have distal ends formed by the corresponding metatarsal heads and the proximal limit formed by the base of calcaneum. However, out of the two, the medial longitudinal arch is higher, more pliable and a better shock absorber.

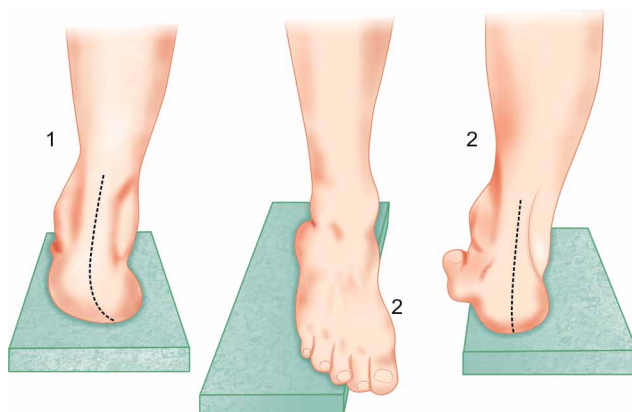


Fig. 7.18: Coleman block test—when the patient stands on the edge of a block, the hindfoot recorrects itself if it is supple.

PES CAVUS (HIGH ARCHED FOOT)

In "Pes Cavus", the medial longitudinal arch of the foot is exaggerated, and often there is also clawing of the toes (Fig. 7.17). The heel is mostly inverted (in varus) and the soft tissues of the sole are tight.

Causes

All forms of this deformity generally result from some kind of muscle imbalance and hence it is seen mostly in association with neuromuscular disorders like poliomyelitis (most common cause), hereditary motor/sensory neuropathy (HMSN), cerebral palsy, diastematomyelia, tethered cord syndrome, muscular dystrophies, etc. Occasionally the deformity occurs secondary to trauma (e.g. Burns contracture or compartment syndrome leading to Volkman's contracture of sole).

Clinical Presentation

Patients are generally older children or young adolescents that present with a calcaneo-cavo-varus deformity of foot. Due to associated clawing of the toes, the metatarsal heads are forced into the sole and callosities form over pressure areas, that may be painful.

An important aspect of examination is to check if the deformity is reversible. For this the Coleman Block Test is performed (Fig. 7.18).

A thorough neurological examination must also be done to elucidate the cause.

Diagnosis

On a lateral foot radiograph, the Meary's angle and the calcaneal pitch are useful to deduce the diagnosis.

Meary's angle is drawn (page 278) and an angle that is greater than 4° convex downward is considered "pes planus" while an angle greater than 4° convex upward is considered as "pes cavus".

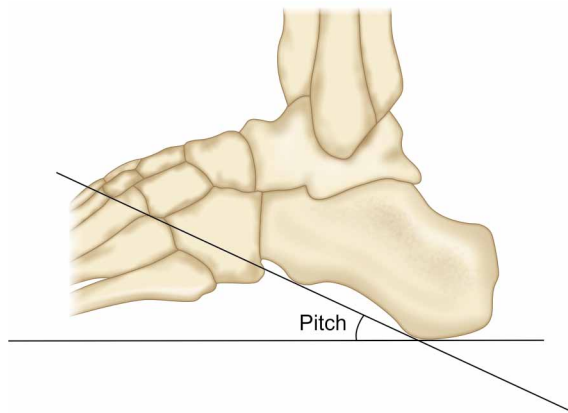


Fig. 7.19: Calcaneal pitch.

Calcaneal pitch (Fig. 7.19): A line is drawn from the plantar-most surface of the calcaneus. The angle made this line makes with the plantar surface of foot is the calcaneal pitch. In pes cavus, the pitch is increased than normal.

Treatment

Only symptomatic patients need to be treated. Patients are advised custom made shoes with moulded inserts (arch supports). In patients where the deformity is severe and fixed (deduced from Coleman block test), surgery is often needed. Mobile deformities can often be managed by soft tissue release operations like plantar fascia release while in case joints are fixed then corrective calcaneal osteotomies are the options.

PES PLANUS/PLANO VALGUS (FLAT FOOT)

Flat foot refers to flattening of the medial longitudinal arch of the foot. In these patients the medial border of the foot touches the ground, and often the heel is in valgus (Planovalgus, Fig. 7.20). On lateral foot X-ray one can confirm the diagnosis by finding a decreased Meary's angle (page 278).

The deformity is classified into following types for a better understanding:

Flexible (Correctable) Flat Foot

In flexible type, the deformity appears when the patient is bearing weight on the foot but once the foot is in the air, the arch reappears. Or one may be able to recreate the arch in such patients by dorsiflexing the great toe (this maneuver stretches the plantar fascia that makes the medial arch prominent even in normal people). Most of the cases are idiopathic, however, it may appear in patients with ligament laxity and in those who have a hypermobile



Fig. 7.20: Flat foot.

foot. At times the deformity is just physiological in toddlers as the intrinsic muscle tone in foot takes some time to develop and the arches thus take some time to fully appear.

Treatment in most such cases is conservative. Patients are prescribed flat foot exercises and may be given special shoes with elongated and crooked heels (Thomas heel) or arch supports to tone up the arches. Although these patients are compatible for almost all normal life activities, however, they face eligibility problems at times when they apply for jobs requiring high level of fitness, so reassurance is important.

Rigid Flat Foot

This is the noncorrectable fixed variety of flat foot, the cause of which varies as per the age of presentation. When small children or new borns are brought with this deformity, a condition called as "Congenital Vertical Talus" (discussed below) must be considered while in the adolescents and adults the cause is generally a segmentation defect of tarsal bones, a condition called as "Tarsal Coalition" (discussed below). Not uncommon cause in middle aged women is a condition called "tibialis posterior tendon dysfunction". The etiology is unknown but the tendon attrition occurs mostly in diabetic people or in those who have been injected steroids into the tendon. Since "tibialis posterior" is an invertor and plantar flexor important for maintaining medial longitudinal arch of foot, its dysfunction often ends in flat foot.

Compensatory Flat Foot

Flat foot deformity may be acquired at times even in adult life to compensate for any condition that affects the posture like a genu valgum deformity of knee, spasm of peroneal muscles, malunited fracture of calcaneum, arthritis in foot joints as in rheumatoid arthritis, diseases causing flaccid paralysis and loss of foot muscle tone and sometimes even in cases with morbid obesity.



Fig. 7.21: Congenital vertical talus.

Courtesy: Dr Heren Patel (BJ medical college Ahmedabad)



Fig. 7.23: Accessory navicular.

CONGENITAL VERTICAL TALUS (ROCKER BOTTOM FOOT)

This is a rare congenital condition seen in infants where the medial longitudinal arch is not just flat but the undersurface of the foot is convex downwards giving the appearance of rocker bottom chair. The deformity is called “Congenital Vertical Talus” as the talus in these patients lies malpositioned vertically as opposed to normal horizontal position (Fig. 7.21). X-ray clearly shows the malpositioned talus with the navicular dislocated dorsally over the talar head.

Treatment is very difficult as by the time the child is seen the dorsolateral structures are severely contracted. Hence surgery must be done early usually before the age of 2 years. Surgery involves open reduction and realignment of talonavicular and subtalar joints (Ramsay

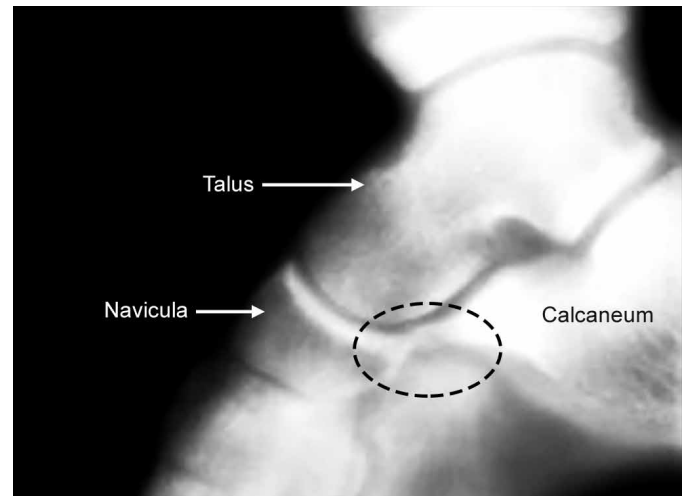


Fig. 7.22: X-ray of tarsal coalition between calcaneum and navicular.

procedure). In later stages (generally later than 4 years) the subtalar joint has to be fused (Grice Green subtalar arthrodesis).

TARSAL COALITION (PERONEAL SPASTIC FLAT FOOT)

This is an autosomal dominant condition characterized by segmentation defect of tarsal bones. The problem although is present since birth usually becomes symptomatic during early adolescence. The patient generally presents with a painful rigid flat foot often accompanied by the spasm of peroneal muscles. On X-ray one finds coalition (a connecting bar of bone) between talus and calcaneum (most common) and/or between calcaneum and navicular (Fig. 7.22). Treatment is initially conservative but nonresponders usually need excision of the connecting bar.

HIGH-YIELD POINTS

- A force platform is used to record pressure changes in the foot as one walks and the technique is called as “pedobarography”.
- *Accessory navicular:* Some patients (with flexible flat foot mostly) have an accessory ossicle lying just medial and little proximal to the navicular bone on their X-ray (Fig. 7.23). It is usually asymptomatic. This accessory navicular may be cause of flat foot in some although the real significance is still debatable. In symptomatic cases tenderness can be elicited directly over it. Conservative treatment is usually successful. In non-responding cases excision of accessory navicular is performed (Kinder’s procedure).

DEFORMITIES OF TOES

HALLUX VALGUS

It refers to lateral deviation of the hallux (great toe) in relation to the first metatarsal (Fig. 7.24). It is the most common foot deformity with females affected more often than men.

ETIOLOGY

Exact cause is unknown but contributing factors include pronated flat foot, hypermobility of foot, long first ray, etc. Other disorders which may cause hallux valgus include gout, rheumatoid arthritis, Ehler-Danlos syndrome, Marfan syndrome, Charcot-Marie-Tooth disease, etc. People who wear tight shoes may be more prone.

PATHOANATOMY

On the medial side of the great toe metatarsophalangeal (MTP) joint, there is medial joint capsule and abductor hallucis muscle while on the lateral aspect lie the lateral joint capsule and the adductor hallucis muscle. As the toe deviates towards lateral aspect, the lateral structures, viz. adductor hallucis and lateral joint capsule get contracted while the medial structures are stretched. Over time the deformity gets fixed. As subluxation of the first MTP joint occurs, the metatarsal head gets prominent medially. A bursa develops in the overlying area that together with thickened soft tissues lead to bunion formation. As the deformity increases, there occurs crowding of the lesser toes and lesser toe deformities may also result.

CLINICAL FEATURES

Patient presents with unsightly deformity, difficulty in wearing shoes, and pain over the bunion (most common presenting complaint). Secondary to the deformity, more

weight is borne on lateral metatarsal heads, resulting in transfer metatarsalgia, stress fractures and callosities of the lateral metatarsals. In longstanding cases there may be osteoarthritis of MTP joint causing severe pain.

DIAGNOSIS

An X-ray is done to measure the hallux valgus angle (angle between first metatarsal and proximal phalanx); an angle greater than 15° is diagnostic (Fig. 7.25). Inter metatarsal angle (between long axis of first and second metatarsals) is also increased (normal is 9°).

Treatment: Initial form of treatment is nonoperative, including shoe modifications (wide toe box), orthotics like toe wedges or inserts. If conservative treatment fails or if deformity is severe, a corrective osteotomy (Aikin or Chevron) is performed. In patients with low functional demands like elderly, an excision arthroplasty (Keller's operation) can be performed.

HIGH-YIELD POINTS

Hallux rigidus: It refers to stiffness or rigidity of the first MTP joint. It can occur in a number of conditions like gout, pseudogout or even osteoarthritis and mostly it is bilateral.

LESSER TOE DEFORMITIES

The important deformities of lesser toes include: Claw toes, Hammer toe and Mallet toe.

Claw Toes

This is characterized by hyperextension at MTP joints and flexion at both proximal and distal interphalangeal joints

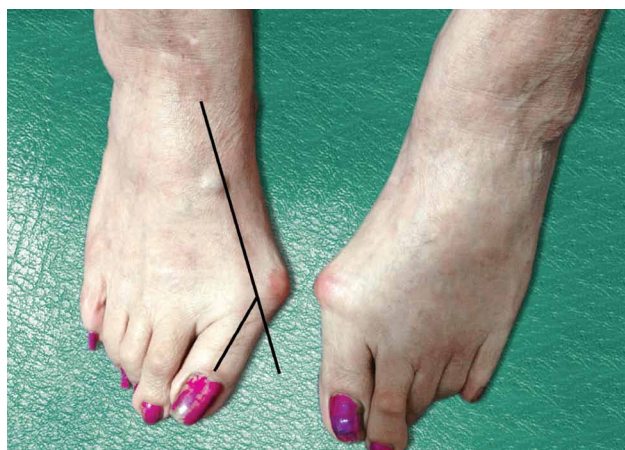
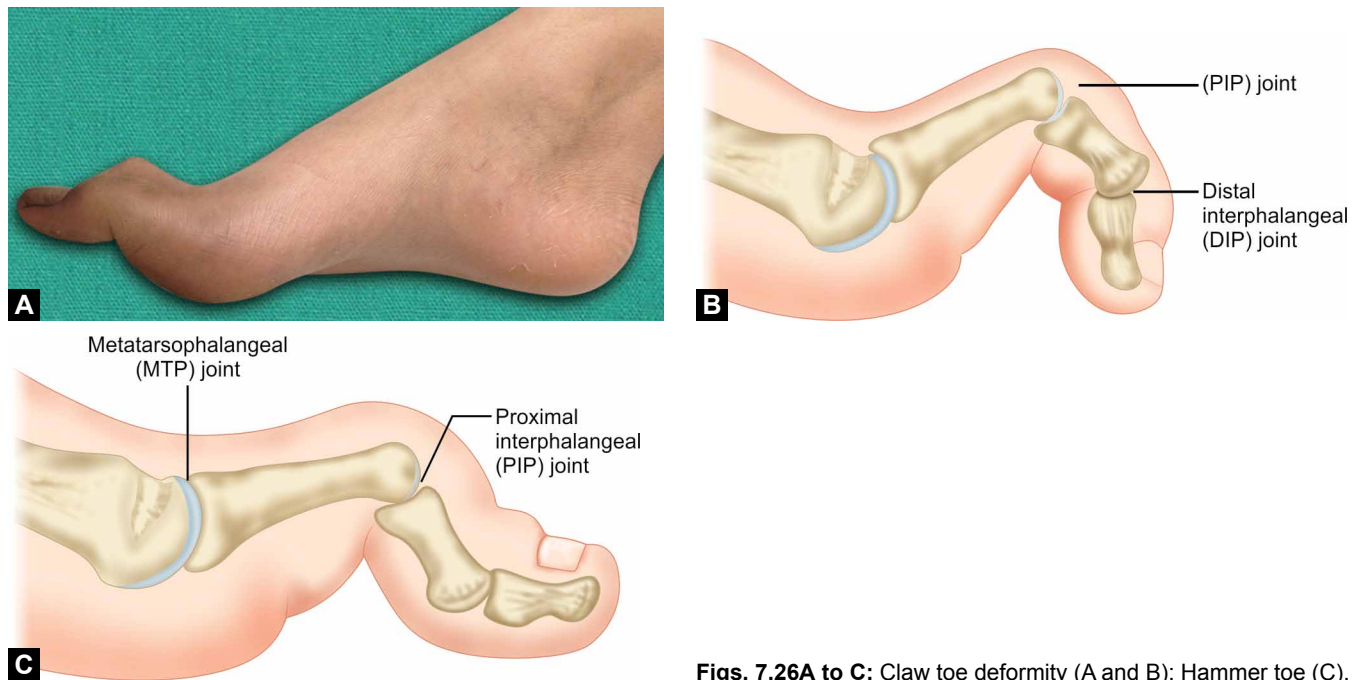


Fig. 7.24: Bilateral hallux valgus.



Fig. 7.25: X-ray of patient with hallux valgus.



Figs. 7.26A to C: Claw toe deformity (A and B); Hammer toe (C).



Figs. 7.27: Macroductyly.

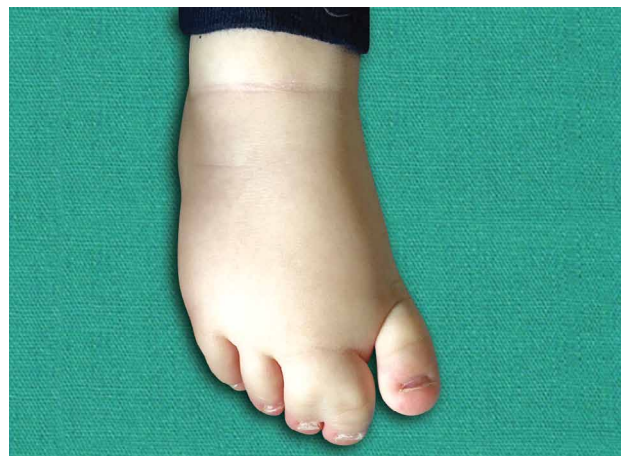


Fig. 7.28: Syndactyly.
Courtesy: Chelsea Laffleur and M-cm community.

(Figs. 7.26A and B). It is an intrinsic minus deformity due to paralysis of intrinsic muscles of foot and hence is seen mostly in diseases like peroneal muscular atrophy, poliomyelitis, peripheral neuropathies, etc. Rheumatoid arthritis is also an important cause. Surgical treatment involves re-routing the long toe extensor tendons through the neck of metatarsals (Modified Jones operation).

Hammer Toe (Fig. 7.26C)

In this the PIP is fixed in flexion while the distal interphalangeal (DIP) and MTP are fixed in extension. The second toe is most commonly affected. The deformity is congener of Boutonniere's deformity of finger and possible cause seems to be extensor dysfunction.

Mallet Toe

In Mallet toe the DIP joint is fixed in flexion. The tip of the toe presses into the shoe producing a callosity.

Other Deformities

Cock-Up deformity: The MTP joint is dislocated and the little toe sits on the dorsum of the metatarsal head.

Macroductyly (Fig. 7.27): Refers to presence of an enlarged sized digit. Most commonly affected is index followed by the long finger.

Syndactyly (Fig. 7.28): It is a condition where two or more digits are fused.



Fig. 7.29: Polydactyly.

Polydactyly (Fig. 7.29): Presence of an extra digit is called “polydactyly”.

Cleft foot (Fig. 7.30): It is an anomaly where a single cleft extends proximally into the foot. It is also called as “lobster foot”.



Fig. 7.30: Cleft foot.

Symbrachydactyle: In this condition there is absence of parts of fingers.

Symphalangism: This refers to stiffness of the PIP joint.

DEFORMITIES OF LEG AND ANGULAR DEFORMITIES AROUND KNEE

CONGENITAL PSEUDOARTHROSIS OF TIBIA

This is a congenital condition characterized by bowing of tibia (mostly anterolateral bowing) (Fig. 7.31). Neurofibromatosis type 1 is found in 50–55 % of patients with congenital pseudoarthrosis (while 10% of patients with neurofibromatosis have pseudoarthrosis). It is equally distributed in boys and girls and is almost always unilateral.

There is little tendency for the lesion to regress, and the bone eventually fractures through the weakened area. Re-fracture through the lesion is common after initial union. The lesion is usually in distal half of the tibia (Figs. 7.32A and B).

Boyd classified this lesion into six types. The lesion may present on radiographs as sclerosis of medullary canal, an hour-glass constriction of the tibia or a cystic lesion in the medullary canal of tibia.

Treatment: Before a fracture occurs, a total contact orthosis is prescribed as prophylaxis. But once a fracture occurs, surgery is indicated. Various surgical options include intramedullary nailing with bone grafting, fibular grafting, Ilizarov fixator, or even amputation in cases with failed surgical attempts, severe stiffness or shortening more than 2–3 inches.

ANGULAR DEFORMITIES OF KNEE

Introduction

Normal progression of lower limb alignment is as follows:

- At birth: Physiological genu varum is there.

- After 12 months of age the varus starts to reduce. By 18–24 months, neutral relationship is attained.
- After 5–6 years of age, valgus of about 5–6° is attained, which persists into adult life.

GENU VARUM (BOW LEGS)

Introduction

It is a common pediatric problem where ankles are approximated but knees remain divergent apart (Fig. 7.33).

Important causes of genu varum are:

- Physiological genu varum (birth till 18–24 months of age)
- Pathological genu varum
 - Rickets (most common cause)
 - Idiopathic (second most common cause)
 - Tibia vara (Blount’s disease)
 - Physeal injury (Trauma, infection, tumor involving medial side of knee)
 - Renal osteodystrophy
 - Osteogenesis imperfecta
 - Skeletal dysplasias
 - Focal fibrocartilaginous dysplasia.

Diagnostic Aspects

The deformity is confirmed by measuring the distance between medial joint lines of both knees with ankle of patient approximated. If genu varum is present, then this distance is more than 8 cm. On X-ray (Fig. 7.34) one may find an increased femoro-tibial angle (normal is around 10°).



Fig. 7.31: Congenital pseudoarthrosis of tibia.



Figs. 7.32A and B: (A) X-ray of pseudoarthrosis of tibia and (B) deformity of distal leg in neglected pseudoarthrosis of tibia.

Courtesy: Dr Matad Lokeshwaraiah Chetan (SS institute of medical sciences, Davangere)



Fig. 7.33: Child with bilateral genu varum deformity.

Courtesy: Dr RK Sharma, (Indraprastha Apollo hospital New Delhi).

Treatment

If child is less than 4 years old, full time (23 hour/day) orthotic brace (mermaid brace) may be used for treatment. Otherwise, an osteotomy to achieve valgus overcorrection is done. The crucial age for osteotomy is 4 years, because risk of recurrence increases after 4 years of age.

BLOUNT'S DISEASE

This is a developmental (not a congenital) disorder characterized by progressive bow leg deformity (genu varum) that results due to defective enchondral ossification of posteromedial proximal tibial growth plate. This disease has three components: (1) genu varum, (2) genu recurvatum (hyperextension at knee) along with (3) tibial internal rotation (Fig. 7.35).

It is classified as infantile (onset up to 3 years of age, most common subtype), juvenile (4–10 years) and adolescent (after 10 years of age) forms.



Fig. 7.34: X-ray of a patient with genu varum deformity.

The diagnosis is confirmed by drawing metaphyseal-diaphyseal angle of Drenan (Fig. 7.36), which if more than 11° , confirms the diagnosis.

Treatment

Generally a proximal tibial osteotomy is performed for correction of deformity.

GENU VALGUM (KNOCK KNEE)

Introduction

In this condition, the knees are touching each other while the ankles tend to be divergent (Figs. 7.37A and B).

Important causes include:

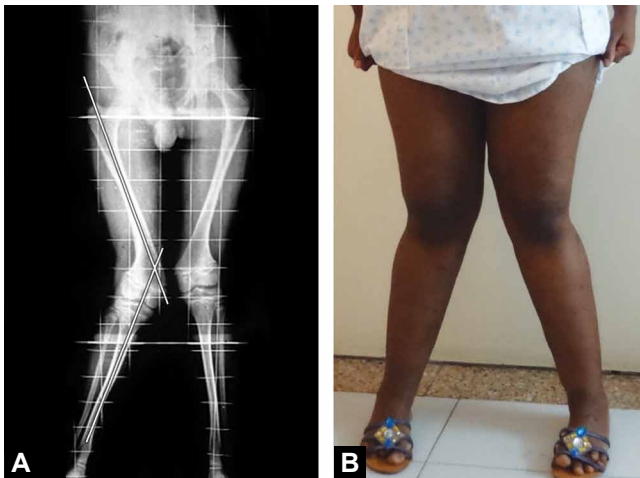
- Physiological genu valgum (between 2 to 7 years)
- Pathological genu valgum
 - Idiopathic (commonest)
 - Rickets (second commonest)



Fig. 7.35: Blount's disease



Fig. 7.36: Metaphysiodiaphyseal (MD) angle of Drenan



Figs. 7.37A and B: (A) X-ray both lower limb AP view (scanogram) showing genu valgum deformity (B) A child with bilateral genu valgum deformity.

Courtesy: Dr Sachin Ingole (Indraprastha Apollo hospital New Delhi).

- Physeal injury (Trauma, tumor, infection of lateral part of physis)
- Skeletal dysplasias
- Congenital dislocation of patella.

Diagnostic aspects: The deformity is confirmed by measuring the distance between medial malleoli of both ankles with knees of patient approximated. If genu valgum is present, then distance is more than 10 cm.

Treatment

Excessive physiological valgus after 6–7 years of age requires treatment if symptomatic.

If there is significant growth potential remaining, i.e. boys less than 12 years and girls less than 10 years of age, reversible hemiepiphyodesis with staples is done. Staples are applied on medial side of growth plate to prevent the medial side from growing so that only the lateral side grows with age and the deformity corrects itself. Once the desired correction is achieved, staples may be removed.

Otherwise, a timed permanent hemiepiphyodesis can be done at a time when the remaining growth potential of the opposite half of the physis just corrects the deformity before naturally fusing.

In skeletally mature cases, corrective osteotomy is done.

Note: In genu valgum or varum, the deformity can be there in either tibia or femur. The method to assess is very simple. The patient is made to flex the knees to 90° and observed from foot end. If the deformity disappears, it is in femur and must be corrected by a femoral osteotomy else if the deformity is in tibia, it will persist on flexion and should be addressed by proximal tibial osteotomy.

HIGH-YIELD POINTS

- Malunion of a proximal tibial fracture commonly produces a genu valgum (Cozen's fracture of proximal tibial metaphysis).
- Rickets more commonly causes genu varum because the most common form of rickets is nutritional rickets which occurs during the age group of physiological varus. Hypophosphatemic rickets also causes genu varum. But renal osteodystrophy typically occurs later in life, hence it produces genu valgus.
- In case of rickets, metabolic abnormality is always corrected first, before going in for a corrective osteotomy.
- In reversible hemiepiphyodesis for genu varum, staples are applied on lateral side while in genu valgum they are applied on medial side.
- Genu recurvatum refers to hyperextension deformity at knee (Fig. 7.38) and may be seen in diseases that produce lax ligaments (like Marfan's syndrome), secondary to malunited fractures or due to epiphyseal growth defects.
- **Siffert Katz sign:** In Blount's disease, the medial tibial plateau is deformed due to abnormal growth plate. The medial femoral condyle subluxates posteromedially into the depressed medial tibial plateau at

10–20 degrees of knee flexion. This is called Siffert-katz sign.

- *Congenital dislocation of the knee:* It is thought to result from abnormal fetal position that causes the knee to get locked in hyperextension. It is usually seen in patients with neuromuscular syndromes like arthrogryposis multiplex congenita, Larsen syndrome, Ehler Danlos syndrome, etc. Classically new born presents with hyperextension deformity of the knee. Often there is congenital absence of cruciate ligaments with fibrosis of quadriceps and hypoplastic patella. 70% cases are associated with ipsilateral DDH and 50% with CTEV. patients are managed with serial casting to achieve up to 90 degrees flexion. If it fails surgical correction is undertaken by 6 months to 1 year.



Fig. 7.38: Genu recurvatum.

HIP DEFORMITIES

DEVELOPMENTAL DYSPLASIA OF HIP (DDH)

Introduction

Hip joint is the most stable joint in the body with a big socket, i.e. the acetabular cup and a well-sized ball, i.e. the femoral head. Also the strongest ligament in the body (Iliofemoral ligament) is present around this joint to provide stability. To dislocate such a stable joint a good velocity trauma would be needed. However, the term “congenital dislocation of hip (CDH)” refers to spontaneous dislocation of hip that occurs at birth without any documented evidence of severe trauma. This clearly indicates that these patients must be having some predisposing factors that make their hip unstable so that a dislocation results spontaneously.

A better understanding of the condition was provided by Klissic. He observed that although a group of patients with this condition are born with a hip that is dislocated at birth, a subset of children exist in whom the joint spontaneously dislocates shortly after birth. Thereby, he introduced the term “developmental dysplasia of hip (DDH)” to signify that these patients have dysplastic hips that are the predisposing cause. Either their femoral head is small and does not ossify in time or their acetabulum is flat and shallow due to faulty development.

Technically, DDH comprises a spectrum of disorders with the common underlying etiology. i.e. a lax hip capsule and dysplastic hip joint resulting in failure to maintain the femoral head within the acetabular socket. In children where dislocation exists from birth, the primary cause is faulty development while in those where dislocation generally occurs bit later, ligament laxity is the more important predisposing factor.

Incidence

- Actual dislocation is reported in 1/1,000 live births (incidence of positive clinical findings, i.e. frank dislocations and lax dislocatable hips combined, is higher).
- Male: Female ratio is 1:5
- It is bilateral in approximately one-third cases
- Left hip involvement is more common (Left > Bilateral > Right)

The condition is more common in first born female child with fair complexion (whites or Caucasians) who had a positive family history and at birth had a Faulty intrauterine position (breech delivery)—“The Five F’s”.

It is uncommon in India because mothers carry child straddled on the side of their waist with the hips of child abducted (Fig. 7.39). This tends to reduce unstable hips because when the femur goes into abduction, the head falls back into the acetabulum.

Etiology

Important factors implicated are:

- *Ligamentous laxity:* Often inherited. Maternal hormone relaxin may play a role. It is possible that the hormone crosses the placenta and if patient is a female the environment is more conducive for the hormone to relax the hip capsule and ligaments.
- *Breech presentation:* Unstable hip is 10 times commoner.
- *Postnatal positioning of child*—wrapped up with the hips swaddled in extension predispose to easy dislocation.
- *Oligohydramnios:* Likely that this causes crowding of the fetus in utero and faulty presentation thereby predisposing to dislocation.
- Associated congenital disorders include torticollis (strongest association), metatarsus adductus and congenital knee dislocation. No proven association with genu varum or CTEV exists.



Fig. 7.39: Mother carrying baby by side causing abduction of hips.

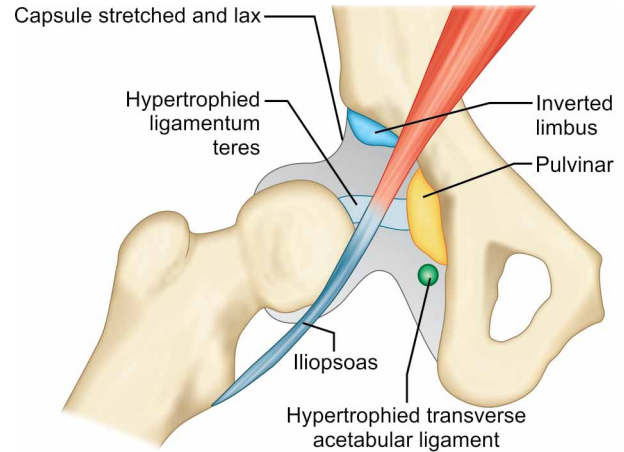


Fig. 7.40: Pathological changes in congenital dislocation of hip (CDH).

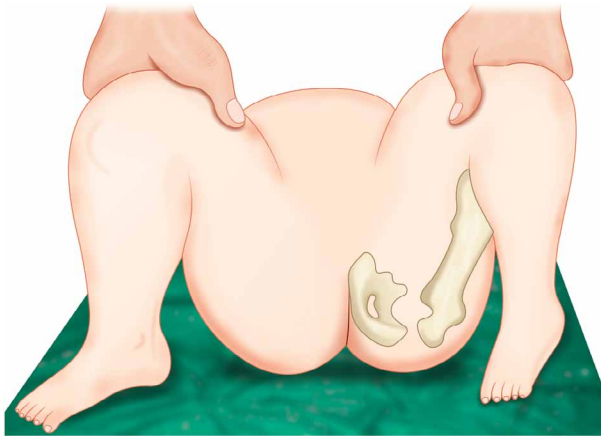


Fig. 7.41: Barlow's test.



Pathological Changes Seen in these Dysplastic Hips (Fig. 7.40)

- The femoral head epiphysis is small and ossifies late and when dislocated, the head moves upwards and laterally. This is due to the upward pull of gluteal muscles that arise from pelvis and are inserted on the greater trochanter.
- The acetabulum is shallow (not cup shaped) due to faulty development. This is the most common pathology central to the pathogenesis.
- Labrum (fibrocartilagenous rim around acetabulum) is inverted and hypertrophied and folded into the acetabulum (Inverted limbus)*
- Hypertrophied fibrofatty tissue (pulvinar) fills up the empty acetabulum*
- Ligamentum teres as well as the transverse acetabular ligament is hypertrophied (the former possibly due to stretching and the latter probably in an attempt to provide stability)*
- Capsule is stretched and lax and develops an hour glass constriction (as it is crossed in its lower half by

iliopsoas tendon) which tends to block reduction of head into acetabulum*

- *Adductors are shortened:* Main adductor (adductor magnus) extends from the ischial tuberosity and attaches near the medial femoral condyle into a bony prominence called the adductor tubercle. When the head is dislocated, this muscle pulls the distal femur medially and over time the adductors relatively shorten up.*
- There is excessive anteversion of both femoral neck and acetabulum.

**Factors preventing successful closed reduction on treatment attempt.*

Clinical Presentation

New Born

Although no standard guidelines for screening of DDH exist, it is a general consensus that all newborns must be screened for an unstable hip. Two conventional methods in practice for this are the Ortolani and the Barlow's tests (Fig. 7.41). Both the tests use a similar principle, the



Fig. 7.42: Asymmetrical skin folds.

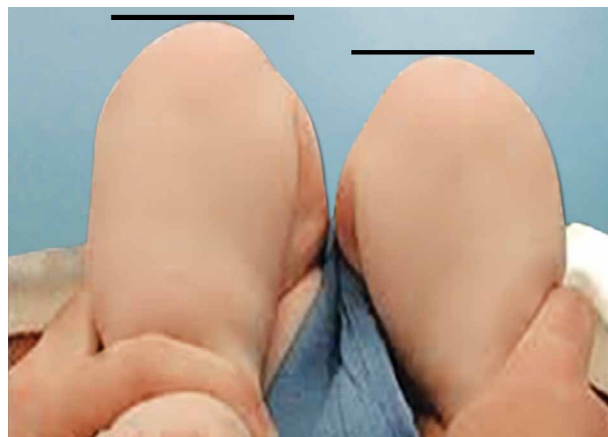


Fig. 7.43: Allis sign.

Table 7.3: Classification of developmental dysplasia of hip (DDH) by Graf's method

Grade (Class)	Alpha angle	Beta angle	Description (Head)	Treatment
I	> 60°	< 55°	Normal	None
II	43–60°	55–77°	Delayed ossification	Pavlik harness
III	< 43°	> 77°	Lateralization	Pavlik harness
IV	Unmeasurable	Unmeasurable	Dislocated	Pavlik harness/closed reduction/open reduction (age dependant)

unstable hip is dislocated or reduced and the clunks of dislocation/reduction are appreciated.

Barlow's test (more preferred, Fig. 7.41): Two parts—(1) adduction and (2) abduction.

With the hips and knees flexed, grasp thighs with fingers over greater trochanter and thumb in front. Gently adduct the hip and give slight outward pressure with thumb to dislocate the hip, producing the characteristic "Clunk of dislocation". This occurs in unstable dislocatable hips, which are not already dislocated. This part of test is negative in already dislocated hip.

In second part, pressure is released and hips abducted, which will relocate the hip and produce the "Clunk of relocation". Clunk, and not click, is significant.

Ortolani test (abduction test): Similar to second part of Barlow's test so can be applied only to already dislocated hips.

Older Children

Ortolani and Barlow's tests are rarely positive after 3 months of life because of soft tissue contractures. Other clinical findings that may suggest the diagnosis in older child include:

- Asymmetrical thigh folds/groin creases and a wide perineum (Fig. 7.42).
- The affected limb is shortened and externally rotated.
- Restricted abduction (especially in flexion) is one of the most sensitive sign. (Sensitivity—69%, Specificity—54%)
- There is excessive internal and external rotation of the dislocated hip

- **Galeazzi's sign (Allis sign) (Fig. 7.43):** With the child lying supine with both hips and knees flexed, the knee is lower on affected side. It is due to shortening of the affected lower extremity.

- Telescopy at hip is positive.
- Vascular sign of Narath (page 100) may be appreciated.
- Lumbar lordosis may be exaggerated (mostly in bilateral cases)

In a walking child Trendelenburg's gait (abductor lurch) and Trendelenburg's test may be positive. Children with bilateral CDH walk with a waddling gait/duck gait/sailor's gait.

Investigations

X-ray is of little value in a child less than 6 months. This is because the proximal femoral epiphysis is not ossified at birth and hence not visible on X-rays for the first 6–12 months of life. The investigation of choice (for screening as well as for diagnosis) for this age group (< 6 months old) is ultrasonography (USG), although the best investigation for any age would be a magnetic resonance imaging (MRI).

Ultrasonography classifies DDH by Graf's method (Table 7.3). The radiologist measures two angles on hip ultrasound—(1) Alpha angle (between baseline of ilium and roof of bony acetabulum) and (2) Beta angle (between baseline of ilium and cartilaginous acetabular roof). Normally alpha angle is more than 60° and decreases with increasing severity while beta angle is less than 55° and increases with increasing severity of DDH. Various grades

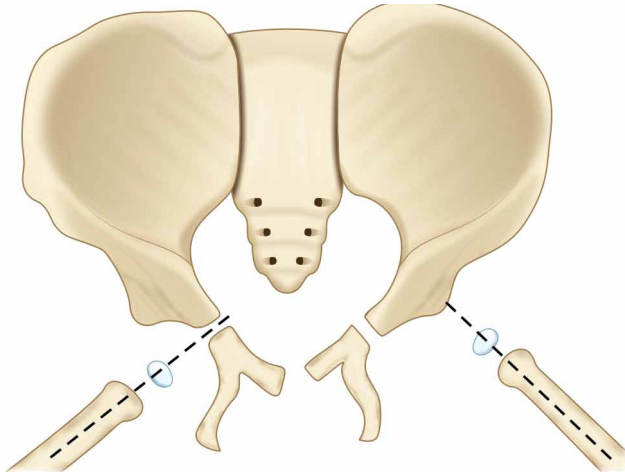


Fig. 7.44: Von Rosen view to identify dislocated hip.

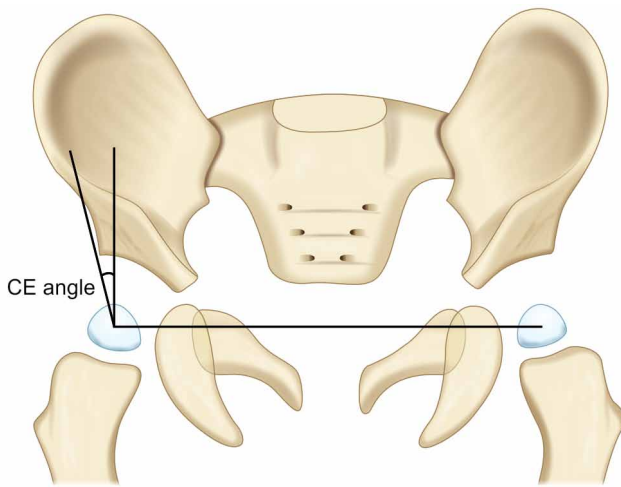


Fig. 7.46: Center edge (CE) angle of Wiberg.

are described and this grading helps in guiding treatment. However, the ultrasound findings commonly improve with age, so the decision to treat DDH should be based on USG at 6 weeks and not at birth.

X-rays are useful in relatively older children. Delayed appearance of upper femoral epiphysis (Normally it appears at 6 months) and delayed development (smaller size), shallow acetabulum, a broken Shenton line (line from proximal medial neck to inferior border of superior pubic rami) and lateral and upward displacement of ossific center of femoral head are some of the findings that guide the diagnosis.

Von Rosen's view may be especially useful in children under 1 year age. The view is taken with hips abducted, internally rotated and extended. Normally, axis of the femoral shaft should intersect the acetabulum. In dislocation, the line crosses above the acetabulum (Fig. 7.44).

Another way to confirm the findings is to draw the Hilgenreiner's line (horizontal line connecting the two triradiate cartilages) and the Perkin's line (vertical line on

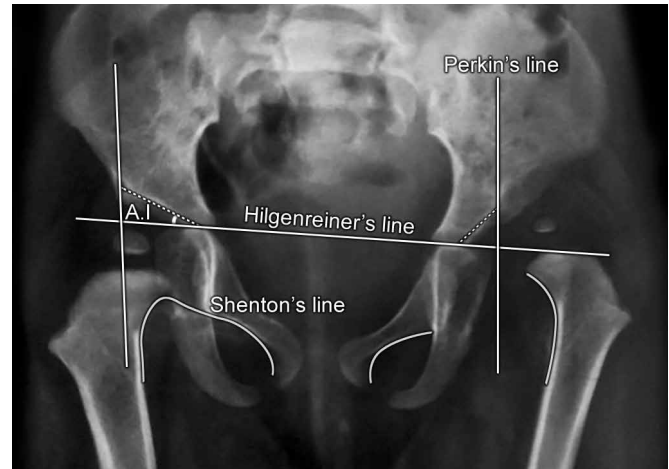


Fig. 7.45: Quadrants around hip and calculation of acetabular index (AI).

each side passing through lateral margin of acetabulum) such that four quadrants are formed across each hip (Fig. 7.45). Normal position of femoral head (proximal metaphyseal beak more specifically if head is not visible) is the inner lower quadrant whereas a dislocated head migrates into the upper outer quadrant.

Acetabular index (Fig. 7.45) is calculated from these radiographs to know if the acetabulum is dysplastic or not. The index is determined by measuring the angle between Hilgenreiner's line and a line connecting triradiate cartilage and lateral lip of acetabulum. Normally this angle is less than 30° . Greater values mean a more vertical, shallow and dysplastic acetabulum.

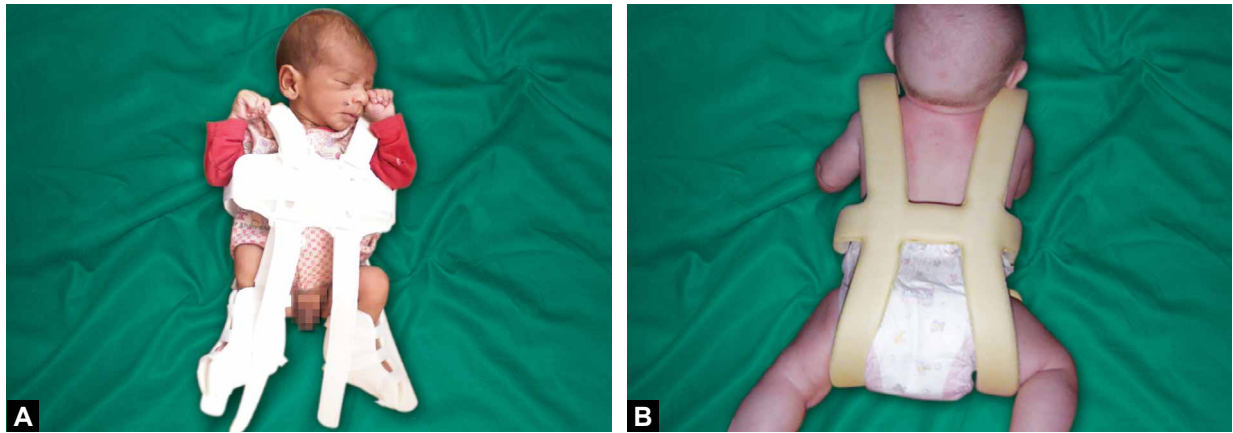
Center Edge angle of Wiberg (Fig. 7.46) is another radiographic measurement to establish the diagnosis. The angle is formed by a line drawn from the center of femoral head to the outer edge of the acetabular roof, and a vertical line drawn through the center of femoral head. Normally this is greater than 20° and lesser values indicate dislocated hip.

Treatment

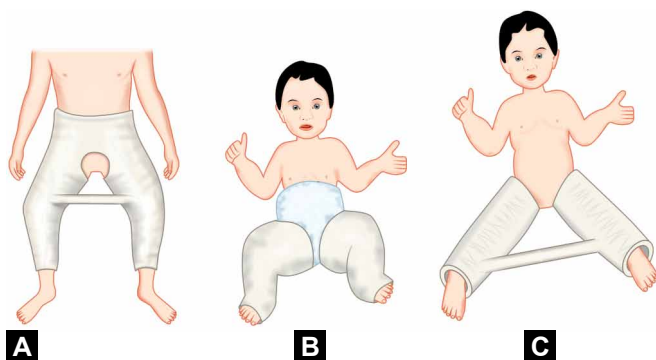
Treatment of this condition is dictated by the age at which the patient presents to the doctor. Aim is achieving concentric and stable reduction of head into acetabulum and maintaining the same. It has been seen that in young children if the head is maintained inside the acetabulum for a time, under the mould like effect of the head the acetabulum gradually develops into a cup like shape and covers the head to full extent.

Age Less than 6 Months

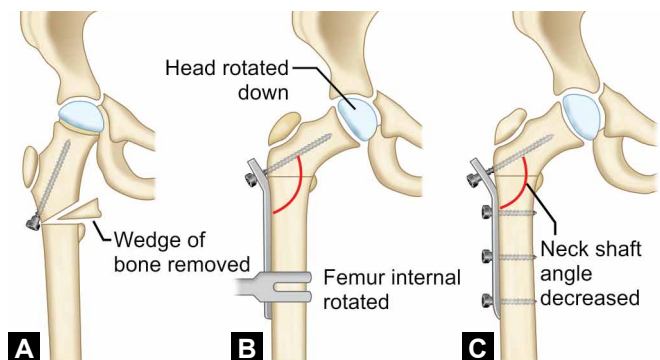
Method of reduction: In neonates with unstable but reduced hips, place the child in a hip abduction splint for 6 weeks. In 1–6 months, place the child in an abduction splint for unstable hips. If the hips are already dislocated close reduction under general anesthesia is done and then child is placed in an abduction splint.



Figs. 7.47A and B: (A) Pavlik harness and (B) Von Rosen splint. (Courtesy: Dr. Zeeshan Khan, JN medical college, AMU)



Figs. 7.48A to C: (A) Hip spica; (B) Frog leg and (C) Bachelor's cast.



Figs. 7.49A to C: Femoral derotation osteotomy.

Maintenance of reduction: Pavlik harness (Fig. 7.47A) (dynamic abduction splint; most commonly used).

- Other abduction splints
 - Von Rosen splint (Fig. 7.47B)
 - Frejka pillow.

Age 6–18 Months

Method of reduction: A trial of closed reduction may be given. However, many a times the acetabulum is filled with fibrous tissue and open reduction needs to be opted if close reduction fails. Preoperatively a short period of traction is cited to be useful, but its role is controversial.

Maintenance of reduction: Pavlik harness is not effective in this age group, so a “hip spica cast” or “frog leg (Lorenz)” or “bachelor cast” for 3 months is used (Figs. 7.48A to C). The reduction should be maintained in cast in “human position” (90° hip flexion and 45° abduction). Excessive abduction should be avoided to reduce chances of avascular necrosis. Investigation of choice to confirm adequacy of closed reduction is CT scan.

Age 18 Months to 10 Years

After this age the development potential of acetabulum is no longer there. So even if the head is reduced and maintained, once the maintenance brace is removed the

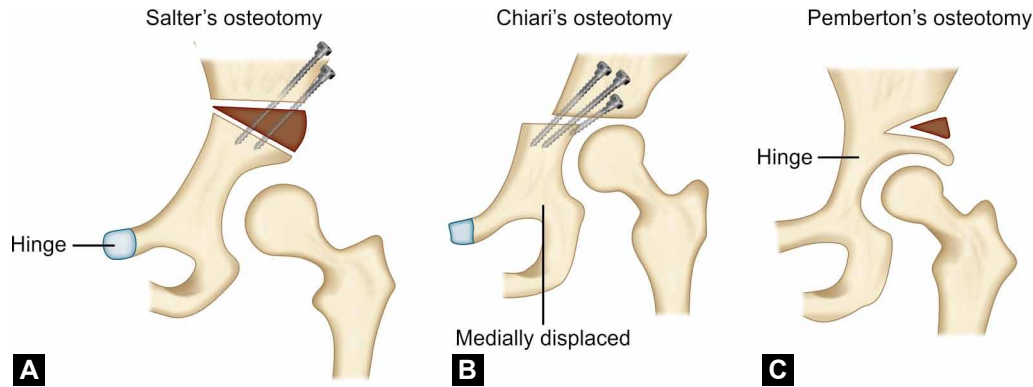
head would dislocate again. So after 18 months of age, an open reduction is usually combined with either a femoral or an acetabular osteotomy to ensure that the head stays in the acetabulum even if further development is not there.

Primary open reduction is done first, as closed reduction is not successful because of contracted soft tissue. Femoral shortening procedure is added to allow easy reduction of head into the acetabular socket. As the child gets older, there is more likelihood of adding a pelvic osteotomy (Salter or Pemberton) to the primary procedure. The need for a pelvic procedure is decided on the operating table; if after reduction and femoral shortening the acetabular coverage of head is insufficient, a pelvic osteotomy is added. Pelvic osteotomies basically decrease the acetabular index to better accommodate the head.

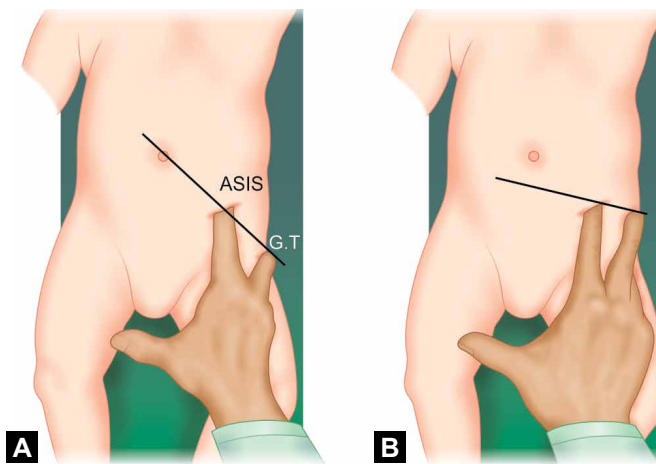
On the other hand, if acetabular index is close to normal range, but hip requires extreme abduction and internal rotation to relocate during surgery, femoral subtrochanteric varus derotation osteotomy (Figs. 7.49A to C) is done to provide inherent abduction-internal rotation to proximal femur to endure head stays reduced. Both may need to be done in some cases.

More than 10 Years

Treatment only if pain present. Consider total hip replacement or arthrodesis in unilateral cases.



Figs. 7.50A to C: Pelvic osteotomies (Acetabular reconstruction procedures).



Figs. 7.51A and B: Klisic sign.

Acetabular Reconstruction Procedures (Figs. 7.50A to C)

- **Salter's osteotomy:** It is iliac osteotomy above the acetabulum which passes through the greater sciatic notch. Acetabulum rotates hinging at the pubic symphysis, improving coverage of the head. It requires temporary internal fixation.
- **Pemberton periacetabular osteotomy:** It is curved osteotomy starting just above the anterior inferior iliac spine. It hinges at the triradiate cartilage. No internal fixation is required.
- **Chiari osteotomy:** Salvage procedure done when concentric reduction of head is not possible. It is transverse osteotomy just above acetabulum to greater sciatic notch, with medialization of acetabulum.

HIGH-YIELD POINTS

- Twin pregnancy is not a risk factor for CDH.
- **Neolimbus:** Thickened articular cartilage over the posterolateral acetabulum (responsible for characteristic clunk)
- **Klisic sign (Figs. 7.51A and B):** In a supine child, place middle finger over greater trochanter and index

finger over anterior superior iliac spine (ASIS). Normally, an imaginary line through these points crosses at umbilicus, but in dislocation the line crosses below the umbilicus. The sign is positive in both unilateral and bilateral cases.

- In bilateral cases following signs are seen—Increased lumbar lordosis, waddling gait, no limb length discrepancy (as both are shortened), short stature, negative Allis sign.
- Routine USG screening is not required in all newborns but a thorough clinical examination should be done.
- The American Academy of Pediatrics recommends routine USG screening in female infants with either a positive family history or those born in breech position.
- Kashiwagi classification of DDH is based upon MRI findings.
- A Pavlik harness is contraindicated in teratological dislocation of hip (dislocated before birth and not reducible on examination, occurs in paralytic disorders).
- After 2 years, attempted closed reduction can cause avascular necrosis of femoral head; hence it should never be attempted.

PERTHES DISEASE (SYN. OSTEOCHONDRITIS OF FEMORAL HEAD/COXA MAGNA/COXA PLANA)

Introduction

This disorder of a growing child characterized by avascular necrosis (osteonecrosis) of the femoral head was described almost at same time (1910) by three different scientists—Legg (USA), Calve (France) and Perthes (Germany), hence better known as Legg-Calve-Perthes disease. The condition affects children in the age range of 4–8 years.

Incidence

- 1 in 10,000
- Boys affected five times more commonly than girls
- Bilateral in 10% cases.

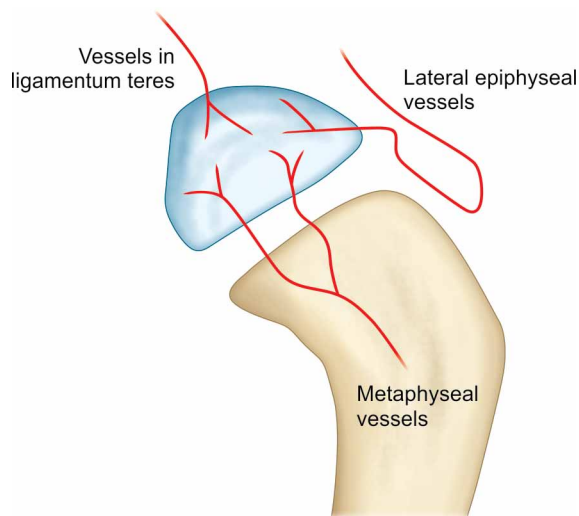


Fig. 7.52: Pathogenesis of Perthes disease (blood supply of femoral head).

Etiology

Exact cause is unknown but the common underlying feature is ischemia of the head.

Factors linked to causation of this ischemia include:

- Coagulopathies (Protein C and S deficiency, Factor V Leiden mutation)
- Sickle cell anemia
- Hereditary (Mutation in type II collagen)
- Hyperactivity (Attention deficit hyperactivity disorder—ADHD)
- Passive smoking
- Trauma
- Sequelae of synovitis (controversial).

Pathogenesis

The characteristic age range (4–8 years) is related to the variation in blood supply of femoral head with age (Fig. 7.52, also see page 94). From birth till 4 years of age supply is from retinacular (lateral epiphyseal) as well as metaphyseal vessels, after 8 years of age supply from vessels from ligamentum teres takes over. So, during the age 4–8 years, supply is mostly from retinacular vessels only. This single source during this age range renders the head susceptible to ischemia if any insult or predisposing factor comes up.

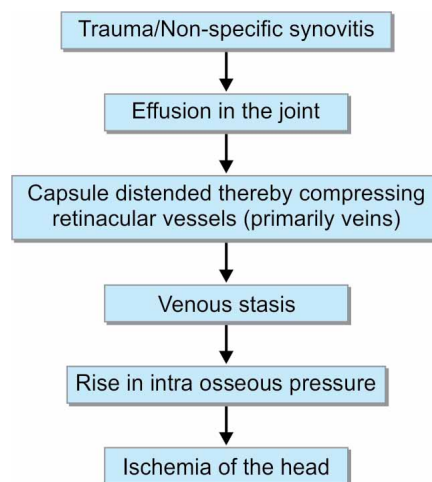
It is postulated that the inciting event may be traumatic or an episode of transient synovitis (Flowchart 7.1), but this remains to be proved.

Pathology

The course of the disease is divided into four stages (Waldenstrom classification):

1. *Ischemia*: Ischemia leads to necrosis of ossific nucleus, which stops growing and becomes dense.

Flowchart 7.1: Pathogenesis of ischemia of femoral head in perthes disease.



2. *Revascularization and repair*: Dead bone is then slowly resorbed and replaced by new bone during the repair process in an attempt to restore normal shape. However, during this repair stage the soft head deforms under pressure. This stage is also known as fragmentation stage.
3. *Repair (Re-ossification)*: If the repair is rapid head shape returns to normal. In other situations, epiphysis collapses and head becomes flattened (Mushroom shaped/Coxa plana) and enlarges (Coxa magna).
4. *Healed*—Gradual return to normal architecture.

Clinical Features

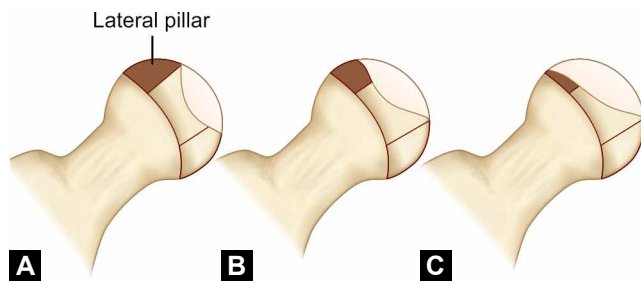
This self-limiting disease characteristically has a waxing and waning course, with periods of alleviation and exacerbation of symptoms. Most common presenting complaint is limp. Classically, a painless limp is present but there may be pain during the periods of exacerbation. Second most common complaint is pain in the hip (may be referred to knee). There is limitation of abduction and internal rotation in severe cases. When the hip is flexed, it may go into obligatory external rotation (Catterall Sign). On examination, Trendelenburg test is positive, as the head is flattened there is upward migration of greater trochanter which slackens the gluteus medius. One may also note shortening of the affected limb.

Radiographic Features

In the early course the X-ray may be normal with only widening of the joint space appreciated. As the head undergoes ischemia and bone death, the area becomes sclerotic (appears radiodense) and starts fragmenting (Fig. 7.53A). Eventually the head collapses, becomes flattened (Mushroom shaped) and enlarged (Coxa magna) (Fig. 7.53B).



Figs. 7.53A and B: Radiological signs of perthes disease (A) fragmented head with Gage sign (B) mushroom shaped head, Gage sign and Sagging rope sign.



Figs. 7.54A to C: Herring's classification.

Some classical X-ray signs that may aid the diagnosis include:

Gage sign (Fig. 7.53A): a radiolucent V-shaped area can be appreciated in the lateral part of femoral head epiphysis.
Sagging rope sign (Fig. 7.53 B): A thin radio-opaque line in upper femoral metaphysis. It indicates damage to growth plate with marked metaphyseal reaction.

Bone scan detects changes quite early in the course of disease but MRI is the investigation of choice and detects the changes at the earliest.

Important radiographic classification systems:

- **Catterall classification:** It is based on the amount of epiphysis involved. It classifies the disease in four stages ranging from stage I (only anterior part of head is involved) to stage IV (whole of the head is involved).
- **Salter Thompson classification:** It classifies into two groups based on extent of head involved in X-rays, Group A (less than half of head involved) and Group B (more than half).
- **Herring's lateral pillar classification** (Figs. 7.54A to C): It is most commonly used classification nowadays to guide the treatment. It is based on the height of the lateral pillar of the head (the head being divided into medial central and lateral pillars).
 - Group A—no loss of height in lateral pillar
 - Group B—More than 50% height maintained
 - Group C—Less than 50% height maintained.

- Group B—More than 50% height maintained
- Group C—Less than 50% height maintained.
- **Stulberg classification:** It is a prognostic classification based on the final appearance of head and its relation to acetabulum (roundness of head and its congruency in relation to acetabulum) in the healed stage. Spherical congruent head has best outcome and aspherical noncongruent head has poorest outcome.

Poor Prognostic Factors

- Early age at onset (< 5 years) (most important)
- Bilateral disease
- Presence of Catterall's head at risk signs (*see below*)
- Extensive subchondral fracture lines seen
- Aspherical incongruent head (Stulberg classification)
- Lateral pillar C (Herring classification).

Catterall's Head at Risk Signs (Seen on X-ray)

- Gage sign present
- Calcification present lateral to the femoral head epiphysis
- Lateral subluxation of head there
- Horizontally lying growth plate
- Cysts visible in metaphysis of femur.

TRANSIENT SYNOVITIS (TOXIC SYNOVITIS/ OBSERVATION HIP/IRRITABLE HIP)

Introduction

It is a self-limiting acute inflammation of synovium of hip joint (synovitis) occurring commonly in children between the age group of 4–10 years (mean age at onset is 6 years). Most cases are unilateral (95%), occur twice as frequently in boys as in girls. Right and left hips are equally affected.

Etiology

The exact cause is unknown. Most children give a history of viral upper respiratory tract infection. History of trauma may also be there.

Clinical Features

Child presents with an acute onset of hip pain and limp (antalgic gait). Hip is held in flexion, abduction and external rotation due to the effusion (position of ease as joint volume is maximum). The terminal ranges of movements at hip are painful and restricted. Condition is characterized by conspicuous absence of a high-grade fever. Temperature is rarely more than 38.5°C. Laboratory investigations [white blood cell (WBC) counts, erythrocyte sedimentation rate (ESR), C-reactive protein (CRP)] are generally within normal limits. Child is not as toxic looking as in a fulminant condition like septic arthritis. Blood culture is sterile. Joint aspirate is sterile.

Investigations

X-rays: Usually are normal, except for the widening of medial joint space due to effusion in some cases.

Ultrasonography: Shows effusion of hip (anechoic). USG-guided aspiration of the hip is the investigation of choice to support the diagnosis and more importantly, to exclude a possible septic arthritis of hip.

Differential Diagnosis

- **Septic arthritis:** The most important differential diagnosis is septic arthritis. It is important to differentiate between the two because the diagnosis of septic arthritis warrants emergent surgery (arthrotomy with joint lavage) to save the hip joint, whereas synovitis can be managed conservatively. The most definitive way of differentiating between the two is aspiration of the hip and analysis of aspirate. Joint aspirate reveals more than 50,000 WBCs/mm³ with 90% neutrophils. Gram stain and culture of joint aspirate may show bacteria.
Few points that favor septic arthritis over transient synovitis are:
 - Sick looking/toxic child
 - Fever greater than 38.5°C
 - All range of movements painful (c.f. terminal range of movements painful)
 - Raised CRP, ESR, WBC counts
 - Blood culture is positive in 50% cases
 - Ultrasonography shows echogenic effusion.
- **Osteomyelitis of proximal femur:** Features suggesting diagnosis of it are swelling of proximal thigh, elevated WBC count, elevated ESR and CRP, febrile child, X-rays showing initially soft tissue swelling and later periosteal reaction and bone destruction.

- **Perthe's disease:** Radiographic widening of joint space is more characteristic of Perthe's disease than of transient synovitis. All laboratory workup is within normal limits in Perthe's disease also, so differentiation is best made on X-rays (smaller femoral head and subsequently increased density of head). It is said that 1–3% of children with an episode of transient synovitis may progress to Perthe's disease.
- Juvenile rheumatoid arthritis (JRA).

Treatment

Patient is advised bed rest with traction and nonsteroidal anti-inflammatory drugs (NSAIDs) (for relieving muscle spasm and reducing pain). The patient must be kept under observation (observation hip). The condition is self-limiting. Most patients are symptom free by 2 weeks and condition resolves by itself.

HIGH-YIELD POINTS

- Transient synovitis > Septic arthritis > Perthe's disease is the most common cause of painful limp in a child less than 10 years of age.
- Order of investigations in inflammatory HIP joint swelling: X-ray → USG-guided aspiration of joint fluid → MRI
- **Kocher's criteria:** Criteria to differentiate between transient synovitis and septic arthritis. make arthrodiastasis a separate point Arthrodiastasis (distraction of a joint) is a relatively new treatment for Perthes disease. Here a distraction force is maintained across hip joint by an external fixator. It is postulated that by creating a space between the articulating surfaces, mechanical stress is minimized and the synovial circulation improves. This encourages fibrous repair of defects of articular cartilage and preservation of a congruent femoral head.

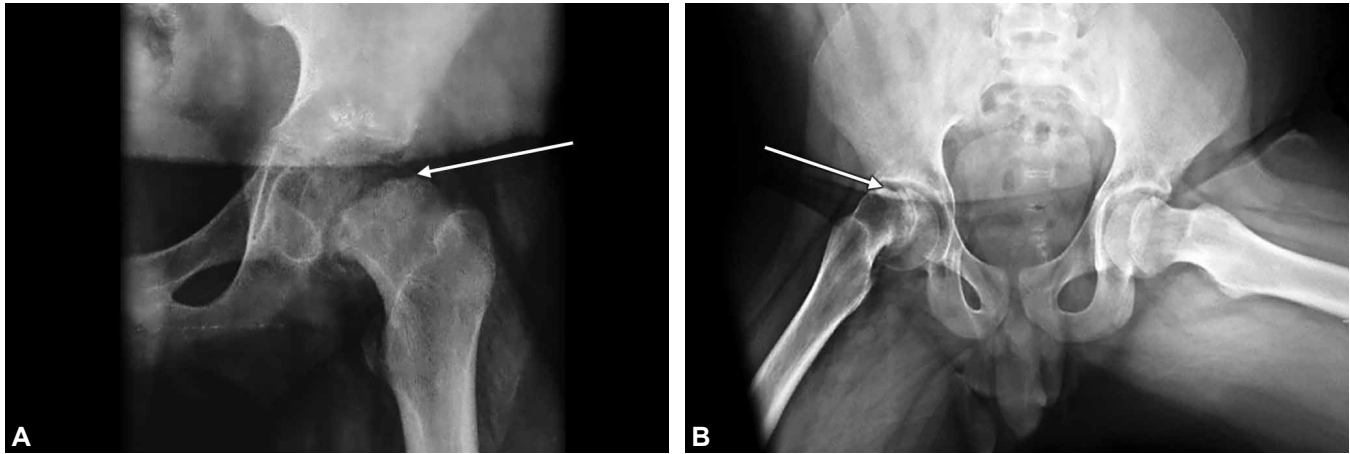
SLIPPED CAPITAL FEMORAL EPIPHYSIS

Introduction

Slipped capital femoral epiphysis (SCFE) refers to displacement or slipping of the femoral capital epiphysis (femoral head epiphysis) from its normal position relative to the neck. In true sense, the capital epiphysis remains seated in the acetabulum, the physis disrupts and the neck rotates anteriorly (Figs. 7.55A and B). The slip characteristically occurs during the period of rapid growth spurt (puberty) when the physis is relatively weak and excessive body weight results in excessive shear forces on the physis, causing it to disrupt.

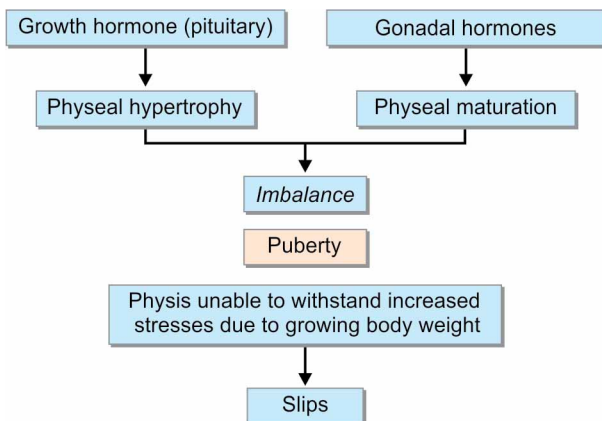
Incidence

- Boys of age 12–15 years and girls of age 11–13 years are commonly affected
- Male: Female = 2:1
- Bilateral in 20–40% cases.



Figs. 7.55A and B: (A) X-ray left hip and (B) X-ray pelvis with both hips AP view showing slipped femoral epiphysis (arrow).
Courtesy: Dr. Nitin Agarwal (JN medical college, AMU).

Flowchart 7.2: Mechanism of slip.



Etiology

Majority of patients have no underlying cause. But some have associated conditions like hypothyroidism (most common), panhypopituitarism, hypogonadism, growth hormone excess, craniopharyngioma. Single most important risk factor for SCFE is obesity.

Typical body habitus is short, fat and sexually immature child nearing puberty. There is disparity between the growth hormone (pituitary) and gonadal hormone levels. While the former try to cause physeal hypertrophy the latter try to achieve physeal maturation. Imbalance makes the physis unable to resist shearing stresses generated by body weight thereby causing slipping of capital epiphysis (Flowchart 7.2).

Clinical Features

Slips are classified as (Loder classification): Stable (child can bear weight on extremity) or unstable slip (child not able to bear weight). They can also be classified as “acute (<3 weeks)”, “chronic (>3 weeks)”, or “acute on chronic”.

Chronic slips are the most common. In acute slips classical presentation is an adolescent child, typically short and fat, complaining of groin pain and antalgic limp. Excessive external rotation of involved side during walking (Out-toeing gait) is characteristic. Restricted abduction and internal rotation are noted on examination. When the hip is flexed it goes into obligatory external rotation, this is called as “axis deviation”. Some degree of shortening of affected extremity is there.

Investigations

Slip is best seen in a frog leg lateral X-ray view of the affected hip.

Earliest sign is wide and irregular physis with rarefaction in its juxtaepiphyseal region (preslip). Grading can also be done based on distance of slip in AP view. Up to one-thirdslip is mild, one-third to two-thirds is moderate and more than two-thirds is severe.

Normally, a line drawn along the superior border of neck (Klein's line), should intersect some part of epiphysis (head). But in SCFE, this line intersects a very small part of epiphysis or not at all (Trethowan sign, Fig. 7.56).

Computed tomography: It is usually not necessary for diagnosis, but gives a more accurate measurement of slip angle than plain radiography.

Magnetic resonance imaging: It detects physal widening and irregularity when X-rays and CT are negative. It can detect disease in preslip stage.

Ultrasonography: It is not much useful but may show joint effusion and a step between head and neck of femur.

Treatment

Primary aim is to prevent further slip and promote closure of physis. Reduction of existing slip is not always possible and may even be harmful (causes AVN). So, in situ pinning (fixing slip with smooth pins or screws) is the preferred treatment in chronic slips that are mild or moderate

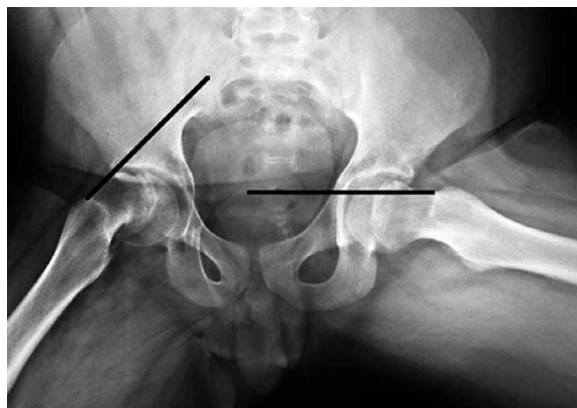


Fig. 7.56: Trethowan sign in SCFE (right side).



Fig. 7.57: In situ fixation of SCFE.



Fig. 7.58: Metaphyseal Blanch sign (arrow).

grade (Fig. 7.57). Severe chronic slips may need corrective osteotomy. In acute slips, gentle reduction may be tried, followed by in situ pinning.

HIGH-YIELD POINTS

- The physeal disruption in SCFE occurs through the hypertrophic zone of the cartilage.
- Important complications of unstable slips: Avascular necrosis of head and Chondrolysis (lysis of the articular cartilage of hip joint diagnosed radiologically by less than 3 mm wide joint space).
- Some other important X-ray signs in SCFE:
 - Metaphyseal Blanch sign of steel (Fig. 7.58) is a crescent-shaped area of increased density overlying the metaphysis (neck) adjacent to physis.
 - *Scham's sign* is the loss of dense triangular appearance of inferomedial neck (normally appears dense as it overlaps the posterior wall of acetabulum). Normally the posterior acetabular margin cuts the medial corner of metaphysis, but in SCFE whole of metaphysis is lateral to acetabular margin.
 - *Southwick's slip angle* (Head shaft angle in both AP and lateral views) (Fig. 7.59) is a measure of severity of slip. It is an angle between axis of femoral shaft

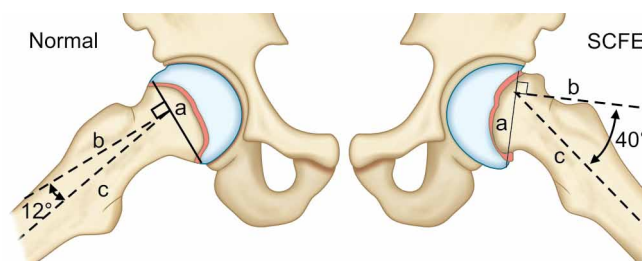


Fig. 7.59: Southwick's angle.

and a line perpendicular to the base of epiphysis. The difference between affected and contralateral normal side depicts the severity. Difference of less than 30° is mild slip, 30°–60° is moderate and more than 60° difference is severe slip.

- Idiopathic chondrolysis of hip (ICH): In some cases, more commonly in females, loss of articular cartilage (joint space on X-ray < 3 mm) occurs without obvious reasons and they constitute the entity ICH. Condition is postulated to be auto-immune but exact etiology is unknown.

CONGENITAL COXA VARA

Introduction

Normal neck shaft angle of proximal femur is 125°–135° (average 127°). An angle less than 125° is called “coxa vara”. Congenital coxa vara is caused by a primary cartilaginous defect in the inferomedial part of femoral neck (the cartilage remnant being called as “Fairbank's triangle”), which causes a defect in ossification of femoral neck (Fig. 7.60). There is relative overgrowth of greater trochanter and a short femoral neck causing coxa vara with progressive shortening of the affected extremity. The varus deformity develops only once the child starts walking.

Incidence

- Males = Females
- Bilateral in 30–50% cases.



Fig. 7.60: Congenital coxa vara showing Fairbank's triangle.

Clinical Features

Painless limp is the characteristic feature. Trendelenburg gait occurs due to upridding of greater trochanter with short limb component in unilateral cases, waddling gait is seen in bilateral cases. Limb length discrepancy in unilateral cases is mild (shortening is not more than 3 cm). The patient has restricted abduction and internal rotation.

X-ray

- Decreased neck shaft angle ($< 125^\circ$).
- Triangular piece of bone in the medial femoral neck (Fairbank's triangle) bounded by two radiolucent lines forming an inverted V or inverted Y is a characteristic sign (Fig. 7.60).
- *Hilgenreiner epiphyseal (HE) angle* (Fig. 7.61): This is an angle between Hilgenreiner line (horizontal line through triradiate cartilage) and a line parallel to physis. Normal is between 0° – 25° . It has prognostic value, more the HE angle poorer the prognosis.

Treatment

- Based on Hilgenreiner epiphyseal angle:
- Less than 45° —Observation
- 45 – 59° : Surgery or observation depending on symptoms (symptomatic limp or progressive deformity)
- Greater than 60° —Surgery.

Surgery: Subtrochanteric valgus osteotomy is done (Fig. 7.62) to restore neck shaft angle. Ideal age for surgery is 4–5 years. Before this age, internal fixation is relatively difficult in cartilaginous femoral head.

Shortening is usually mild and can be dealt with shoe-lift.

HIGH-YIELD POINTS

- | | |
|---------|------------------|
| • Age | Neck shaft angle |
| Birth | 150° |
| 3 years | 145° |

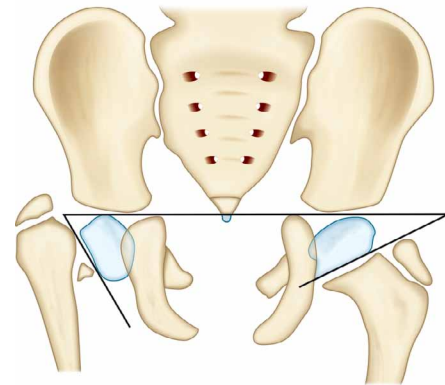


Fig. 7.61: Hilgenreiner epiphyseal (HE) angle.



Fig. 7.62: Valgus osteotomy for coxa vara.

9 years	138°
Adult	125 – 135°

- Acquired coxa vara may be seen in
 - Perthe's disease
 - Slipped capital femoral epiphysis
 - Developmental dysplasia of hip
 - Post-traumatic (Neck femur fracture)
 - Postinfective (septic arthritis)
 - Fibrous dysplasia
 - Renal osteodystrophy
 - Osteogenesis Imperfecta
- Cases where Fairbank's triangle is present:
 - Congenital coxa vara
 - Nonunion fracture neck of femur
 - Perthe's disease.

PROXIMAL FEMORAL FOCAL DEFICIENCY

Introduction

Proximal femoral focal deficiency is a rare congenital deficiency that is characterized by varying degree of femoral and acetabular hypoplasia causing limb shortening. It is often associated with other abnormalities like fibular aplasia/hypoplasia, foot abnormalities, cruciate ligament

deficiencies, patellar abnormalities, shortened tibia and fibula, etc. Fibular hemimelia is the most common associated abnormality. Child presents with short, flexed, abducted and externally rotated limb. Feet are usually normal.

Hypoplasia range from short femur with coxa vara and bowing to complete absence of acetabulum and proximal femur (Fig. 7.63). Aitken classification is used to classify the disease.

Treatment: treatment should be individualized according to deformity. Children with bilateral deformities may be observed. In other children treatment is usually difficult and may include amputation/arthrodesis and knee prosthesis, extension prosthesis, femoro-pelvic fusion, limb lengthening and contralateral epiphysiodesis and Van Nes rotationplasty.

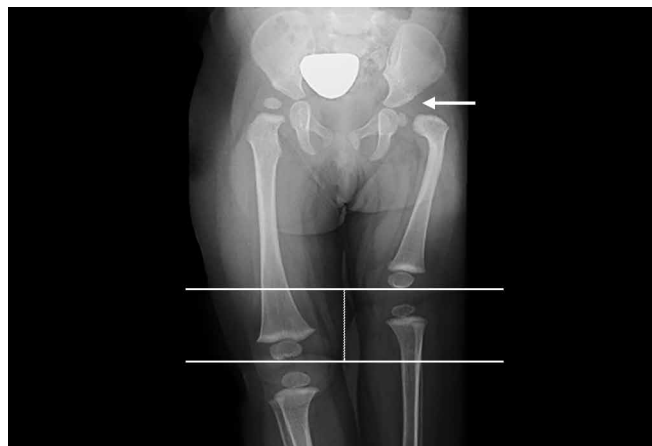


Fig. 7.63: Proximal focal femoral deficiency.

TRUNK AND MISCELLANEOUS DEFORMITIES

TORTICOLLIS (WRY NECK)

Introduction

Derived from Latin words tortus (twisted) and collum (neck), it refers to abnormal and asymmetric neck position. Most often it is due to painful lesions of the neck causing reflex muscle spasm. It is of various types:

- Congenital muscular torticollis
- Acquired [cervical lymphadenitis, tonsillitis, adenoiditis, retropharyngeal abscess, tuberculosis (TB) of cervical spine, cervical spine tumors, cervical prolapsed disk and cerebellar tumors]
- Idiopathic cervical dystonia
- Compensatory (squint).

Congenital (Infantile) Muscular Torticollis

It is a painless condition caused by fibromatosis of the sternocleidomastoid muscle, resulting in the formation of a palpable mass (palpable at birth or within 2 weeks of birth, sternomastoid tumor).

Etiology: It is due to muscle ischemia due to increased pressure in-utero (packaging problem). It is postulated that ischemia is due to intrauterine or perinatal compartment syndrome localized to neck. An increased incidence is reported in breech delivery and first born cases. It is thought to be associated with CDH and metatarsus adductus (also packaging defects).

Clinical features: The deformity is usually apparent at birth or shortly thereafter. Head is tilted towards the involved muscle and chin is rotated towards opposite side (Cock Robin appearance) (Fig. 7.64). Mass spontaneously

regresses in a few months leaving behind a fibrosed muscle, but the deformity persists. A cord may be palpable in the muscle. Infant may also have a “bat ear” due to folding in-utero. Asymmetrical development of face (plagiocephaly) may occur later in life, because child always sleeps on one side causing flattening of that side. Radiography of the cervical spine should be done to rule out segmentation defects of cervical spine.

Treatment: Most can be treated with a conservative regime of regular stretching. Severe deformity may be treated with surgery. Unipolar release (at clavicular attachment only) or bipolar release of sternocleidomastoid (Z plasty at clavicular side and release at mastoid attachment, preferred method) followed by physiotherapy is done. Surgery is ideally done at 5–6 years of age.

SPRENGEL SHOULDER

Introduction

Congenital elevation of the scapula is known as “Sprengel shoulder”. Scapula is hypoplastic and lies more superior in relation to chest cage (Figs. 7.65A and B).

Etiology

Scapula forms at higher level and descends. Interruption in normal caudal descent of scapula results in this deformity. One-third of patients have an extra bone (Omoverttebral bar) connecting scapula to cervical spine that obstructs the normal descent.

Associated congenital anomalies include cervical rib, Klippel-Feil syndrome, congenital scoliosis and renal anomalies.



Fig. 7.64: Congenital muscular torticollis.

Clinical Features

Head is often deviated to the affected side and shoulder abduction is limited.

Treatment

Mild-to-moderate cases require no treatment. Only if deformity is causing severe cosmetic and functional impairment, surgery is indicated. Surgery is done once child reaches 3 years of age. Operative techniques include Green's procedure and Woodward's procedure (preferred). Most important complication of surgery is brachial plexus injury.

KLIPPEL-FEIL SYNDROME

Introduction

This is characterized by congenital fusion of cervical spine due to failure of segmentation. There is failure of normal division of cervical somites. It may even involve the craniocervical junction (occiput-C1-C2).

Clinical Features

Classical triad consists of short-webbed neck, low posterior hair line and restriction of neck movements. Torticollis is present. Scoliosis (congenital or idiopathic) occurs in 60% of patients. Sprengel deformity of shoulder accompanies the syndrome in 50% cases. Other associated conditions include genitourinary abnormalities (structural abnormalities like double collecting system, horse shoe shaped kidney, renal aplasia, etc), congenital heart defects, hearing loss, synkinesis, ocular anomalies and cervical canal stenosis.

Segment of spine near the fused part becomes hypermobile, causing degenerative changes, which may lead to radiculopathy or myelopathy in young adult life.



Figs. 7.65A and B: Sprengel shoulder.

Treatment

Symptomatic children with cervical instability require fixation with halo vest or surgical fusions.

OSTEOGENESIS IMPERFECTA (LOBSTEIN-VROLIK'S DISEASE/BRITTLE BONE DISEASE/FRAGILITAS OSSIUM)

Introduction

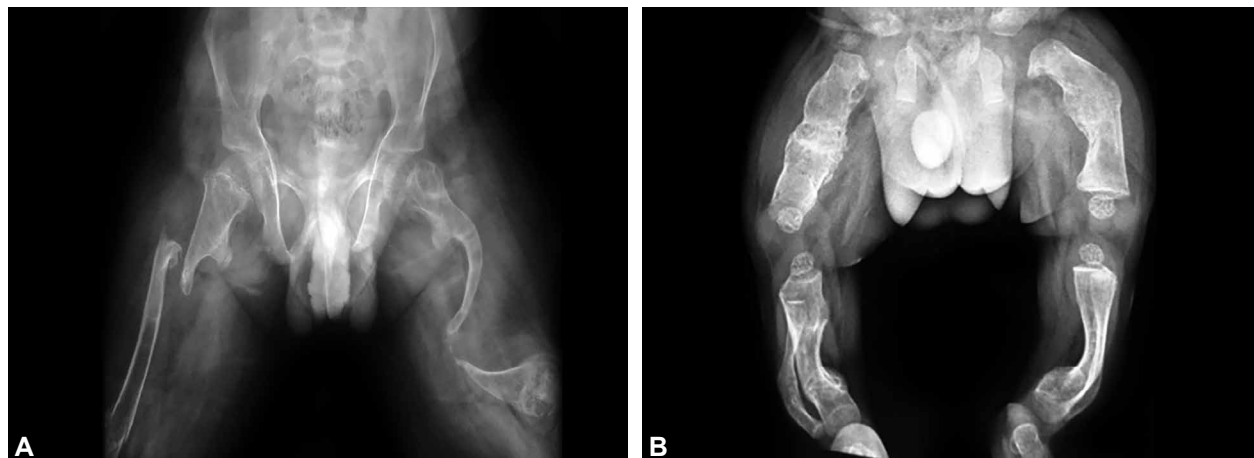
It is a rare connective tissue disorder characterized by brittle bones which fracture easily. Basic defect is impaired cross linking of immature collagen, leading to impaired formation of mature polymerized collagen. Type I collagen is seen in skin, ligaments, bone, teeth and sclera and consequently these are the tissues involved.

INHERITANCE

Ninety percent have genetic mutation in *COL1A1* and *COL1A2* genes resulting in glycine substitution in pro-collagen molecule which causes abnormal collagen crosslinking. It is transmitted in autosomal dominant (predominant) and autosomal recessive patterns.

PATHOLOGY

There is decreased production of collagen as well as production of abnormal collagen. Both these factors result in insufficient osteoid production. Osteoblasts cannot form adequate osteoid resulting in abnormal remodeling. There is increased diameter of haversian canals and osteocyte lacunae, replicated cement lines, increased number of osteoblasts and osteoclasts and paucity of trabeculae. The cortex of the bone is thinner than normal.



Figs. 7.66A and B: Osteogenesis imperfecta—see multiple fractures in various stages of healing, callus formation and bony deformities.

CLINICAL FEATURES

Bone and Joint Involvement

There is osteopenia that leads to frequent fractures even after trivial trauma. Recurrent fractures occur due to brittle bones, disuse osteopenia, progressive long bone deformity with joint stiffness occurring due to immobilization. Healing is normal but remodeling is defective, resulting in progressive bowing of long bones (Figs. 7.66A and B), saber shin appearance of tibia, short stature, scoliosis, cod fish vertebra (compression fracture), basilar invagination and olecranon apophyseal avulsion fractures. Fractures tend to heal with abundant callus but the callus is of poor quality. Hyperplastic callus may sometimes be difficult to differentiate from osteosarcoma. Fractures can occur in utero, at the time of birth or later. Frequency of fractures, declines after puberty and rises again after menopause in women. New bone is pliable for long time due to defective osteoid formation resulting in malunion and deformities. Hyperlaxity of ligaments with hypermobility of joints is also present. Wormian skull bones (puzzle piece intrasutural skull bones) are characteristically found. Other features include scoliosis and protrusio acetabuli.

Ocular Involvement

As a consequence of the thin collagen layer in sclera, sclera appears blue due to underlying uveal vessels.

- *Saturn's ring*: white sclera immediately surrounding the cornea
- *Arcus juvenilis*: white opacity concentric to limbus in the periphery of cornea
- Hypemetropia and retinal detachment can also occur.

Auditory Involvement

Conductive hearing loss is due to otosclerosis and leads to deafness. Onset is in adolescence or adulthood.

Sensorineural hearing loss can also coexist due to pressure on the auditory nerve as it emerges through the skull.

Dental Involvement

Crumbling teeth/Dentinogenesis imperfecta is characteristic. Yellowish brown/bluish gray discoloration of teeth is seen. Enamel, which is ectodermal in origin, is normal. Deciduous and permanent teeth both are involved, they break easily and are prone to carries. Lower incisors are particularly more severely affected.

Skin and Muscle Involvement

Skin is thin and translucent and is prone to subcutaneous hemorrhages. Muscles are hypotonic due to multiple fractures and deformities. Hernias are common.

Metabolic Features

A hypemetabolic state exists, resulting in excessive sweating and heat intolerance. Patient is susceptible to hyperthermia during general anesthesia.

PRESENTATION

Mild cases: multiple fractures during childhood. Number of fractures typically decrease with age and usually stop after puberty.

Severe cases: Present with fractures at birth and can lead to stillbirth.

Basilar invagination (softening of base of skull): Presents with apnea, altered consciousness, ataxia, or myelopathy. It is usually seen in 3rd or 4th decade of life, but can be as early as teenage years.

Sillence described the seven types of osteogenesis imperfecta (Table 7.4).

Type V, VI, VII have been added to the original classification system (these have no Type I collagen mutation

Table 7.4: Sillence classification

Type	Inheritance	Sclera	Features
I	AD	Blue	<ul style="list-style-type: none"> Mildest form Commonest form. Presents at preschool age Hearing deficit in 50%.
II	AR	Blue	<ul style="list-style-type: none"> Lethal in perinatal period (hence living cases not seen)
III	AR	Normal	<ul style="list-style-type: none"> Fractures at birth Progressively short stature Most severe survivable form.
IV	AD	Normal	<ul style="list-style-type: none"> Moderately severe form Bowing bones and vertebral fractures common No hearing loss.
V			<ul style="list-style-type: none"> Hypertrophic callus after fracture Ossification of interosseous membrane between radius and ulna and tibia and fibula.
VI			<ul style="list-style-type: none"> Moderate severity Similar to type IV
VII			<ul style="list-style-type: none"> Associated with rhizomelia and coxa vara.

but have abnormal bone on microscopy and a similar phenotype)

Cases can also be classified into congenital form (fractures present at birth) and tarda form (less severe, fractures occur later on).

Diagnosis

Radiography: Skeletal survey shows multiple fractures in various stages of healing, abundant callus formation and bony deformities (Figs. 7.66A and B). Cortices are thin with generalized osteopenia. Skull has a mushroom appearance with a very thin calvarium. Wormian bones, which are detached portions of primary ossification centers of adjacent membranous bones, may be seen in the skull X-ray. They are said to be significant if more than 10 in number, measure at least 6 mm × 4 mm and are arranged in general mosaic pattern.

Iliac crest biopsy which shows a decrease in cortical widths and cancellous bone volume with increased bone remodeling.

A molecular defect in type I procollagen is detected by incubating the skin fibroblasts with radioactive amino acids and analyzing the pro alpha chains by polyacrylamide gel electrophoresis. It shows a decreased rate of synthesis of pro alpha 1 chains and abnormal pro alpha chains.

Polymerase chain reaction: useful for screening other family members at risk of a diagnosed case.

Prenatal diagnosis: Polymerase chain reaction is conducted on chorionic villi biopsy at 8–12 weeks demonstrating the synthesis of abnormal pro alpha chains. Prenatal USG shows multiple fractures.

A positive family history, characteristic clinical features and typical radiographic findings are usually sufficient for a diagnosis, but the most definitive proof is detection of defective collagen or identification of the mutation.

Treatment

Fracture Prevention

Early bracing is done to reduce deformities and lessen the chance of fractures.

Bisphosphonates: These are given to reduce fracture rate and pain and to increase cortical thickness by inhibiting osteoclast function. They do not prevent development of scoliosis. Chronic use causes horizontal metaphyseal bands on radiographs. Growth hormone may be used due to its anabolic effects.

Fracture Treatment

Treatment is mostly nonoperative if the child is less than 2 years of age. For children above the age of 2 years, fixation with telescoping rods (e.g. Bailey Dubow rods) is preferred. This splints the whole bone to reduce further fracture risk and also allows long bone growth to continue uninterrupted.

Bowing deformities of long bones are treated with multiple realignment osteotomies with rod fixation (Sofield-Miller procedure/Seek kebab treatment).

BATTERED BABY SYNDROME (SHAKEN BABY)

Introduction

As battered baby is also characterized by multiple fractures, it is an important differential diagnosis of osteogenesis imperfecta (OI). It is characterized by multiple fractures caused by nonaccidental trauma. Although it may be very difficult at times to differentiate between the two, some features might be useful to arrive at a particular diagnosis. In case diagnosis is unclear, best course of action is to get fibroblast culture and collagen analysis. Most cases of battered baby syndrome are seen before age of 3 years (more than 50% before age of 1 year). Accidental fractures are rare before age of 1 year. In battered baby syndrome diaphyseal fractures are more common than metaphyseal fractures. Most commonly fractured bones are femur followed by humerus and tibia.

Features Suggestive of OI

- Positive family history
- Blue sclera
- Dentinogenesis imperfecta
- Hypermobility joints
- Short stature
- Abnormal bone on X-rays (osteopenia, thin cortices).

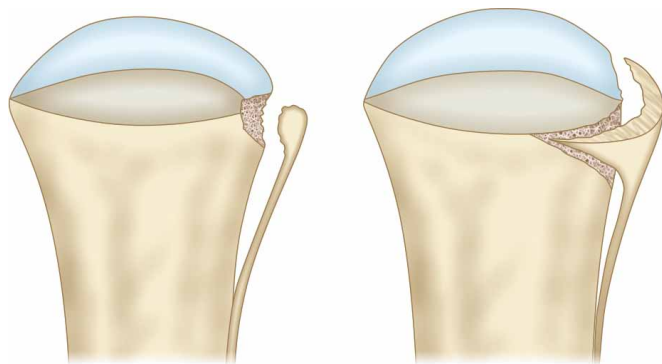


Fig. 7.67: Metaphyseal corner and metaphyseal bucket handle fractures.

Features Suggestive of Battered Baby (Child Abuse)

- History obtained from parents does not correlate with clinical examination and radiological dating of fractures (e.g. parents claiming injury is 1 day old but callus visible on X-rays; fracture callus appears roughly between 5 days to 14 days after fracture in children).
- Metaphyseal corner fractures and metaphyseal Bucket handle fractures (Fig. 7.67) are almost pathognomic of child abuse.
- High risk family (Divorced or separated parents; maternal history of depression, alcohol abuse, drug abuse; uneducated parents)
- Skull fractures (Eggshell fractures, occipital impression fractures, fractures crossing suture lines)
- A transverse femur fracture in a child less than 1 year old and a transverse humerus fracture in a child less than 3 years old should highly be suspected to have such a cause.
- Subdural hemorrhages
- Characteristic pattern of bruising (multiple bruises in clusters; bruising at places away from bony prominences; uniformly shaped bruises; imprint bruising; ligature marks).

HIGH-YIELD POINTS

- Although the pathognomic are metaphyseal fractures but more commonly seen are diaphyseal fractures mostly involving the femur, humerus and tibia.
- Causes of Wormian bones:
PORKCHOPS
(Mnemonic)
P-Pyknodysostosis
O-Osteogenesis imperfecta
R-Rickets
K-Kinky hair syndrome



Fig. 7.68: X-ray fore arm lateral view showing thickened cortices due to Caffey's disease.

C-Cleidocranial dysostosis
H-Hypothyroidism/hypophosphatasia
O-Otopalatodigital syndrome
P-Primary acroosteolysis (Hajdu-Cheney)/Pachydermoperiostosis/Progeria
S-Syndrome of Downs

- Actually most common cause of wormian bones is idiopathic. Osteogenesis imperfecta and cleidocranial dysostosis are next common causes. These are most commonly located within the lamboid suture.

CAFFEY'S DISEASE (INFANTILE CORTICAL HYPEROSTOSIS)

Introduction

This is a self-limiting inflammatory disease seen mainly in infants less than 6 months old characterized by intense diaphyseal periostitis (Fig. 7.68) and hyperostosis (thickening of cortex of bone often leading to doubling of width of bone), occurrence of soft tissue nodules and growth abnormalities. The characteristic triad includes cortical bone thickening, painful soft tissue swellings and systemic symptoms (irritability and fever). The cause is not known. However, it exists in two forms: (1) Familial (AD inheritance) and (2) Sporadic (more common). Most common site of involvement is mandible and its presentation often mimics jaw tumors. Other common sites include the clavicle, ribs, scapula and the long bones. Clinically the disease is often confused with osteomyelitis.

Management

The condition is self-limiting and usually resolves in 6 months to 1 year time. NSAIDs (indomethacin and naproxen) may be used. Corticosteroids are reserved for extensive disease. Antibiotics have no role, but some patients might be given antibiotics early on as fever and leukocytosis suggest a systemic infection.

DEFORMITIES OF UPPER LIMB

HEMIMELIA

Hemimelia are a group of disorders where there are congenital deficiencies of long bones. They can be of two types: (1) Terminal deficiencies where there is an amputation with no body parts distal to the affected site and (2) Inter-calary deficits where a middle segment of limb is missing (Fig. 7.69). Fibula > Radius > Femur > Tibia are the most common involved bones in order of frequency.

RADIAL CLUB HAND (RADIAL HEMIMELIA)

Introduction

In radial club hand, there is congenital deficiency of the radial (preaxial) side of upper limb. It is slightly more common in males and is bilateral in 50% cases.



Fig. 7.69: Fibular hemimelia showing absent fibula and bent tibia.

Etiology

Pathogenesis is related to a defect in apical ectodermal ridge (AER). Most cases are sporadic, but few may be linked to exposure to teratogens such as thalidomide and radiation.

Clinical Features

There is absence of radius that may be partial or complete (more common). Forearm is short and radially deviated (Manus valgus, Figs. 7.70A and B). In complete absence of radius, hand is almost perpendicular to the forearm. It is commonly associated with hypoplastic or absent thumb. Carpals (scaphoid and trapezium commonly) may be absent. Flexor muscles of forearm are underdeveloped.

Associated syndromes include Holt Oram syndrome (heart defects, commonly ASD), thrombocytopenia absent radius (TAR) syndrome, vertebral, anal, cardiac, tracheal, esophageal, renal and limb (VACTERL) syndrome, coloboma of the eye, heart defects, atresia of the nasal choanae, retardation of growth or development, genital or urinary abnormalities, and ear abnormalities and deafness (CHARGE) syndrome and Fanconi anemia.

Treatment

It is wise to always rule out cardiac defects (which may need to be treated earlier). Passive stretching should be done before surgery. Surgical treatment consists of centralization of the wrist (carpus) on the ulna. An absent thumb can be reconstructed, a procedure called as “pollicization”.



Figs. 7.70A and B: Radial club hand.

Courtesy: Dr Matad Lokeshwaraiah Chetan (SS institute of medical sciences, Davangere).



Fig. 7.71: X-ray both wrist AP and lateral views showing Madelung deformity (Radius has grown volarwards and ulna is sticking out dorsally).

MADELUNG DEFORMITY (FIG. 7.71)

In this deformity the lower end of radius curves forwards carrying with it the carpus and the hand but leaving the ulna sticking out on the back of the wrist. The left out ulna can be balloted like a piano key (Piano key sign). The deformity may be congenital or post-traumatic. In congenital type also even though the pathology is present since birth, the deformity becomes obvious by 10 years as growth occurs. Function is excellent and only severe cases need corrective osteotomy.

RADIOULNAR SYNOSTOSIS

Synostosis refers to osseous fusion between two bones. Radioulnar synostosis may be of two types:

1. Congenital (Rare)
2. Traumatic

Congenital Radioulnar Synostosis

It occurs due to a defect in the longitudinal segmentation of radius and ulna. Most commonly occurs in proximal one-third of forearm (Fig. 7.72). Usually, the forearm is fixed in pronation. It is seen with equal frequency in both



Fig. 7.72: Radioulnar synostosis.

Courtesy: Dr Deepak Raghav (JN medical college, AMU).

sexes, with 60% cases being bilateral. Muscles and fascial tissues in the forearm are also anomalous to varying degrees, so simple resection of the bony bridge does not restore motion (supination and pronation). Hence surgery is not indicated in most patients, and moreover most patients are able to carry on daily activities with some adjustments.

Only rarely when deformity is bilateral and severe, surgery may be done. Aim of surgery is to reposition forearm in a different position rather than to provide movement. Osteotomy is done to place one forearm in neutral and other in slight pronation (10–20°).

Traumatic Synostosis

Most common cause is an operatively treated forearm fracture. Highly comminuted and open fractures, especially with both bones fractured at same level pose a greater risk. Patients with a concomitant head injury are more likely to land up with this complication (owing to greater growth factors released after injury). Treatment is indicated when the restriction of forearm rotation is disabling. Resection of synostosis along interposition of fat/muscle/fascia/silicone is done. Unlike in congenital variety, the results of resection are good.

CHAPTER 8

Neuromuscular Disorders



CEREBRAL PALSY

INTRODUCTION

Cerebral palsy (CP) is defined as “a nonprogressive neurological disorder primarily affecting movement and muscle coordination, due to insult to the developing brain before, during or just after birth”. This neurological deficit is non-progressive, as the damage that has once occurred is static but the clinical picture may appear to worsen with growth due to the progressive nature of the joint contractures. As the muscles are fibrotic and contracted, they cannot lengthen and adapt to growing bones, resulting in progressively worsening joint contractures as the child grows. By definition, the onset of the condition must be before the age of 2 years.

A number of classifications have been proposed for the condition:

- **Geographic classification:** Based on the extent of neurological deficit:
 - *Monoplegia (rare):* Only one extremity is involved (commonly lower)
 - *Hemiplegia:* Ipsilateral upper and lower extremities (upper > lower), 50% patients are mentally retarded
 - *Paraplegia:* Both lower extremities involved equally
 - *Quadriplegia:* All four extremities involved equally
 - *Diplegia (most common):* All four extremities involved (lower > upper)
 - *Double hemiplegia:* All four extremities involved (upper > lower)
 - *Total body:* Severe involvement all four extremities, along with absent head and neck control (resulting in drooling, dysphagia, dysarthria)
- **Physiological classification:** Based on the part of brain involved:
 - *Spastic type (most common form 80%):* This is characterized by corticospinal tract involvement. Lack of coordination and balance, joint contractures and joint subluxations and dislocations are common. Clonus and Babinski sign are present. There is hyperreflexia and jack knife spasticity.
 - *Extrapyramidal type:* This is further subdivided into various subtypes depending on different areas of brain that may be involved (basal ganglia, thalamus, cerebellum, substantia nigra):

- *Athetoid:* Dyskinetic, purposeless worm-like movements. Reflexes are normal and joint contractures are uncommon.
- *Choreiform:* Continuous purposeless movements of wrist, fingers, ankles and toes.
- *Rigid:* Cogwheel or lead pipe rigidity without hyperreflexia or clonus. It is the most hypertonic type of CP.
- *Ataxic:* Very rare type due to damage to cerebellum. Patient has tremors and drunken gait.
- *Hypotonic:* Weakness accompanied by hypotonia and normal deep reflexes. It may later evolve into spastic or ataxic types.
- *Mixed*
- **Etiological classification:** Based upon the cause of the insult:
 - *Prenatal (most common 70%):* Infection [TORCH (Toxoplasmosis, Other agents i.e. HIV, measles, varicella etc., Rubella, Cytomegalovirus, and Herpes simplex) agents], toxins (e.g., methyl mercury), Rh incompatibility (kernicterus), congenital malformations of brain, vascular insult
 - *Perinatal:* Traumatic delivery, prematurity, birth asphyxia, chorioamnionitis
 - *Postnatal:* Infection (meningitis, encephalitis), hypoxic ischemic encephalopathy, child abuse, traumatic brain injury.

CLINICAL FEATURES

Children with this condition present with varied forms of neurological involvement as discussed above. Abnormalities of tone and movement are there. Developmental milestones are delayed or never appear (Table 8.1). Primitive reflexes persist longer than usual (Table 8.2).

Common gait patterns seen in children with CP: Toe walking (equinus), crouched knee gait (hip flexion, knee flexion and ankle dorsiflexion), jump knee gait (hip flexion, knee flexion and ankle plantar flexion) (Figs. 8.1A and B), Scissoring gait (due to spasm of hip adductors) (Fig. 8.2) and Stiff knee gait.

Common deformities seen in children with CP are as follows:

Table 8.1: Appearance of some important milestones	
Head control	3–6 months
Sit without support	6–9 months
Crawling	8–9 months
Walking without support	2–18 months

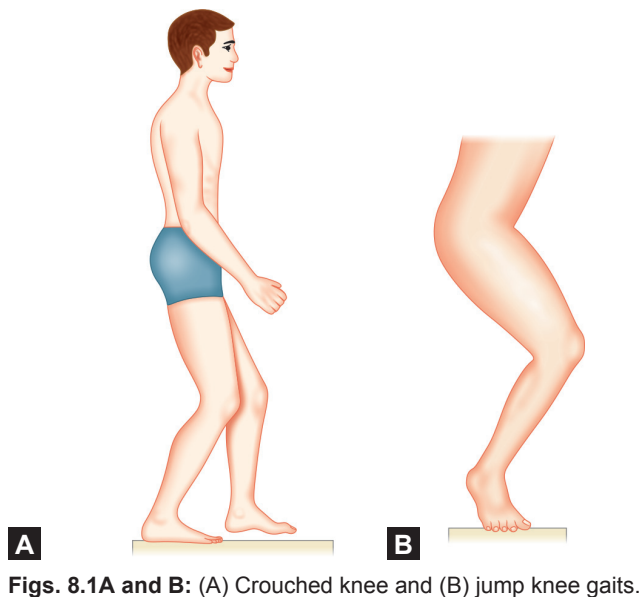


Table 8.2: Some important primitive reflexes and their usual time of disappearance	
Primitive reflexes	Usual time of disappearance
Palmar grasp	Appears at 34 weeks gestation and disappears by 2–4 months
Plantar grasp	Disappears by 9–12 months
Asymmetric tonic neck reflex	Disappears by 4–6 months
Moro reflex	Appears at birth and disappears by 4–6 months
Placing reflex	Appears at birth and disappears by 5–9 months
Stepping reflex	Appears at birth and disappears by 1–2 months
Parachute reflex	Appears at 6–9 months and thereafter persists



Fig. 8.2: Scissoring gait.

- Osteoporosis
- Hydrocephalus.

DIAGNOSIS

The diagnosis is largely clinical and is reached by eliciting proper history which may reveal a low IQ, disappointing school performance and delayed developmental milestones. A thorough clinical examination greatly aids if one goes for muscle tone and power charting. Finding of presence of primitive reflex patterns persisting longer than usual also help in clinching the diagnosis.

MANAGEMENT

Management can be described under the following headings:

- *Mechanical measures and medical management:* Spasticity can be managed by physical therapy, gait training, bracing and splinting, and by drugs. Effective drugs include:
 - *Dantrolene:* It acts at the level of skeletal muscle (peripherally acting) by inhibiting release of calcium ions. It is used less frequently because of the potential to result in profound weakness and liver toxicity.

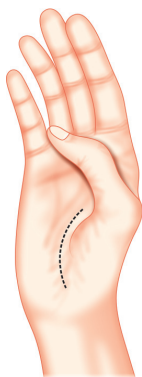


Fig. 8.3: Thumb in palm deformity.

- *Upper extremity deformities:* Internal rotation contracture of shoulder, flexion deformity of elbow, flexion and ulnar deviation of wrist, thumb in palm deformity (Fig. 8.3) and flexion of fingers.
- *Lower extremity deformities:* Subluxation and dislocation of hip (mostly posterior), flexion contracture of knee (due to hamstring spasm), variable deformities of foot and ankle (equinus, equinovarus, equinovalgus, cavus).

Associates conditions in children with CP:

- *Mental retardation [low intelligent quotient (IQ)]:* 40–60%
- *Seizures:* 40%
- Visual impairment
- Constipation
- Dysphagia
- Hearing impairment

- *Baclofen*: It is a gamma aminobutyric acid (GABA) agonist, which acts at level of spinal cord (centrally acting) and inhibits the release of excitatory transmitters. It can be administered orally or via intrathecal route. Intrathecal infusion dose is 1/30th of oral dose and can be delivered via an implantable subcutaneous pump to ensure continuous delivery. Important complications include pump and catheter infection, spinal fluid leak and respiratory depression.
- *Botulinum A toxin*: It acts at the neuromuscular junction (peripherally acting) to inhibit the release of acetylcholine. It is directly injected into spastic muscles where the effect may last up to 6 months. The goal is to use the effect obtained to facilitate physiotherapy and mobilization and delay surgical intervention. However, the efficacy of repeated injections may reduce due to development of antibodies. Inadvertent systemic injection has the potential of causing severe respiratory depression. Contraindications to its use include known resistance or antibodies, failure of previous response, myasthenia gravis, fixed contracture and concomitant use of aminoglycosides.
- *Surgical management*
 - *Selective dorsal rhizotomy*: One of the pathogenetic mechanisms behind CP is that end organs generate abnormal sensory impulses that lead to excessive stimulation of excitatory fibers. In this procedure, the rootlets carrying excessive stimulatory information to dorsal sensory fibers are cut. Goal is to reduce the stimulatory input that goes from dorsal sensory fibers to efferent motor fibers. Ideal patient is 3–8 years old child with spastic diplegia, voluntary trunk and motor control, pure spasticity and no fixed contractures. It is not recommended in spastic quadriplegia and hemiplegia.
 - Muscle-tendon lengthening/release procedures or tendon transfers or rarely osteotomies may be done as per the clinical scenario.
 - Some notable procedures include:
 - Equinus in CP patients is generally due to selective contracture of soleus muscle and is treated by vulpius release.
 - Equinovarus deformity at foot can also occur and tendon transfer of Kaufer (tibialis posterior to peroneus brevis) and Hoffer (tibialis anterior to medial cuneiform) are useful for correction. On the contrary, equinovalgus if occurs is corrected by tendon transfers of Perry (peroneus brevis to tibialis posterior)
 - Hip dislocation in CP occurs due to flexion adduction contracture at hip and can be managed by San Diego procedure.
 - Scissoring occurs due to adductor spasm at hip and is managed by adductor tenotomy if abduction is less than 30°.

HIGH-YIELD POINTS

- Cerebral palsy is the most common permanent disability of childhood.
- *Difference between spasticity and rigidity*: Spasticity is velocity dependent increase in muscle tone with passive stretch, caused by exaggeration of muscle stretch reflexes while in rigidity the tone is equally increased throughout the range of motion independent of velocity of stretch.
- *Complications of selective dorsal rhizotomy include*: lumbar hyperlordosis, hip subluxation/dislocation, spondylosis and weakness etc.

POLIOMYELITIS

INTRODUCTION

Polio is an acute infectious disease caused by poliovirus. The target population is the pediatric age-group and the target organs include the spinal cord (anterior horn motor cells) and the brainstem (bulbar nuclei).

EPIDEMIOLOGY

In the past, polio was an epidemic occurring mainly in the summer months. Most of the countries are now free from the disease due to effective preventive measures (effective immunization and surveillance). Only three countries are endemic as of 2014: Pakistan, Nigeria and Afghanistan, although sporadic cases occur in many other also.

India's last case (due to type 1 virus) was reported on January 13, 2011 from Howrah, West Bengal. As of now

India is free from new cases. This does not mean that the disease is no longer of significance to health-care providers. Patients with sequelae of disease are still abundant and although these cases are not infectious, many of them are crippled and are considered outcast in the modern society. The role of orthopedic surgeon is not during acute phase, but to effectively treat its sequelae to help these people lead a more normal life.

ETIOPATHOGENESIS

Infection is caused by poliomyelitis virus, which belongs to group *Enterovirus* and family *Picornavirus*. Lipid envelope encloses a single-stranded ribonucleic acid (RNA) core. Three different strains of virus are there (type I, II and III) with no cross immunity. It enters body via feco-

oral route, multiplies in intestine where it may manifest as episode of diarrhea and then reaches the nervous system through bloodstream. The virus has special affinity for some brainstem nuclei (bulbar polio) and anterior horn cells of the spinal cord (especially the lumbar and cervical enlargements of the cord). Damage to these neurons produces flaccid type of paralysis. The proportion of motor units destroyed is variable and the resultant weakness depends on the percentage of motor units that have been destroyed.

COURSE OF DISEASE

The disease process is divided into three phases.

1. **Acute phase:** The child presents with fever, mild headache, malaise, sore throat and diarrhea. This is preparalytic stage that lasts for 5–10 days. Diagnosis in this stage is very difficult unless the area is endemic.
Soon muscle weakness appears, generally after 2–3 days of onset of fever and peaks over another 2–4 days and in rare cases may progress to cause dyspnea and dysphagia (bulbar polio affecting motor neurons of the respiratory and cardiovascular centers of the medulla). This is the paralytic stage. If patient does not succumb to respiratory paralysis, fever subsides after 7–10 days and patient enters convalescent stage.
2. **Convalescent phase:** Also known as phase of recovery, this lasts up to 16–24 months. Maximum recovery occurs in 3–6 months and no recovery beyond 24 months. This phase is divided into sensitive and insensitive phases. In sensitive phase, muscles are tender and in spasm while in insensitive phase muscles are nontender but still in period of recovery.
3. **Chronic residual phase:** This phase is also known as the stage of post-polio residual paralysis (PPRP). It is seen after 24 months when maximum recovery has occurred and residual paralysis persists. The paralysis is lower motor neuron (flaccid) type which is asymmetrical and patchy in distribution with no sensory loss and no bladder bowel involvement. In PPRP, the major causes of deformity are: muscle imbalance, faulty posture and continuous growth of bones against fibrotic contracted muscles.

DIAGNOSIS

The diagnosis of polio must be considered in endemic areas whenever a child presents with acute flaccid paralysis after ruling out the other conditions that may present in similar manner (Table 8.3).

POLIO AND ORTHOPEDICS

The orthopedic surgeon is primarily expected to deal with the extensive muscle paralysis that may ensue and protect the patient from developing resultant deformities.

Almost any pattern of paralysis in the involved muscles of limb is possible; however, some important points of consideration are as follows:

Polio most commonly involves the muscles of the lower limb; acute fatality is because of the involvement of the respiratory muscles generally. The most common muscle to be affected is quadriceps femoris, which is partially paralyzed in majority of cases. The most common completely paralyzed muscle in polio is tibialis anterior. In the upper limb most commonly involved muscle is deltoid. Although hand muscles are rarely involved, the most common affected muscle of hand is opponens pollicis.

Important Deformities in Polio

The major deformities in polio occur in lower limb due to the iliotibial band (ITB) contracture.

Relevant anatomy (Fig. 8.4): The iliotibial tract/ITB is a longitudinal fibrous reinforcement of the fascia lata. Three muscles give origin to ITB: (1) tensor fascia lata (TFL), (2) gluteus medius and (3) gluteus maximus, and it inserts at lateral condyle of the tibia at Gerdy's tubercle. The action of the ITB and its associated muscles is to extend, abduct and externally rotate the hip. In addition, the ITB contributes to lateral knee stabilization.

Tensor fascia lata is an abductor and medial rotator of hip while it extends the knee. This muscle originates from iliac crest and inserts into the iliotibial tract.

Deformities: Iliotibial band contracture can lead to:

- Flexion, abduction and external rotation deformity at hip (most common)
- Flexion and valgus at knee or sometimes triple deformity at knee (flexion, posterior subluxation and external rotation of tibia on femur)
- Equinovarus at ankle and foot
- Lumbar scoliosis and pelvic obliquity at spine and pelvis respectively.

To test for ITB contracture, Ober's test is done (Fig. 8.5). To perform this test, make the patient lie in the lateral position, support the knee and flex it to 90°. Then extend and abduct the hip. Then release the knee support. Failure of the knee to adduct is a positive test.

MANAGEMENT

The management of polio is subdivided into prevention and treatment of the disease.

Prevention

Polio is best prevented by immunization. Two types of vaccines are available: oral polio vaccine (OPV) and inactivated polio vaccine (IPV). OPV is more effective and is included in National Immunization Program. Even if a patient has had an attack of polio, he should be immunized as there are three strains of the virus and he can get

another attack due to infection by another strain. Intramuscular injections should be avoided in children in the polio endemic zones.

Treatment

Treatment depends on the phase of the disease.

- **Acute phase:** The aim of treatment in the acute phase is to provide symptomatic treatment and to avoid the deformities. Patient is given rest and paralyzed limbs are supported in splints to reduce the pain and muscle spasm. Active movements are avoided. Respiratory muscle paralysis warrants ventilatory support. Hot fomentation and analgesics are given for pain relief.
- **Convalescent phase:** Joints are splinted to reduce pain and adequate joint mobilization exercises are begun to gain the range of motion and prevent occurrence of deformities.

Once infection occurs there is no way to limit the severity of paralysis or prevent it. The aim is to limit the resultant deformities and comorbidities.

Treatment of PPRP

Once the paralysis is established and recovery has halted, the aim of treatment in this stage is to correct the deformities if they have developed and to provide maximum attainable function.

- **Nonoperative methods:** Use of splints and traction to prevent and correct the existing deformities.
- **Operative procedures:**
 - **Soft-tissue release operations:** Iliotibial band contracture is corrected by release of contracted soft tissues, e.g., Yount's release.
 - **Tendon transfers:** Muscle imbalance is corrected by transferring the tendon of normal muscle to the site which provides the function of paralyzed muscle.

Some important tendon transfers include:

- **Saha transfer (for deltoid paralysis):** Trapezius to deltoid transfer
- **Steindler's flexorplasty (for loss of elbow flexion):** Shifting flexor origin proximally for about 5 cm to strengthen elbow flexion

Table 8.3: Differentials of poliomyelitis

Guillain-Barré syndrome	It is an ascending symmetrical myelopathy that occurs a bit later in life. Facial nerve involvement can be seen. Most cases have complete recovery.
Acute transverse myelitis	There is acute sensory and motor paralysis below a particular level at which the vascular supply to cord has been interrupted.
Traumatic paraplegia	There is history of trauma and radiograph may show the fracture.
Neuropathy	Usually presented with both motor and sensory loss that is generally bilateral. Treating the cause may lead to improvement.
Myopathy	Since the paralysis is lower motor neuron type with no sensory loss, the condition is an important differential. Mostly this condition is genetic. The pattern is predictable and generally symmetrical. The paralysis tends to worsen over time. Creatine phosphokinase (CPK) levels may be raised and a muscle biopsy may provide the diagnosis.
Spinal dysraphism	Patients tend to have tuft of hair or swelling at the back. There may be both motor and sensory loss and the paralysis may deteriorate with growth.

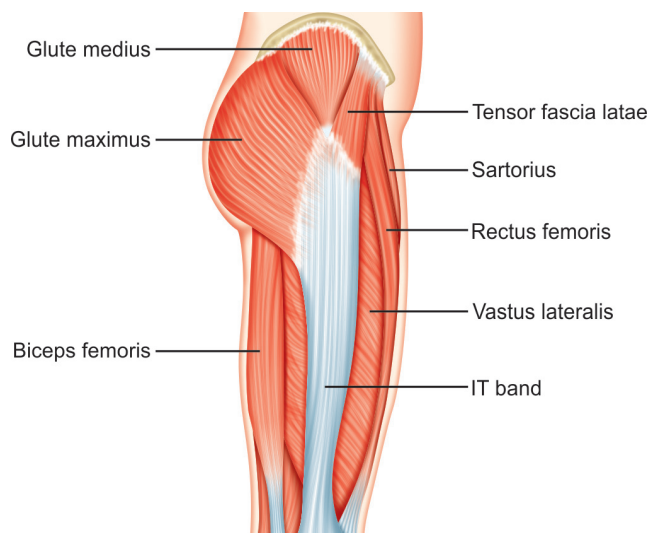


Fig. 8.4: Iliotibial band (ITB).



Fig. 8.5: Ober's test for iliotibial band (ITB) contracture.

- *Sharrard/Mustard transfers (for paralysis of hip abductors and extensors, i.e., gluteus medius and maximus):* Transfer of iliopsoas to greater trochanter.

Tendon transfers are not to be done before 4 years of age as the rehabilitation exercises could not be taught to a child of less than 4 years of age. However, an undue delay should be avoided as a delay in tendon transfers in case there is a muscle imbalance would lead to a progressive deformity.

Bony Procedures

Joint stabilization procedures (arthrodesis): Fixed deformities cannot be corrected by soft-tissue procedures alone, it is important to correct the deformity and then stabilize the joint by arthrodesis, e.g., in deformities of ankle and foot, triple arthrodesis may be needed in which talocalcaneal, talonavicular and calcaneocuboid joints are fused or a flail subtalar joint may need to undergo the Grice Green subtalar arthrodesis.

HIGH-YIELD POINTS

- The first description of polio was given by Underwood in 1789.
- Although polio has been a disease of the past, recent attention is focused on new cases caused by oral vaccine, so-called vaccine-associated poliomyelitis. The risk of contracting polio from vaccine is however extremely low.
- Another manifestation that has received attention over recent years has been the post-polio syndrome. This is characterized by generalized weakness, fatigue and multiple body aches in people who contracted polio a couple of decades earlier.
- In polio, the most common bone fracture is supracondylar femur fracture. Femur is also the most common bone fractured in muscular dystrophies and arthrogryposis.
- Fractures in polio heal rapidly.

SPINA BIFIDA AND OTHER RELATED CONDITIONS (MYELOYDYSPLASIAS)

INTRODUCTION

It is a neural tube defect (NTD) characterized by failure of fusion of the neural tube posteriorly. The spinal cord may lie exposed from the back due to incomplete closure of the vertebral arches and patient may land up with a progressive neurological impairment. The condition is often associated with maldevelopment of spinal cord and the membranes.

The severity of the defect varies and based on the same, the condition is divided into following types:

- *Spina bifida occulta:* This is the mildest form. The laminae fail to fuse to form spinous processes resulting in bifid spinous processes. The meninges do not herniate through the bony defect and the defect is covered with skin. It is the most common type but not usually diagnosed, as it is asymptomatic. Overlying skin may have stigmata, such as a hairy patch, hemangioma, dermal sinus, nevus, or a lipoma, which is an indicator of underlying spina bifida. It is the most common in lumbosacral region ($S_1 > L_5$) and usually diagnosed incidentally on radiographs in adults. In rare cases there may be neurological impairment due to tethering of the cord to the undersurface of the skin by a fibrous membrane (membrana reunions), tethering of the cord to filum terminale (see tethered cord syndrome), a presence of septum dividing the spinal canal (see diastematomyelia) or defective neural development.
- *Spina bifida cystica:* This is the more severe form where the defect not only involves the vertebral arches but also extends to the overlying meninges, soft tissues and skin. It includes meningocele, myelomeningocele and syringomyelocele.

- *Meningocele:* It refers to herniation of meninges through the bony defect to form a posterior midline sac containing cerebrospinal fluid (CSF). Nerve roots and cord do not herniate into the sac, hence the child is neurologically normal. The meninges are covered by skin (closed defect). It is the most common in lumbosacral region.
- *Meningomyelocele/myelomeningocele:* The spinal cord or nerve roots (cauda equina) along with the meninges herniate through the bony defect. The sac is not covered by skin (open defect). The cord is usually splayed open within the sac and is referred to as neural placode. It is commonly accompanied by other anomalies such as Chiari malformation and hydrocephalus.
- *Syringomyelocele:* It refers to a cord with dilated central canal and very thin cord substance herniating through the bony defect. The sac is covered by skin.

ETIOLOGY

Risk factors during gestation implicated in causation of NTDs include folic acid deficiency, gestational diabetes and anticonvulsants (valproate, carbamazepine).

DIAGNOSIS

An increase in the level of maternal serum AFP (alpha fetoprotein) during second trimester is a sensitive indicator of open NTDs. If raised, it can be confirmed by measuring levels of AFP and acetylcholinesterase in amniotic fluid.

Ultrasonography (USG) is also highly specific for detection of NTDs, and can confirm diagnosis as early as 18 weeks of gestation.

Otherwise the classical clinical presentation, hair tufts or swelling at the back point towards the diagnosis that is aided by radiography.

TREATMENT

Spina bifida occulta needs no treatment. In other more severe cases, closure of sac and ventriculoperitoneal shunting is done in perinatal period (preferably within 2–3 days of birth). In-utero closure is also attempted now-a-days, as damage to neural structures can be minimized by early closure.

However, one must remember that most of the defects in children can be prevented by adequate intake of folate by pregnant women.

Spina Bifida and Orthopedics

Role of the orthopedic surgeon comes later when deformities develop due the muscle paralysis caused due to damage to cord and nerve roots.

Common orthopedic problem in such children include hip dislocation, knee flexion or extension contractures, external tibial torsion, rigid talipes equinovarus. Management of such problems is challenging and often not satisfactory, e.g., a rigid clubfoot in meningocele may need decancellation of talus and cuboid (subchondral excision of talus and cuboid, known as Verbelyi-Ogston procedure).

Diastematomyelia

It is a congenital malformation in which the spinal cord is split vertically into two halves by a bony, fibrous, or

fibrocartilaginous spur. It is different from Dimyelia which means complete duplication of the spinal cord. Diastematomyelia is most common in lumbar region. Midline cutaneous stigmata like tuft of hair, dimple, lipoma, and hemangioma are common. On X-rays, there is widening of the interpedicular distance on anteroposterior (AP) view, along with any associated vertebral body defects that are commonly seen. Child is usually neurologically normal at birth and neurological defect develops later on. Excision of the septum is recommended only when there is a progressive neurological defect, and not routinely in all patients.

Tethered Cord Syndrome

This condition is characterized by tethering/pulling of the spinal cord at the base of the spinal canal. As the child grows, this tethering causes the spinal cord to stretch. Fluid pressures in the cord fluctuate leading to cyst formation and hence syringomyelia. Tight filum terminale may be a causative factor.

Clinical symptoms may be in the form of hairy patches, dimples or fatty tumors on the lower back, back pain, weakness in legs, bladder bowel involvement and scoliosis. The symptoms are progressive and worsen with growth. Magnetic resonance imaging (MRI) is the investigation of choice and provides the diagnosis.

Treatment is largely supportive. One may attempt at cutting the affected nerve roots in order to provide pain relief in patients in severe pain. The prognosis is very poor.



CHAPTER

9

Genetic and Developmental Disorders in Orthopedics

SKELETAL DYSPLASIAS

INTRODUCTION

Skeletal dysplasias are a heterogeneous group of developmental disorders of bone with a wide spectrum of manifestations ranging from early onset of osteoarthritis with normal survival to death in utero or in early infancy. These are characterized by disordered growth of bone resulting in abnormalities of long bones, skull, chest, pelvis and spine. More than 300 skeletal dysplasias have been described, all are rare but some are extremely rare. Osteogenesis imperfecta is the most common skeletal dysplasia. Common skeletal dysplasias are listed in Box 9.1.

CLASSIFICATION

These are classified based on which part of bone is predominantly involved, i.e. epiphysis, metaphysis and diaphysis (Table 9.1). The word “spondylo” is used as prefix to indicate involvement of spine.

Skeletal dysplasias are also classified based on which portion of the bone is shortened:

- Rhizomelia indicates shortening of proximal portion of limb due to shortening of femur or humerus.
- Mesomelia indicates shortening of middle portion of limb due to shortening of leg or forearm bones.
- Acromelia is due to shortening of foot and hand bones.

HIGH-YIELD POINTS

- Thanatophoric dysplasia is the most common lethal skeletal dysplasia.
- *Dysostosis*: It is isolated dysplasia of a bone or a group of bones, i.e., craniofacial dysostosis, polydactyly, syndactyly, etc.
- Achondroplasia is the most common form of dwarfism (abnormal short stature).
- Short stature is defined as the height less than the 3rd percentile for the chronological age of the patient.

Box 9.1: Common skeletal dysplasias

- Osteogenesis imperfecta—most common
- Multiple epiphyseal dysplasia (MED)
- Spondyloepiphyseal dysplasia (SED)
- Achondroplasia
- Pseudochondroplasia
- Metaphyseal chondrodysplasia

- Phocomelia (meaning seal like limbs) is a birth defect wherein the proximal bones of the limbs are shortened such that the hands and the feet are located very close to the trunk. It was the prime concern in children whose mothers had been on Thalidomide anti-emetic drug which led to stoppage of the drug.

Diagnosis of Skeletal Dysplasia

Diagnosis of many skeletal dysplasias can be made by using prenatal ultrasound and postnatal X-ray of baby. Diagnosis can be confirmed by molecular testing of mother and child.

Table 9.1: Classification of dysplasias based on which part of bone is predominantly involved

Epiphyseal dysplasias	<ul style="list-style-type: none"> • Spondyloepiphyseal dysplasia (SED) • Multiple epiphyseal dysplasia (MED) • Dysplasia epiphyseal hemimelica (Treavor's disease) • Chondrodysplasia punctata
Physeal and metaphyseal dysplasia	<ul style="list-style-type: none"> • Achondroplasia • Hypochondroplasia • Hereditary multiple exostosis • Enchondromatosis
Metaphyseal and diaphyseal dysplasia	<ul style="list-style-type: none"> • Metaphyseal dysplasia (Pyle's disease) • Diphysal dysplasia (Engelmann's disease) • Osteopetrosis (marble bone disease) • Pycnodysostosis • Craniometaphyseal dysplasia
Mixed dysplasia	<ul style="list-style-type: none"> • Cleidocranial dysplasia • Nail-patella syndrome • Diastrophic dysplasia • Pseudoachondroplasia
Connective-tissue disorder	<ul style="list-style-type: none"> • Ehler-Danlos syndrome • Osteogenesis imperfecta • Larsen's syndrome
Storage disorders and metabolic defects	<ul style="list-style-type: none"> • Gaucher's disease • Homocystinuria • Alkaptonuria • Mucopolysaccharidoses: <ul style="list-style-type: none"> – Hunter's disease – Hurler's syndrome – Morquio syndrome
Chromosomal disorder	<ul style="list-style-type: none"> • Down syndrome



Figs. 9.1A and B: Typical appearance of an 8-year-old achondroplastic boy.

COMMON SKELETAL DYSPLASIAS AND RELATED ORTHOPEDIC DISORDERS

Achondroplasia

Genetics

Autosomal dominant transmission; mutation in fibroblast growth factor receptor gene-3 (FGFR-3).

Clinical Features

Normal intramembranous ossification leads to normal skull and clavicles, whereas abnormal enchondral ossification results in shortening of long bones.

Short stature (Figs. 9.1A and B): Rhizomelic micromelia, i.e., arms and thighs are most severely shortened. Short stature is apparent at birth. Hands are short and broad. All fingers are approximately of same length (starfish hand) with wide separation between middle and ring finger (trident hand, Fig. 9.2).

Facial features: Achondroplastics have large head with prominent mandibles, small maxillae and depressed nasal bridge.

Elbow contracture, broadening of ends of long bones, angular deformities of lower limbs and waddling gait are often present.

There may be protuberant belly and obesity. These children have normal intelligence (circus dwarf).

X-ray Features

Bones are short and thick. In spine there are posteriorly scalloped vertebrae, short pedicles and short interpediculate distance. Bullet-shaped vertebrae are seen in infants. Pelvis is broad and flat (champagne glass pelvis, i.e., width is greater than depth) with squared iliac wings,

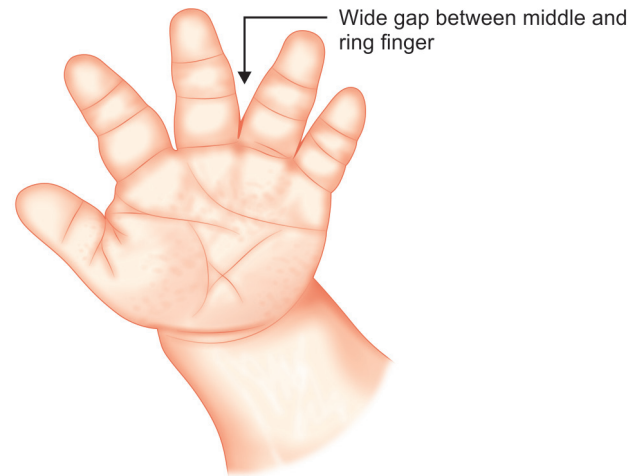


Fig. 9.2: Trident hand.

horizontal acetabular roofs and narrow sciatic notches. Epiphyses are normal.

Orthopedic consultation is usually required for cervical and lumbar canal stenosis, angular deformities of knee and for limb lengthening.

Hypochondroplasia

It is similar to achondroplasia but less severe. It cannot be detected at birth and may remain undiagnosed until puberty when child fails to achieve growth spurt. Final height is short but more than achondroplasia. X-ray features are similar to achondroplasia.

Pseudoachondroplasia

It is also a type of rhizomelic dwarfism. Child is normal at birth and shortening may not become apparent until after infancy. Distinguishing features from achondroplasia are involvement of both epiphysis and metaphysis, normal skull and facies and normal interpediculate distance (spinal stenosis is not a feature).

Multiple Epiphyseal Dysplasias

Genetics: Autosomal dominant transmission, mutation in cartilage oligomeric matrix protein (COMP) gene on chromosome 19.

Clinical features: Basic pathology is abnormal fragmented and flattened epiphyses, especially those of femoral and humeral heads. Patients present in early childhood with stiff painful joints due to arthritis and waddling gait. Height is mildly short and true dwarfism (height below 3rd percentile for height) is usually not present.

X-ray features: Late appearance of ossification centers and fragmented and flattened epiphyses and premature osteoarthritic changes are characteristic features. Coxa vara and double layered patella may be seen. Flat bones

like skull, pelvis, mandible, clavicles, ribs, scapulae and sternum are normal. There is no vertebral involvement. Orthopedic consultation is usually required for painful hip joints due to early arthritic changes. Due to fragmentation of femoral head epiphysis and coxa vara picture may look like a bilateral Perthes disease.

Spondyloepiphyseal Dysplasia

It is of two types: (1) SED congenita and (2) SED tarda.

1. SED congenita:

Genetics

Autosomal dominant transmission, mutation in COL2A1 locus on chromosome 12.

Clinical Features

It is characterized by abnormal epiphyses, short trunk dwarfism and rhizo and mesomelic dwarfism of limbs.

Facial features: Short neck and wide set eyes.

Limbs: Genu valgum and coxa vara are common. Club foot deformities may be seen.

Trunk: Excessive lumbar lordosis with protuberant abdomen.

X-ray Features

Late appearance of ossification centers of carpal and tarsal bones. Epiphyses are irregular and flattened. Secondary ossification centers of long bones are delayed in appearance.

Odontoid dysplasia put the patient at risk of atlantoaxial dislocation. Platyspondyly is seen (flattened vertebral bodies).

Small iliac wings, flat acetabula and coxa vara are commonly seen in pelvis X-ray.

Patients seek orthopedic consultation for spine abnormalities, like cervical instability, excessive lumbar lordosis, scoliosis and lower limb deformities, like coxa vara and genu valgum.

2. SED tarda:

It is less severe form which manifest late in childhood or adolescence. Height is minimally affected. Inheritance is autosomal recessive or X-linked recessive. Child presents with complains of bilateral hip pain (hip osteoarthritis) and short height. X-rays show abnormal hip joints and other epiphyses and platyspondyly.

Dysplasia Epiphysealis Hemimelica (Trevor's Disease/Fairbank's Disease)

It is characterized by involvement of only one half of the epiphysis on only one side of the body. This leads to an asymmetrical limb deformity due to asymmetrical

enlargement of the epiphysis (Fig. 9.3). The lesion is very similar to osteochondroma but always affects a single limb. Knee and talus are the most common sites. Excision of enlarged epiphyseal cartilage is required if it interferes with the joint function.

Osteopetrosis (Marble Bone Disease, Albers-Schonberg Disease)

Osteopetrosis is characterized by defective osteoclastic bone resorption due to defect in their carbonic anhydrase type II proton pump. Defective bone resorption leads to thickened radiologically dense (white) bones and hence the term, marble bone disease.

Two types have been described: (1) malignant osteopetrosis (autosomal recessive) and (2) benign osteopetrosis (autosomal dominant).

Clinical Features

Patients present with features of pancytopenia (abnormal bleeding, anemia, infections and failure to thrive) due to encroachment of marrow cavity by bone overgrowth. Osteomyelitis is common due to decreased immunity. Although bones are thickened but they are defective as there is no remodeling due to lack of osteoclastic activity which makes them susceptible to fracture. Bone pain and pathological fractures are thus common. Healing of fractures is generally normal but abnormal bones are difficult to fix surgically making internal fixation in these patients difficult. Benign form is usually symptom free and diagnosed incidentally on X-rays prescribed for other reasons.

X-ray Features (Fig. 9.4)

Thickened, sclerotic bones are characteristic features. Endobones (Fig. 9.5) or bone-within-a-bone appearance (radiodense tissues inside the cortices of long bones) is

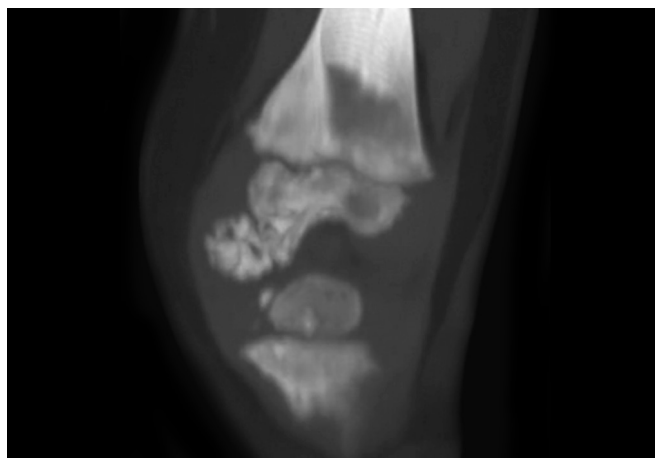


Fig. 9.3: CT scan of knee joint showing half epiphyseal involvement characteristic of Trevor's disease.

Courtesy: Dr. Yuranga Weerakkody, Radiopaedia.org



Fig. 9.4: Thickened sclerotic bone with typical Erlenmeyer flask deformity (arrows) in osteopetrosis.

Courtesy: Orphanet Journal of rare diseases published by BioMed Central.

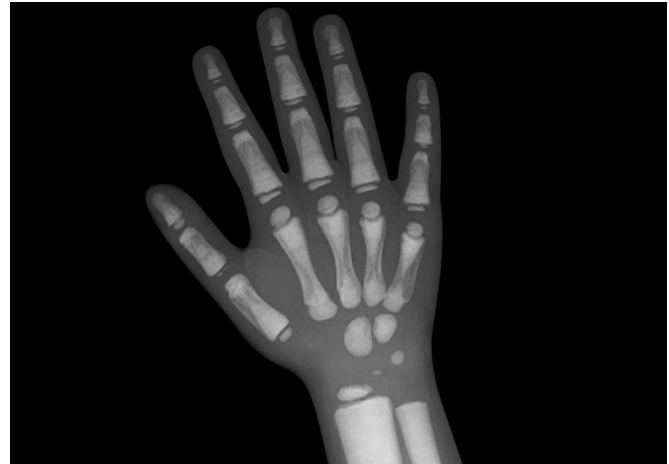


Fig. 9.5: X-ray of hand AP view showing bone within bone appearance in a patient of osteopetrosis.

Courtesy: APY Liu et al. Clinical quiz: answer. HK J Paediatr (New Series) 2011;16:293-94).

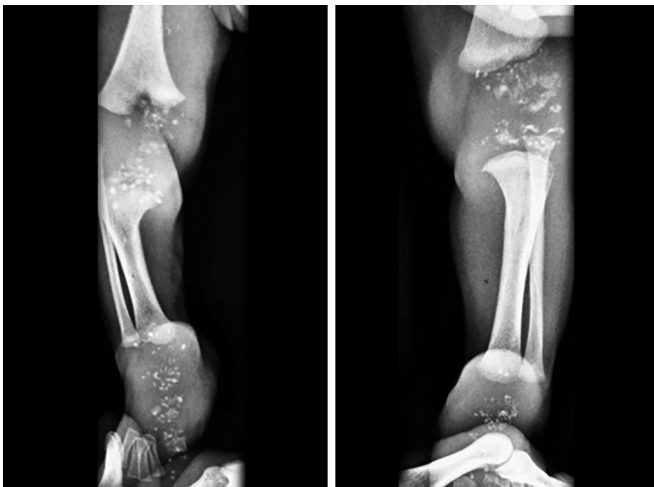


Fig. 9.6: X-ray of lower limb showing calcific stippling of epiphyses of knee and ankle joints characteristic of Chondrodysplasia punctata.

Courtesy: Dr. Tim Luijckx, Radiopaedia.org.

pathognomonic for osteopetrosis. Defective bone remodeling around knee joint causes typical Erlenmeyer flask deformity. Rugger jersey spine (see page 332) may be a feature as well.

Treatment

It can be treated by early bone marrow transplantation.

CHONDRODYSPLASIA PUNCTATA

Chondrodysplasia punctata is a group of disorders which is characterized by calcific stippling of epiphyses and surrounding periarticular soft tissues. Most common is Conradi-Hünemann syndrome which is a X-linked dominant disorder.

Clinical features: Ichthyosis, coarse hair, frontal bossing, epicanthic folds, down slanting palpebral fissure, depressed nasal bridge, rhizomelic shortening of limbs, developmental dysplasia of the hip (DDH), congenital talipes equinovarus (CTEV), scoliosis, congenital cataract and sensorineural deafness.

X-ray features: Punctate calcification of epiphyses (Fig. 9.6) is typical but may disappear after 1st year of life.

CLEIDOCRANIAL DYSOSTOSIS

Genetics: Autosomal dominant, mutation in CBFA gene on chromosome 6.

It is characterized by defective intramembranous ossification, so clavicle, skull and pelvis are abnormal.

Clinical features: Patients are short-statured and have typical appearance with small faces (Elfin facies), wide skull and drooping shoulders. Sometimes bilaterally affected child is able to bring the both shoulder in front of chest and touch them together. Other defects include high and narrow palate, small scapulae, pectus excavatum and delayed permanent dentition. One or both clavicle may be underdeveloped or even missing.

X-ray features: Clavicles are hypoplastic or absent (most commonly lateral end of clavicle is absent). Skull X-ray shows wide suture lines, small maxilla, hypoplastic or absent facial bones and multiple wormian bones (for causes see page 306). X-ray pelvis shows wide symphysis pubis, wide sacroiliac (SI) joint, small iliac wings and thin rami. Other features include coxa vara, spina bifida and hypoplastic terminal phalanges. X-ray hand shows pseudoepiphyses of the metacarpal and metatarsal bones (epiphyses present at both ends of second through fifth metacarpal and metatarsals) resulting in characteristic lengthening of the second metacarpal.

Osteopoikilosis/Spotted Bones

It is characterized by multiple round or oval radio-opacities (Fig. 9.7) in metaphyseal and epiphyseal region of long bones, carpals, tarsals and acetabulum. Condition is asymptomatic and often an incidental finding requiring no treatment.

Melorheostosis/Leri's Disease/Candle Bone Disease

It is rare sclerosing bone disorder, characterized by cortical hyperostosis. Disease may be monostotic or polyostotic. Patients present with soft-tissue contractures and bone pain. Soft-tissue contractures may lead to deformities of joints.

X-ray picture is characteristic (Fig. 9.8) showing asymmetrical, irregular cortical sclerosis (dripping wax down the side of a candle appearance).



Fig. 9.7: X-ray pelvis with both hips AP view showing multiple round opacities characteristic of Osteopoikilosis.



Fig. 9.8: Irregular cortical sclerosis in melorheostosis.

HIGH-YIELD POINTS

- Spondyloepiphyseal dysplasia and MED have remarkable resemblance with Perthes disease. Symmetrical involvement of bilateral hips favors diagnosis of MED and SED.
- *Erlenmeyer flask deformity* (see Fig. 9.4): It refers to a radiographic appearance of relative constriction of the diaphysis and flaring of the metaphysis. It is typically seen on femoral X-ray. It is seen in many conditions, like osteopetrosis, achondroplasia, metaphyseal dysplasia (Pyle's disease), fibrous dysplasia, rickets, rheumatoid arthritis, Ollier's disease, Thalassemia, Gaucher's disease, Niemann-Pick disease, etc.
- *Sclerosing bone (white bone disorders)*: These are characterized by varying sclerosis of bones: osteopetrosis, osteopoikilosis, osteomyelitis, osteopathia striata, melorheostosis, Caffey's disease and pycnodysostosis.
- Bone within bone appearance/Endobones can be seen in osteopetrosis, Sickle cell anemia, Thalassemia, Paget's disease, Acromegaly, Lead poisoning, Growth arrest lines (infancy), Gaucher's disease and congenital syphilis.

Pycnodysostosis

This is a mixed skeletal dysplasia that is best known for being the closest differential of osteogenesis imperfecta. It is also characterized by blue sclera and proneness to fracture. These patients have short limbed short stature, triangular facies, hypoplastic facial bones and mandibles and abnormal dentition. Lateral end of clavicle is hypoplastic or absent, terminal phalanges of fingers are also hypoplastic.

X-ray findings: Generalized osteosclerosis (Fig. 9.9) is a characteristic feature. X-ray of skull shows widened sutures and open fontanels. Spine X-ray may show failure of segmentation of vertebrae in cervical and lumbar region.

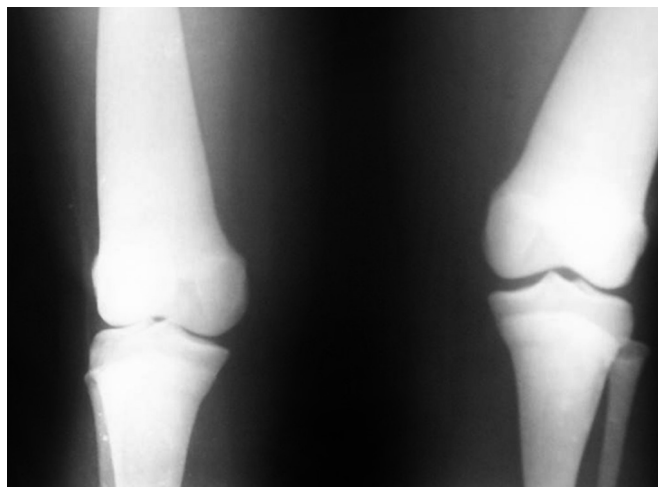
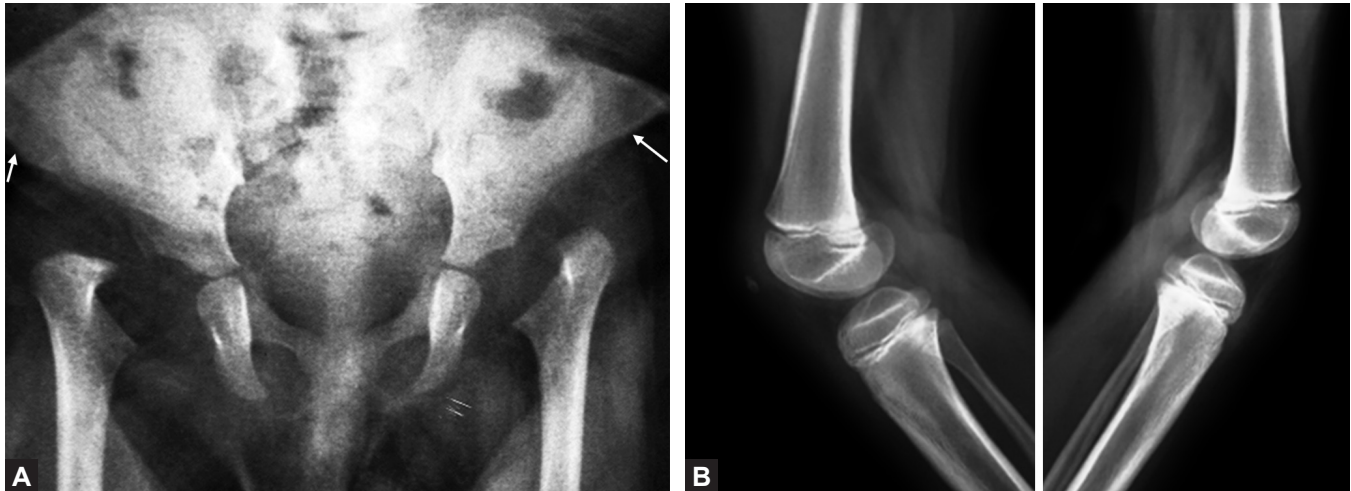


Fig. 9.9: Generalized osteosclerosis in pycnodysostosis.



Figs. 9.10A and B: (A) Bilateral iliac wings (arrows) in nail-patella syndrome (B) X-ray both knees lateral views showing hypoplastic patella on right side and absent patella on left side in a patient of nail-patella syndrome.

Metaphyseal Chondrodysplasia (Pyle's Disease)

It is a heterogenous group of disorders which are characterized by abnormal bulbous metaphyses with normal epiphyses. The Schmidt type is most common type of metaphyseal dysplasia. It is characterized by short stature, genu varum and coxa vara and waddling gait.

X-rays show cupping and splaying of widened metaphyses.

Diaphyseal Dysplasia (Camurati-Engelmann Disease)

This rare disease is characterized by bilateral symmetrical increased density (sclerosis) of shaft of long bones. Child usually presents with muscle weakness and bilateral leg pain. Skull bone thickening may cause cranial nerve palsy.

Nail-Patella Syndrome (Onychoosteodysplasia)

It is a rare autosomal-dominant disorder, characterized by dystrophy of nails (greatest in thumb nail and least in little finger nail which is rarely affected) and hypoplastic or absent patella. Genu valgum and hypoplastic lateral femoral condyle usually lead to recurrent dislocation of patella. Lateral half of elbow joint is hypoplastic which causes cubitus valgus deformity.

Open angle glaucoma, nephropathy, club foot, DDH, scoliosis and Plummer-Vinson syndrome are other associated features.

X-ray features (Figs. 9.10A and B): Hypoplastic or absent patella, bilateral posterior iliac horns (Fong's prongs) and prominent anterior iliac spine are characteristic features.

NEUROFIBROMATOSIS (NF)

Neurofibromatosis is a hereditary genetic disorder characterized by multisystem manifestations due to hamartomatous growths affecting the central and peripheral nervous system, skeletal system and the skin and subcutaneous tissues.

It can be classified into following varieties:

- Single neurofibroma
- Generalized neurofibromatosis (Von Recklinghausen's disease)
- Plexiform neurofibromatosis (affects the fifth cranial nerve). A further variety of plexiform neurofibromatosis is the Pachydermatocoele where a large mass is formed that hangs from the face onto the neck.
- Elephantiasis neurofibromatosa (involves leg causing thickening of the subcutaneous tissue of the limb)

VON RECKLINGHAUSEN'S DISEASE

This is a generalized neurofibromatosis that is further subdivided into peripheral (Type I) and peripheral (Type II) types.

Type I (Peripheral, NF-1)

It is an autosomal dominant condition with 100% penetrance characterized by mutations in tumor suppressor gene 'Neurofibromin' present on chromosome 17 whose function is to inhibit p21 ras oncoprotein. Most commonly these patients present with multiple café-au-lait spots (with smooth edges- coast of California) or at other times with axillary or inguinal freckling (Crowe's sign). In later

Table 9.2: Diagnostic criteria for NF-1 and 2 (Two or more than two criteria of NF-1 should be met for diagnosis of NF-1 and any one of NF-2 criteria should be present to make diagnosis of NF-2)

NF-1 (Peripheral)	NF-2 (Central)
<ul style="list-style-type: none">• ≥ six caif-au-lait spots each over 5 mm in diameter before puberty or over 15 mm in diameter in older individuals.• ≥ 2 neurofibromas or a single plexifor neurofibroma• Freckles in inguinal/axillary region• Optic glioma• ≥ 2 lisch nodules (hamrtomas of iris)• Sphenoid bone dysplasia• Osteoporosis• First degree relative with NF	<ul style="list-style-type: none">• Bilateral eight nerve masses (acoustic neuromas)• A first degree relative with NF type II and either a unilateral 8th nerve mass or any 2 of the following: meningioma, glioma, neurofibroma, schwannoma and posterior subcapsular lenticular opacity.

stages skeletal abnormalities may be seen which include scoliosis (most common), congenital pseudoarthrosis of tibia, hypertrophy of a limb, verrucous hyperplasia i.e. thickened overgrown skin etc. The patients tend to have cognitive deficits and it is not uncommon to get a history of seizures. Hydrocephalous may be seen at birth, hormonal dysfunctions may be evident as they grow and they may also develop optic gliomas.

Type II (Central, NF-2)

The central variety is the less common subtype being an autosomal dominant condition involving mutations in gene Merlin present on chromosome 22. The musculo-skeletal abnormalities encountered in NF-1 are generally not present in type II. These patients classically develop bilateral acoustic neuromas and have visual symptoms due to posterior sub-capsular lenticular opacities. Facial nerve involvement may also be seen and not uncommon are brain and spinal cord tumors (meningioma is seen in almost every second patient.

The diagnostic criteria for the two varieties is given in Table 9.2.

HIGH-YIELD POINTS

- Giraffe spots/Café-au-lait spots (meaning coffee with milk): These are light brown coloured macules present anywhere on body mostly on face and scalp. They are seen in NF-1, Von Hippel Lindau syndrome, Tuberous sclerosis, McCune Albright syndrome, Ataxia telangiectasia, Bloom’s syndrome, Chediak-Higashi syndrome, Peutz Jegher syndrome.
- Pseudoarthrosis (false joint formation) can be congenital or acquired. The most common cause of acquired pseudoarthrosis is a non-union of a fracture. However, the most common cause of congenital pseudoarthrosis is idiopathic followed by neurofibromatosis. The latter is mainly an association and not exactly a cause. Other causes include Osteogenesis imperfecta, Ankylosing spondylitis (see Chapter 11), Cleidocranial dysplasia, fibrous dysplasia, post surgery (e.g. After Triple arthrodesis).

STORAGE DISORDERS AND ORTHOPEDICS

Storage disorders are a group of rare metabolically inherited diseases characterized by accumulation of abnormal substances in body tissues owing to enzyme defects eventually leading to multiple organ dysfunction. Important ones from orthopedic perspective are the lysosomal storage disorders that are discussed below.

GAUCHER’S DISEASE

This belongs to a category called Sphingolipidoses or lipid storage disorders (others in this list are Niemann Pick, Fabry etc.) where sphingolipids accumulation occurs in lysosomes. It is an autosomal recessive disorder. There is deficiency of a lysosomal enzyme glucocerebrosidase causing accumulation of glucocerebroside in

reticuloendothelial system, mainly in liver, spleen and bone marrow.

Orthopedic manifestations include abnormal bone remodelling leading to classical Erlenmeyer flask deformity of distal femur (see Fig. 9.4) and proximal tibia, delayed healing and pathological fractures. Patients of Gaucher’s disease are at increased risk of osteomyelitis and avascular necrosis.

MUCOPOLYSACCHARIDOSIS (MPSs)

The mucopolysaccharidoses (MPSs) are a heterogeneous group of inherited disorders characterized by progressive lysosomal storage of glycosaminoglycans. Orthopedic manifestations have common features across all forms of MPS (Table 9.3).

Table 9.3: Mucopolysaccharidosis

Features	Hurler's syndrome (MPS-I)	Hunter's syndrome (MPS-II)	Sanfilippo syndrome (III)	Morquio's syndrome (IV)	Scheie's syndrome (I-S)	Maroteauxlamy syndrome (VI)
Defective enzyme	α 1 iduronidase deficient	Sulfoiduronate sulfatase low	N heparan sulfatase or α acetyl glucosaminidase low	N- Ac- Gal-6 sulfate sulfatase	α -L iduronidase	N - Ac Gal 4 sulfatase
Increased in urine	Dermatan Sulfate > Heparan Sulfate	Heparan Sulfate> Dermatan Sulfate	Heparan Sulfate	Keratin sulphate	Dermatan Sulfate > Heparan Sulfate	Dermatan Sulfate
Inheritance	AR (Autosomal recessive)	Sex linked recessive, all male patients	AR	AR	AR	AR
Age of presentation	First few months of age	6-12 months	Early childhood	2-4 years	Late childhood	Early to late childhood
Orthopedic manifestations	Dorsolumbar kyphosis, Anterior inferior beaking of body of vertebral bodies (L1, L2), moderately short stature, odontoid hypoplasia, acetabular dysplasia and joint contractures in hand (PIP contractures)	Manifestations are similar to MPS I, but are milder. There is absence of thoracolumbar kyphosis. Carpal tunnel syndrome may be seen in these patients.	Only noticed because of short stature. There is no kyphosis. There may be minimal widening of clavicles at medial ends.	Markedly short stature (severe skeletal dysplasia), thoracolumbar kyphosis, flat vertebral bodies (platyspondyly), marked manubriosternal angle, Wine glass pelvis odontoid hypoplasia, atlantoaxial instability, acetabular dysplasia, coxa valga, genu valgum, pes planus, pectus carinatum are seen. Joint contracture and stiffness are absent (instead joint hypermobility is seen).	Just a less severe version of hurler syndrome. There are small epiphysis in hands of these children.	Same as Hurler's syndrome
Mental retardation	Severe	Late in onset and less severe	Severe	Absent	Absent	Absent

HIGH-YIELD POINTS

- Dysostosis multiplex is the name given to broad constellation of skeletal abnormalities (X-ray features) commonly seen in all mucopolysaccharidosis. These include abnormal bone thickening and irregular epiphyseal ossification, dysplastic femoral heads, acetabular dysplasia, iliac hypoplasia with iliac wings, coxa

valga and genu valgum deformities, flattened vertebral bodies (platyspondyly) with anterior beaking, odontoid hypoplasia, kyphosis, scoliosis, short thickened clavicles, bullet-shaped phalanges, a large skull with a thickened calvarium and J-shaped sella turcica.

- Carpal tunnel syndrome is the most common entrapment neuropathy in mucopolysaccharidoses.

HOMOCYSTEINURIA AND ORTHOPEDICS

It is an autosomal recessive disorder of amino acid metabolism characterized by deficiency of enzyme cystathionine synthase.

Orthopedic manifestations include dolichostenomelia (excessively long and thin limbs), flexion contractures

of digits and elbow, arachnodactyly, planovalgus feet, broadening of metaphyses and epiphyses of long bones, high arched palate, pectus carinatum, pectus excavatum and generalized osteopenia.

CHAPTER 10

Metabolic Bone Diseases



OSTEOPOROSIS

Normal bone is composed of approximately two-third parts mineral (calcium hydroxyapatite) and one-third part organic matrix/osteoid (mainly collagen Type I). Osteoporosis refers to a condition when there is decrease in both the bone matrix as well as the bone mineral content. It is different from osteomalacia where the prime problem is a deficient mineralization while the bone matrix is adequate. By and far it is the most common metabolic bone disease.

EPIDEMIOLOGY

A number of risk factors exist for the disease. Table 10.1 gives the list of some important risk factors implicated in causation of osteoporosis.

CLASSIFICATION

Osteoporosis can be classified as primary and secondary.

Primary osteoporosis is further subclassified into Type I and Type II.

Type I (postmenopausal osteoporosis) is characterized by accelerated bone loss after menopause (due to

decrease in endogenous estrogen production). The loss is largely from trabecular bone (approximately 2–3% of total bone/year) rather than cortical bone. This predisposes the patient to vertebral fractures and distal radius fractures.

In Type II (senile) osteoporosis, the bone loss is more gradual (0.5–1%/year), and involves both cortical and trabecular bone. This increases the risk of hip and vertebral fractures in both men and women over the age of 70 years.

Secondary osteoporosis is caused by external factors as depicted in Table 10.2.

A detailed history of drug intake must be elucidated from every patient with osteoporosis. Corticosteroids are very frequent cause when prednisolone is given in a dose greater than 7.5 mg/day for a long duration. The loss is largely from trabecular bone, more so in the first 6 months of therapy. Heparin can cause a reversible osteoporosis at doses more than 15,000 units/day for more than 4 months.

Table 10.1: Factors affecting osteoporosis

<i>Risk factors</i>	<i>Protective factors</i>
<ul style="list-style-type: none"> • Old age • Thin built • Female sex • Early menopause or late menarche • Prolonged amenorrhea >1 year • Oophorectomy during reproductive years • Treatment with osteoporosis causing drugs • Smoking • Alcohol consumption • High caffeine intake • Inactivity • History of recurrent falls and fractures 	<ul style="list-style-type: none"> • Estrogen replacement therapy • Oral contraceptive use • Thiazide diuretic use

Table 10.2: Causes of secondary osteoporosis

- Drugs:
 - Corticosteroids
 - Heparin
 - Anticonvulsants
 - Furosemide
 - Gonadotropin-releasing hormone agonist
 - Cyclosporine
 - Lithium
 - Excessive thyroxine intake.
- Prolonged immobilization
- Excessive alcohol intake/cigarette smoking
- Systemic diseases:
 - Endocrinal abnormalities:
 - Hyperthyroidism
 - Hyperparathyroidism
 - Cushing's syndrome
 - Hypogonadism
 - Rheumatoid arthritis
 - Osteogenesis imperfecta
 - Multiple myeloma
 - Anorexia nervosa.

It causes a hypocalcemia-induced increase in parathyroid hormone (PTH) activity that leads to the condition. Diuretics need a special mention. While furosemide causes calciuria and leads to osteoporosis, thiazides decrease urinary calcium excretion and are considered to be protective. In fact, they have been recommended as add-on therapy in recalcitrant cases of steroid-induced osteoporosis.

CLINICAL FEATURES

Most patients with the disorder are asymptomatic. Back pain is considered the earliest symptom. Decrease in bone mass causes reduction in strength of bones, thereby leading to pathological fractures. Distal radius is most common site in patients less than 70-year-old while in those more than 70-year-age, it is the dorsolumbar spine that is the common site. However, overall vertebral fractures are more common. Multiple compression fractures develop with resulting loss of height and a progressive kyphosis obvious at the back (called as the dowager's hump). Neurological deficit is however uncommon. Other common osteoporotic fractures include distal radius (Colles fracture) and hip fractures [fracture neck of femur (NOF) and trochanteric fractures].

INVESTIGATIONS

Serum calcium, phosphorus, alkaline (ALK) phosphatase and vitamin D levels are usually normal.

X-rays: At least 30% of the bone mass must be lost for osteoporosis to be apparent on the radiographs. The findings on a spine radiograph that point toward the diagnosis (Fig. 10.1) include loss of vertebral body height, multiple compression fractures, cod fish appearance of vertebral body (biconcave upper and lower vertebral margins).

Osteoporosis can be graded on the basis of hip X-ray by a special index called as Singh's index. The index is based upon the visible number of trabeculae in the femoral neck and grades osteoporosis into six types, Type I being most severe and Type VI being normal.

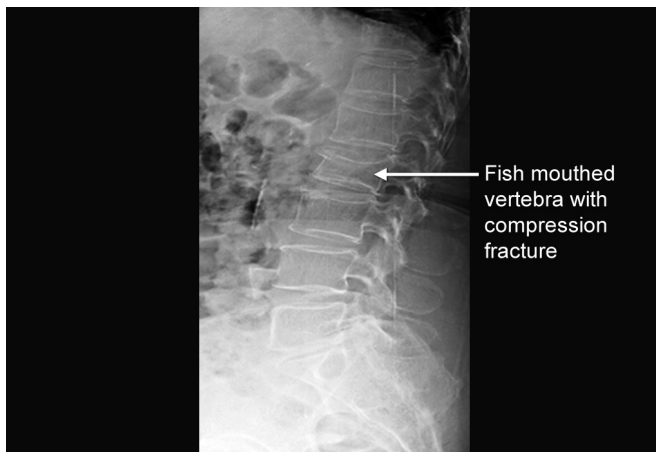


Fig. 10.1: X-ray showing findings of osteoporosis.

Quantitative CT: This is a better indicator but is the most expensive method and exposes patient to maximum radiation.

Single photon absorptiometry (SPA): It is an inexpensive method that measures cortical bone mineral density (BMD) at one site (usually distal radius) by calculating the ratio of photons absorbed and transmitted. Unfortunately, this method is not applicable to entire skeleton.

Dual energy X-ray absorptiometry (DEXA) scan: Based on a similar principle as SPA, this test measures the quantity of mineral salts in the bone. Generally, lumbar spine and hip (NOF) measurements are taken but wrist and ankle can also be evaluated.

The test grades the disease based upon a T-score and a Z-score.

T-score: Measures BMD at its highest level and compares to reference value (30-year-old of same sex, ethnicity).

Z-score: Compares BMD with a subject of same age and sex.

The World Health Organization (WHO) has given the diagnostic criteria for osteoporosis based upon the BMD T-score, measured on a DEXA scan whereby osteoporosis is defined as a T-score of greater than or equal to 2.5 standard deviations (SD) below normal (see Table 10.3 for details).

This test has emerged as the gold standard method for screening of bone mineral mass and diagnosis of the disease in the presenting population. Cost-wise, it is moderately expensive but delivers very low radiation dose to the patient and the scan time is generally less than 5 minutes. The values tend to correlate well with the fracture risk.

The Food and Drug Administration of USA (FDA, US)-approved indications for DEXA include: Primary hyperparathyroidism, estrogen deficient women at risk of osteoporosis, patients on glucocorticoid treatment, history of osteoporotic vertebral fractures, monitoring response to treatment wherein repeat evaluations are suggested at every 2 years thereafter.

PREVENTION AND TREATMENT

Treatment focuses on preventing further bone loss and decreasing the risk of fractures.

Medical Treatment

Options available include:

Table 10.3: Osteoporosis—diagnostic criteria

BMD T-Score	
Normal	< 1 SD below normal
Osteopenia	1–2.5 SD below normal
Osteoporosis	≥ 2.5 SD below normal with no h/o fractures
Severe osteoporosis	≥ 2.5 SD below normal with h/o nonviolent fractures

Calcium Supplements

The daily calcium intake necessary, below which the body has to attain calcium from bone, is 400 mg. A number of calcium preparations are available (Table 10.4) and can be prescribed to match the patient requirements depending upon age and sex (Table 10.5). In the absence of excess of vitamin D, calcium supplementation is rarely associated with renal stones. However, one must remember that dietary fibers and iron therapy impair calcium absorption as do tetracyclins. It is recommended that simultaneous tetracyclins should be administered with at least a gap of 2 hours between the two drugs.

Bisphosphonates

These are the drugs of choice. They exert their action by selectively inhibiting osteoclastic activity and reduce the risk of both vertebral and nonvertebral fractures. Three generations of these drugs are currently available:

- *First generation:* Etidronate—was the first bisphosphonate to be introduced but not for osteoporosis. It primarily has role in Paget’s disease.
- *Second generation:* Alendronate and risedronate: Both of them are FDA-approved for treating osteoporosis in men and women (postmenopausal and steroid-induced osteoporosis). Alendronate is generally given orally in a dose of 70 mg/week. Patient is advised to take 6–8 oz of water and not to lie down for at least half an hour as these can cause esophageal complications.
- *Third generation:* Ibandronate and zoledronic acid: Newer long-acting additions that are given as slow IV infusions on monthly and yearly basis respectively. Ibandronate can also be given 150 mg tablet once a month. Long-term use of these drugs (generally over

Table 10.4: Calcium preparations		
Salt	Elemental calcium %	Solubility
Calcium carbonate	40	Insoluble
Tricalcium phosphate	39	Insoluble
Calcium citrate	21	Soluble
Calcium lactate	18	Soluble
Calcium gluconate	9	Soluble

Table 10.5: Recommended calcium intake	
Age	Elemental calcium (mg/day)
Infants	400–600
1–10 years	800–1,200
Adolescents	1,200–1,500
Adults: Men	1,200–1,500
Women 19–24 years	1,200–1,500
25–50 years	1,000
> 50 years	1,500
Pregnant and lactating	1,500

5 years) has recently caught attention due to special atypical fractures that have been reported in the subtrochanteric area of femur. These are generally transverse insufficiency fractures with thickening of lateral femoral cortex and are associated with slow healing (Fig. 10.2).

Hormone Replacement Therapy

Hormone replacement therapy (HRT) can be particularly indicated in postmenopausal osteoporosis. The daily dose of unconjugated estrogens that has been shown to improve BMD is 0.625 mg (for esterified estrogens, the dose is 0.3 mg) and can be given in combination with progestin (5–10 mg medroxyprogesterone acetate).

Other beneficial effects apart from osteoporosis prevention include relief from vasomotor symptoms of menopause, favorable lipid profile, decreased risk of cardiovascular events and a decreased risk of colorectal cancer.

Most common side effects of HRT include breast tenderness and headaches. The potential risks of prolonged exposure include endometrial cancer, thromboembolic phenomena and risk of getting cholecystitis. There have been concerns over increased risk of breast cancer but not proven. Adding progestin seemingly decreases this risk. Women receiving combination therapy can get withdrawal bleeding. Due to these side effects HRT is not used primarily to prevent osteoporosis.

Selective Estrogen Receptor Modulators (Table 10.6)

These are synthetic compounds that exhibit estrogenic properties in some tissues and antiestrogenic properties in others. Tamoxifen is used in breast cancer and raloxifene has been approved for treatment of osteoporosis. Raloxifene is commonly used in dose of 60 mg daily. Side effects include hot flashes and leg cramps. Risk of thromboembolism increases, especially in the first 4 months of therapy. Raloxifene is usually chosen for osteoporosis



Fig. 10.2: Bisphosphonate induced subtrochanteric insufficiency fracture (arrow).

prevention when there is an independent need for breast cancer prophylaxis. Raloxifene reduces the risk of vertebral fractures only. Newer SERM like lasofoxifene has been shown to reduce the risk of non-vertebral fractures as well.

Anabolic Steroids

These are synthetic derivatives of testosterone. They inhibit osteoclastic bone resorption and increase bone formation through androgen receptors in bone tissues.

Calcitonin

It prevents bone resorption by inhibiting osteoclastic activity and also has an analgesic effect. Calcitonin reduces the risk of vertebral fractures only with no effect on peripheral fractures. Routes of administration can be subcutaneous, intramuscular and intranasal. Dose for nasal route is 200 IU/day. Rhinitis is the most common reported side effect.

Vitamin D

Vitamin D3 at doses of 400–800 IU/day or calcitriol 0.5 microgram/day is recommended as add-on therapy to calcium supplementation for established disease. It primarily increases the absorption of calcium from gut.

Sodium Fluoride

Not approved by FDA yet but used in Europe. It replaces the hydroxyl ion in crystal lattice forming fluoroapatite that forms dense bone. Most of the effect is on trabecular bone as it has higher turnover rate. Therapeutic amounts of calcium have to be administered to ensure beneficial effect. Dose is 30 mg/day (decrease in renal failure patients). GI side effects are the main problem. Twenty percent patients may experience painful lower extremity syndrome due to cortical bone stress fractures.

Strontium

Replaces calcium in hydroxyapatite and is thus anabolic apart from having antiresorptive properties. In a dose of 2 gm/day it reduces risk of both vertebral and nonvertebral fractures.

Table 10.6: Commonly used selective estrogen receptor modulators.

- Tamoxifen
 - *Agonist:* Bone, lipoprotein system, uterus (increased thromboembolic events and endometrial cancer are side effects)
 - *Antagonist:* Breast (used in breast cancer)
- Raloxifene
 - *Agonist:* Bone, lipids
 - *Antagonist:* Breast, endometrium

Recombinant Parathormone/Teriparatide

Parathyroid hormone directly acts on osteoblasts. Although a continuous infusion of PTH stimulates bone resorption, small pulses in form of once daily subcutaneous injections (20 microgram/day) have been shown to improve bone formation and reduce the risk of both vertebral and non-vertebral fractures. Long-term therapy for 1.5 to 2 years is advised for both men and postmenopausal women. Cost is high and its anabolic effects are masked in patients on bisphosphonates, so best is to give as monotherapy. However, it is the drug of choice in patients with bisphosphonate resistant osteoporosis. So, best is to prescribe as a monotherapy. Side effects include gastric intolerance, dermatitis and arthralgias.

Denosumab (Amgen)

Denosumab is a fully human monoclonal antibody that acts against receptor activator of nuclear factor κ -beta (RANK) ligands (RANKL) receptors and inhibits osteoclast function. It has been recently introduced and long-term results are awaited.

Surgical Options

Vertebroplasty and kyphoplasty are minimally invasive percutaneous procedures used for symptomatic compression vertebral fractures without neurological impairment refractory to medical treatment.

Vertebroplasty (Fig. 10.3): It refers to injecting bone cement [polymethyl methacrylate (PMMA)] in vertebral body via transpedicular route to strengthen the collapsing vertebrae, and to avoid further compression.

In kyphoplasty a balloon is inflated inside the vertebral body. After restoration of vertebral height balloon is retracted and cement polymethyl methacrylate (PMMA) is injected under continuous fluoroscopic control. Both vertebroplasty and kyphoplasty provide immediate and significant pain relief. In addition kyphoplasty also reduces the vertebral deformity (kyphosis).

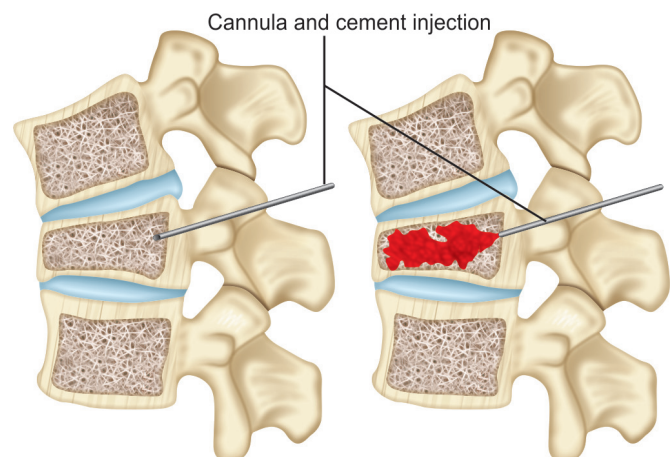


Fig. 10.3: Vertebroplasty diagrammatic representation.

Absolute contraindications to vertebroplasty and kyphoplasty are local or generalized infection, untreated bleeding disorder, healed osteoporotic fractures, allergy to bone cement and spine tumors with cord compression.

HIGH-YIELD POINTS

- Etidronate may prevent bone loss secondary to heparin therapy.
- Bisphosphonates are drug of choice for both senile and postmenopausal osteoporosis. In bisphosphonate resistant osteoporosis teriparatide has been found to be very effective.
- Vertebroplasty is also used in treatment of vertebral hemangiomas.

- *Disuse osteoporosis:* Prolonged immobilization due to any cause reduces muscle mass and bone mineral density. In elderly stroke causing hemiplegia is an important cause of disuse osteoporosis. In hemiplegics maximum drop in bone mineral density occurs in non weight bearing bones of upper limb (maximum in humerus) on the side of hemiplegia.
- Recently many studies have proved role of vitamin K in osteoporosis(gamma-carboxylation of osteocalcin) and vitamin K along with vitamin D is increasingly being given to prevent and treat osteoporosis. Vitamin K deficiency decreases bone mineral density and increases the risk of fractures.

OSTEOMALACIA

Osteomalacia is basically a disorder of inadequate mineralization of bone that occurs in adults due to deficiency of vitamin D in the body. The osteoid production however is unaffected but inadequately mineralized osteoid leads to soft and weak bones and hence the term osteomalacia. It is different from osteoporosis where there is decreased osteoid as well as mineral content, or in other words where the whole bone mass is reduced.

ETIOLOGY

The primary cause is vitamin D deficiency in the body. Since most of the required vitamin D is synthesized in the body by the action of sunlight, the deficiency is common in Muslim women who follow the custom of “purdah”. Other causes may include decreased intake as in malnourished individuals, conditions where absorption is inadequate like malabsorption syndromes, celiac disease or when the requirement may be increased like multiple pregnancies, and lactating mothers. Drugs that interfere with metabolism like anticonvulsants (phenytoin, phenobarbitone, carbamazepine), phosphate-binding antacids, cholestyramine, fluoride and heavy metals may also lead to this clinical condition.

CLINICAL PRESENTATION

Diffuse bone pains, backache and a generalized muscular weakness are common features. Most common symptom is dull aching pain in lower back, pelvis and hips. Pathological fractures can occur, especially in the spine leading to progressive kyphosis.

LAB INVESTIGATIONS

The values of serum and urinary calcium are low and phosphate levels are also on the lower side. There is increase

in alkaline phosphatase and PTH levels. To confirm the diagnosis, one can document reduced levels of vitamin D in the body.

RADIOGRAPHIC FEATURES

The characteristic X-ray findings of osteomalacia are Looser’s zones (named after Emil Looser, Swiss surgeon) also known as cortical infarctions, Milkman’s fractures, increment fractures, umbauzones or pseudofractures (Fig. 10.4) that occur due to incomplete healing of stress fractures by a calcium-deficient callus. They appear as thin transverse lucencies, running at right angles to the involved cortex since the indentations are caused by vascular crossings pressing on a soft bone. The margins may be irregular and sclerotic. Often, they are multiple and symmetrical.

Common sites include: Lumbar vertebrae, pubic and ischial rami, axillary edge of scapula immediately below the glenoid, ribs and clavicle.

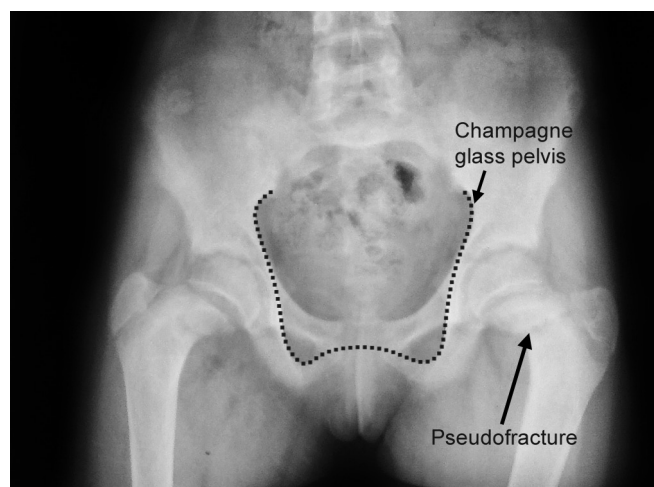


Fig. 10.4: Figure showing Looser’s zone.

Other X-ray findings that point the diagnosis include:

- *Biconcave codfish vertebrae*: Due to indentation on vertebral bodies by the intervertebral disk
- Trefoil or Champagne-glass pelvis
- *Protrusio acetabuli*: Nontraumatic

BIOPSY

Demonstration of excessive uncalcified osteoid on histopathology is the gold standard to confirm the diagnosis, but seldom is needed.

DIFFERENTIAL DIAGNOSIS

Following conditions that can present with multiple site bone pains should be excluded while finalizing the diagnosis:

- Osteoporosis
- Fibromyalgia
- Polymyositis and Polymyalgia rheumatica
- Rheumatoid arthritis
- Multiple myeloma
- Metastatic bone disease.

MANAGEMENT

Vitamin D supplementation along with calcium forms the mainstay of therapy apart from addressing the cause.

HIGH-YIELD POINTS

- Most common cause of osteomalacia (vitamin D deficiency) is lack of adequate exposure to sunlight.
- Most common cause of (nontraumatic) protrusio acetabuli in India is osteomalacia and in world is rheumatoid arthritis. Other important causes include: Paget's disease, osteoarthritis, ankylosing spondylitis, osteogenesis imperfecta, trauma, tubercular arthritis, Marfan's syndrome and psoriatic arthritis.
- Conditions with Looser's zones:
 - Osteomalacia (characteristic)
 - Renal osteodystrophy
 - Fibrous dysplasia
 - Hyperthyroidism
 - Paget's disease of bone
 - X-linked hypophosphatemia
 - Osteogenesis imperfecta

RICKETS

Rickets is a disorder of defective mineralization of growing skeleton (before epiphyseal closure), the pediatric counterpart of osteomalacia. There is deficiency of vitamin D that disturbs the calcium and phosphorus homeostasis and produces the characteristic manifestations.

To understand the disorder, it is necessary to understand the metabolism of calcium and vitamin D in the body.

METABOLISM (FIG. 10.5)

Vitamin D is synthesized primarily in the body from 7-dehydrocholesterol present in the epidermis upon exposure to sunlight while small amounts are added by the dietary sources. The raw compound enters in the liver where hydroxylation occurs, leading to formation of 25-hydroxy vitamin D which enters the renal tubules. In kidney, 1- α hydroxylase (an enzyme stimulated by PTH) acts on it and converts it into active form, i.e. 1-25 dihydroxycholecalciferol (active vitamin D3). This active vitamin D increases absorption of calcium and phosphorus from intestines, increases reabsorption of the compounds from renal tubules and also acts on bone to assist in mineralization.

CAUSES OF DEFICIENCY

The deficiency of vitamin D in rickets results secondary to a number of causes as shown in Figure 10.6.

PATHOPHYSIOLOGY

The prime pathology in rickets is inadequate mineralization or calcification of physis (growth plates) in growing bones due to deficiency of vitamin D. Hence, the zone of provisional calcification is inadequately mineralized and bony trabeculae become weak. Under increasing stresses of body weight, the physis gets deformed, leading to defective growth and bony deformities.

SIGNS AND SYMPTOMS

Nutritional rickets generally manifests in infants and pre-school children. Generalized features are failure to thrive, muscle weakness, listlessness and lethargy. Child may present with tetany (positive trousseau or Chvostek sign) or convulsions because of hypocalcemia. Pathological fractures may result due to weak bones. Once the patient starts walking, bony deformities may develop like bow legs (genu varum, most common), knock knees (genu valgum, occurs in older children), windswept deformity of legs (varum at one knee and valgum at the other).

Some other classical clinical features are:

- Frontal bossing, usually evident after the age of 6 months
- Delayed closure of fontanel
- *Craniotabes (usually first manifestation)*: Refers to soft skull bones that can be pressed like a ping-pong ball
- Delayed dentition

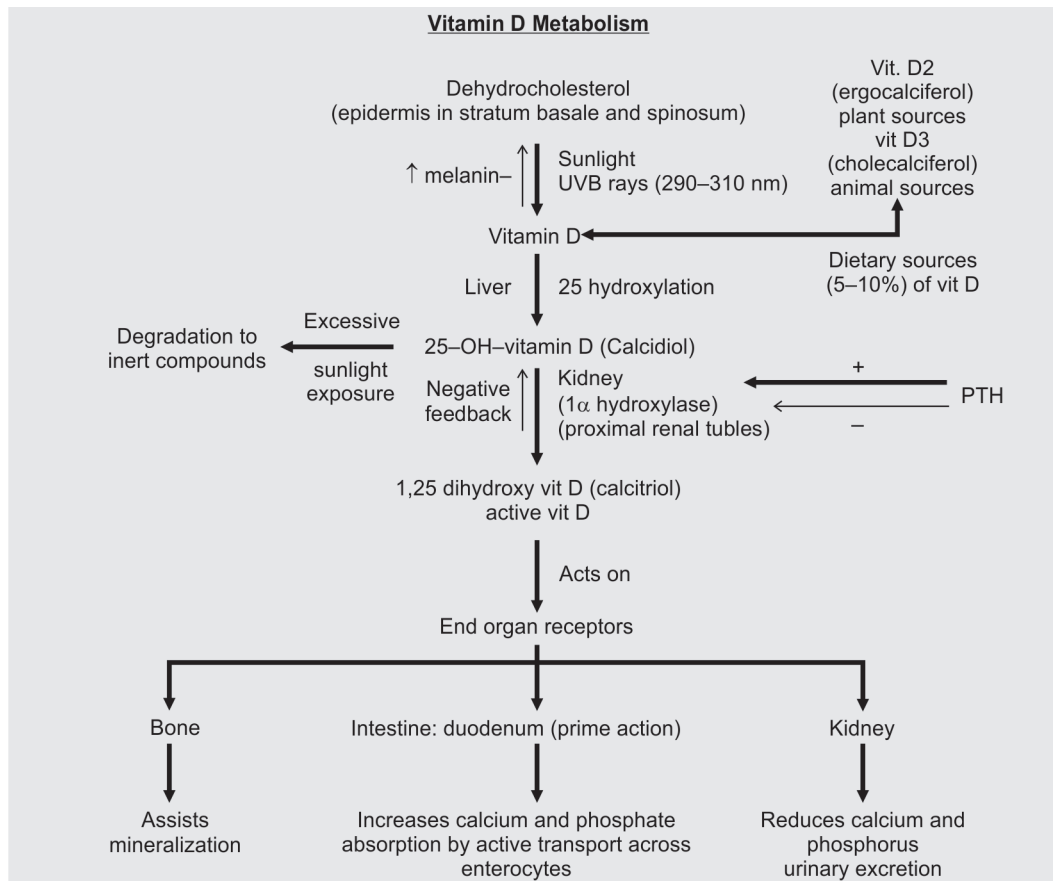


Fig. 10.5: Vitamin D metabolism in body.

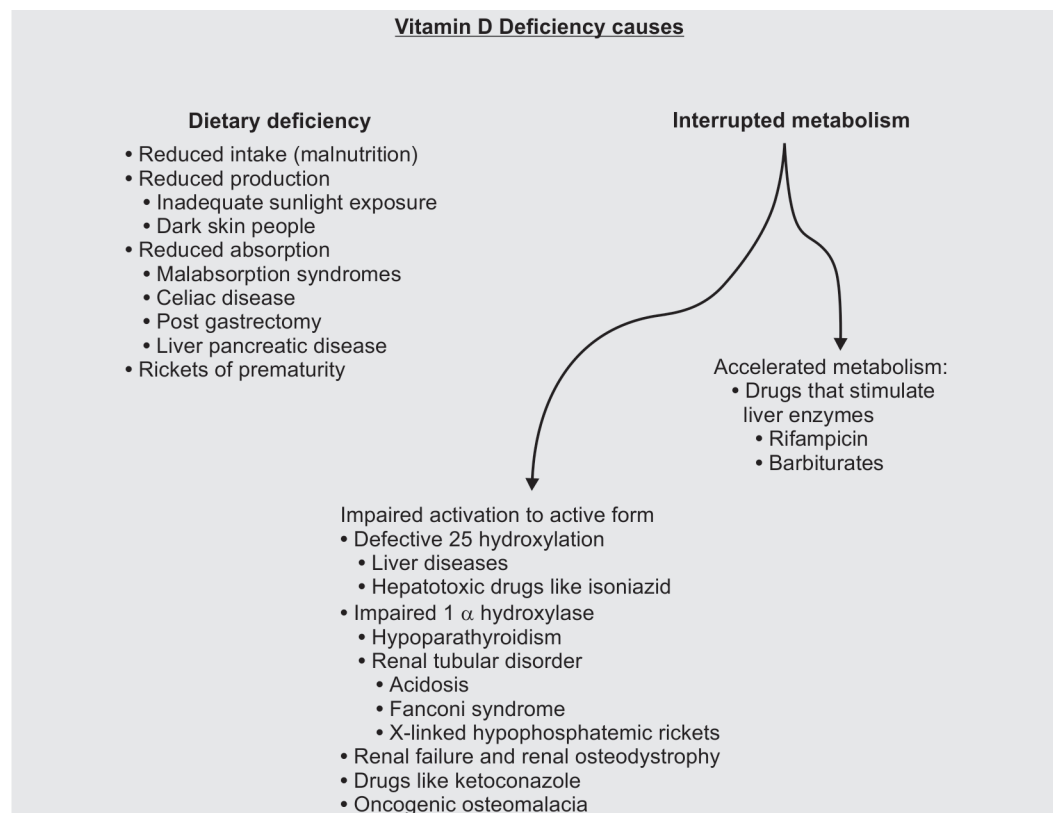
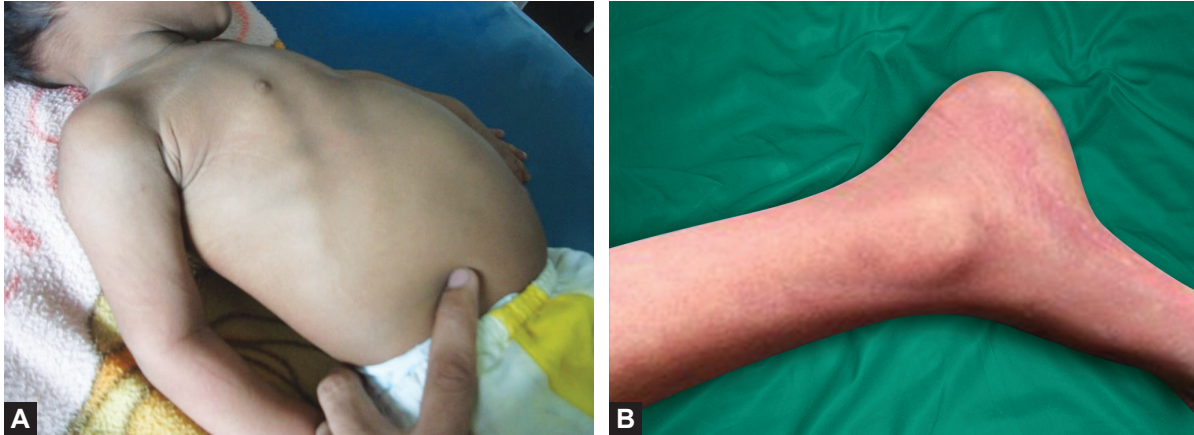
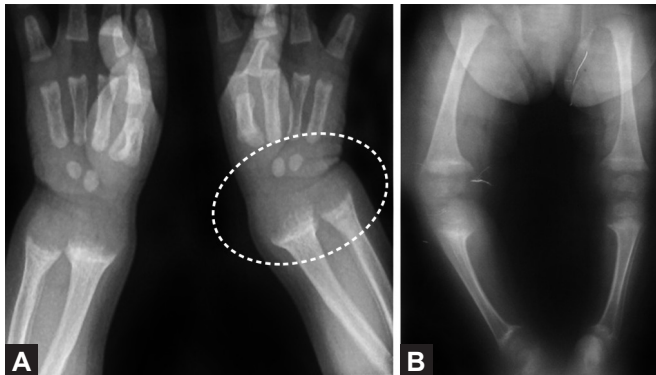


Fig. 10.6: Causes of vitamin D deficiency.



Figs. 10.7A and B: Clinical signs of rickets, (A) Rachitic rosary and (B) Double malleoli sign.
 Courtesy: Kondekar.com peditips.



Figs. 10.8A and B: (A) X-ray of both wrist joint AP views showing widening of wrist joint with cupping and fraying of metaphysis (dotted circle), (B) X-ray of both lower limbs AP view showing cupping and fraying of metaphyses around knee joint.

- *Broadening of ankle, wrist and knee joints:* Due to deformed physis
- *Enlarged costochondral junctions (rickets rosary Fig. 10.7A):* Due to subluxation of the physis
- Indentation over the lower chest at attachment of diaphragm (Harrison's sulcus)
- *Pot belly:* Due to abdominal muscle hypotonia
- *Pigeon chest (pectus carinatum):* Refers to a protruding sternum.
- Double malleoli sign (Fig. 10.7B)—It is seen due to metaphyseal widening.

X-RAY FEATURES (FIGS. 10.8A AND B)

There may be delayed appearance of the epiphysis. The physis is widened (normal thickness is 2–4 mm) due to nonmineralized osteoid that accumulates in the area. There is no zone of calcification due to defective mineralization and the area is filled by irregularly arranged cartilage cells, so the metaphyseal margins touching the growth plate look irregular and frayed. Due to weight-bearing stresses, the metaphysis becomes cup-shaped and splayed

(flat and wide). Generalized osteopenia may be visible and the cortex may thin out. Deformities of bones may be visible in later stages.

LAB INVESTIGATIONS

To order appropriate lab investigations, one needs to know the various types of rickets.

Types of Rickets (Table 10.7)

Nutritional Rickets (Most Common Type in Developing Countries)

It is due to dietary deficiency of vitamin D, so active vitamin D (1-25 OH vitamin D) levels are low. This leads to inability to absorb calcium and phosphorus. PTH is elevated in response to hypocalcemia, corrects the serum calcium, so calcium levels are normal to low while phosphate levels may be low to normal. Alkaline phosphatase (ALP) is elevated.

Vitamin D-Dependent Rickets (VDDR)

In this variety, the dietary intake of vitamin D is normal but there is problem in its metabolism or action.

Vitamin D-dependent rickets Type I: It is an autosomal recessive disorder due to deficiency of 1- α -hydroxylase renal enzyme. It is necessary for formation of the active metabolite of vitamin D which is not formed in adequate amount (1-25 OH vitamin D levels low). This leads to inability to absorb calcium and phosphorus and levels of both minerals are low in serum. PTH is elevated in response to hypocalcemia. ALP is also elevated. To differentiate it from nutritional rickets levels of 25 OH vitamin D and 1-25 OH vitamin are measured. In nutritional variety, both will be low while in vitamin D-dependent rickets (VDDR) Type I, the levels of 25-OH vitamin D will be increased while the active form (1-25 OH vitamin D) will be markedly decreased. The rachitic features appear early with renal tubular dysfunction.

Table 10.7: Biochemical abnormalities in various types of rickets

	Nutritional rickets	Vit D-dependent rickets I Hydroxylation problem	Vit D-dependent rickets II End organ insensitivity	Vit D-resistant rickets Renal tubular rickets	Renal osteodystrophy
S. Calcium	N – ↓	↓	↓	N	N – ↓
S. Phosphorus	↓ – N	↓	↓	↓↓	↑
Alkaline Phosphatase	↑	↑	↑	↑	↑
PTH	↑	↑	↑	N	↑↑↑
25-OH Vit D	↓↓	↑↑	↑↑	N	N
1, 25 OH Vit D	↓	↓↓	↑↑↑	N	↓↓
Urine Ca	↓			↓	↓
Urine Phosphorus	↓	X	X	↑↑	↓

Vitamin D-dependent rickets Type II: It is vitamin D receptor insensitivity disease due to mutation of *VDR* gene. End organs are insensitive to 1-25 OH vitamin D, so calcium and phosphorus can't be absorbed leading to low levels. PTH will be elevated in response to hypocalcaemia. To differentiate it from above two situations, vitamin D metabolite levels are used. Here, both 25-OH vitamin D and 1-25 OH vitamin D would be elevated to increase calcium absorption as there is no problem in the metabolic pathway (Mnemonic: in Type II, the two metabolites are elevated). Alopecia is associated with the rachitic features.

Vitamin D-Resistant Rickets/Renal Tubular Rickets

Also known as familial hypophosphatemic rickets. Here, the basic abnormality is renal tubules inability to retain phosphate. Large amounts of phosphorus are excreted in urine leading to hypophosphatemia; the calcium levels are however normal. Defective mineralization results as both calcium and phosphorus are needed for mineralization. Since calcium levels are normal, PTH is not stimulated and its blood levels remain unchanged so would be the case with vitamin D metabolites as the metabolic pathway is not affected. ALK phosphatase is elevated as in all above forms. The diagnosis is established by documenting a low urinary pH and decreased urinary calcium and increased levels of urinary phosphates.

This situation can occur in renal tubular defects like Fanconi anemia and renal tubular acidosis where there is problem with the kidney to reabsorb phosphorus. In acidosis, body has to excrete fixed base, i.e. bicarbonate and calcium phosphate are excreted along.

X-linked hypophosphatemic rickets is another condition in this category which is a genetic disorder with dominant inheritance characterized by mutations in phosphate regulating gene (*PHEX* gene-having homology to endopeptidases) present on chromosome X. This leads to excessive urinary excretion of phosphate by restricting ability of proximal renal tubular brush border to reabsorb phosphorus and calcium.

Rachitic features in this type appear early, just after infancy. Children lagging behind in growth have severely deformed bones but no myopathy and no hypocalcemia.

Renal Osteodystrophy

Renal osteodystrophy is seen in children who have a chronic renal disease that leads to renal failure. The problem begins with damaged renal glomeruli's inability to excrete phosphorus leading to hyperphosphatemia. Because of kidney failure, less of 1-25 OH vitamin D is produced which eventually leads to hypocalcemia. This stimulates PTH and causes secondary hyperparathyroidism. Increased PTH resorbes calcium from bone in heavy amount, leading to osteitis cystica fibrosa (multiple cysts in bone). Spine radiograph may show alternate bands of sclerosis and lysis referred to as rugger jersey spine. Ectopic calcification can occur due to high phosphate levels. Prolonged stimulation of parathyroid hormone secretion leads to hyperplasia of the parathyroid glands. Parathyroid gland becomes autonomous and insensitive to changes in calcium, phosphate and vitamin D. This causes hypercalcemia and known as tertiary hyperparathyroidism. Diagnosis is never a problem. High serum phosphate level, markedly raised PTH levels and decreased active vitamin D levels with low urinary calcium and phosphorus, in presence of other features of renal failure are enough to establish the diagnosis. Treatment of renal osteodystrophy involves serum phosphate reduction (dietary restriction, use of phosphate binders, calcium salts and dialysis), use of vitamin D analogue and renal replacement therapy. Sodium bicarbonate is used to correct acidosis. Cinacalcet a calcium receptor sensitiser (calcimimetic) that inhibits parathyroid hormone release is usually used in patients on dialysis with advanced disease. Parathyroidectomy may be required for tertiary hyperparathyroidism.

Normal levels: 25 OH vitamin D: 20–60 ng/mL 1,25 OH vitamin D: 15–75 pg/mL.

TREATMENT OF RICKETS

Treatment depends upon the type of rickets.

Nutritional rickets is treated with calcium (75 mg/kg/day) and vitamin D supplementation. Normal vitamin D is recommended dose is 400 IU/day for infants and 600–800 IU/day for children. Patient is also advised to take diet rich in calcium containing foods like fish oil, egg yolk and margarine.

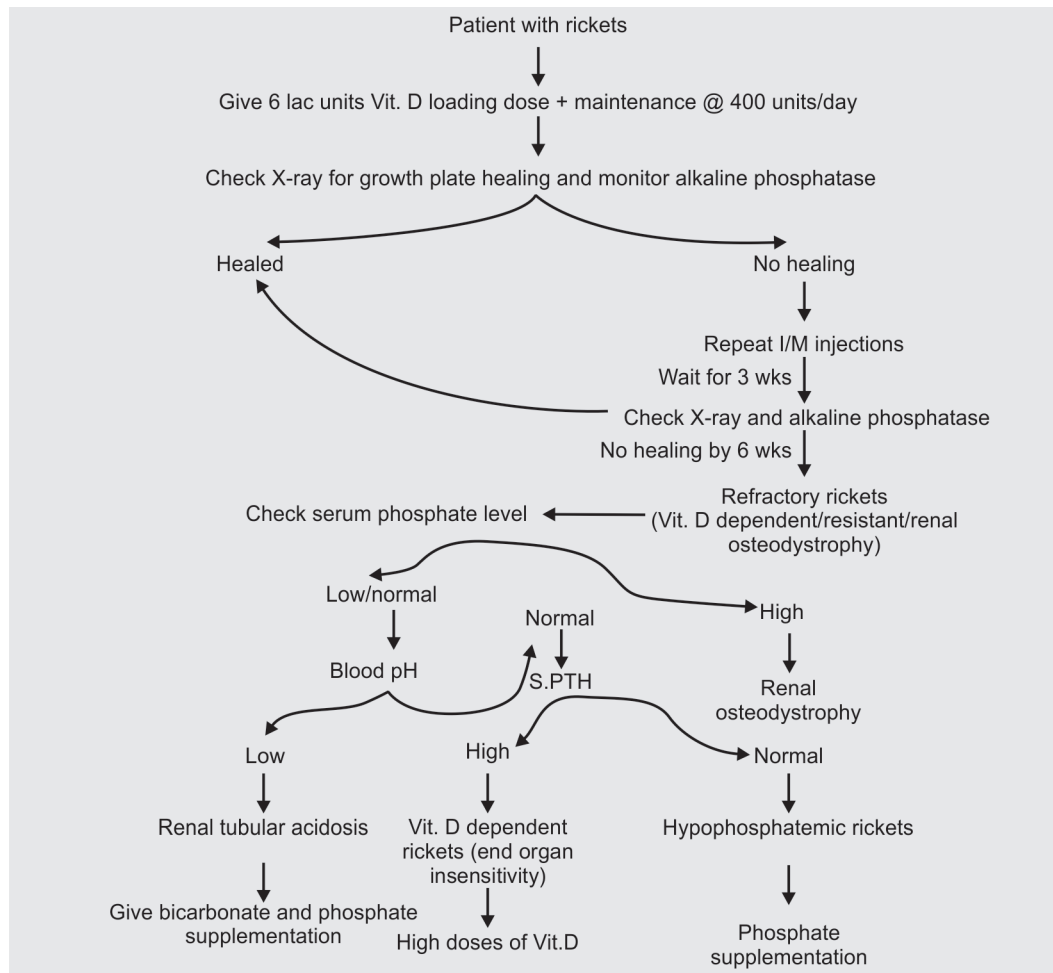


Fig. 10.9: Treatment protocol—rickets.

In VDDR Type I, active form of vitamin (calcitriol) has to be given since 1-hydroxylation is defective.

Vitamin D-dependent rickets Type II has end organ insensitivity and requires very large doses of vitamin D.

Vitamin D-resistant rickets is treated by treating the underlying problem along with phosphate administration to correct hypophosphatemia in association with calcium supplementation.

To monitor the effect of treatment, ALP levels can be used but the best sign to show healing in rickets is healing of the growth plate on X-rays. In later stages of healing as mineralization proceeds in provisional zone of calcification, a white line appears next to the metaphysis called the white line of Frankel.

Treatment Protocol

See Figure 10.9 for deciding treatment protocol.

Treating Rickets with a Deformity (e.g. Genu Valgum/Club Foot)

Again give vitamin D as mentioned above and check ALP levels. As ALP levels will fall, the deformity will automatically

disappear. If ALP levels become normal and deformity still remains, then go for surgery (necessary osteotomy) to correct that deformity. Surgery should be done only after the levels of ALP are brought to normal but best way to check for healing of rickets lesion is growth plate healing on X-ray. Even if growth plate has healed with residual deformity, osteotomy is not done until ALP levels are normal.

HIGH-YIELD POINTS

- In renal osteodystrophy (tertiary hyperparathyroidism) metaphyseal changes resembling rickets are seen in children. Together with cortical erosions this gives a “rotting fence-post” appearance specially at the femoral neck.
- Vitamin D content of human milk is low approximately 30–40 IU/L, so breastfed infants if not exposed to adequate sunlight tend to develop rickets.
- Mother’s supplementation of vitamin D and mother’s sunlight exposure if increased also increases vitamin D content of breast milk.
- Serum ALP is elevated in rickets (all forms), osteomalacia, Paget’s disease, primary hyperparathyroidism and chronic renal failure (CRF) with secondary

hyperparathyroidism, renal osteodystrophy, and lytic bone neoplasms. The levels are normal in osteoporosis, osteopetrosis, fibrous dysplasia, multiple myeloma and hypoparathyroidism. Decreased levels may be seen in Achondroplasia, hypophosphatasias, Cretinism.

ONCOGENIC OSTEOMALACIA/RICKETS

Oncogenic osteomalacia is an unusual paraneoplastic syndrome characterized by mesenchymal tumors that secrete

the fibroblast growth factor that apparently produces osteomalacia/hypophosphatemic rickets with biochemical abnormalities consisting of hypophosphatemia, normocalcemia, and increased levels of ALP. These tumors include fibrous dysplasia, hemangiopericytoma (most common), osteosarcoma, chondroblastoma, chondromyxoid fibroma, malignant fibrous histiocytoma, giant cell tumor, metaphyseal fibrous defect and hemangioma. Most tumors producing this condition are benign and slow growing in nature.

SCURVY AND ORTHOPEDICS

Normal recommended intake of vitamin C for an infant is 30–40 mg and for a child is 40–70 mg. An inadequate intake leads to deficiency of vitamin C, causing the disease called scurvy.

PATHOPHYSIOLOGY

Ascorbic acid (vitamin C) is necessary for the synthesis of collagen (collagen Type I is a major constituent of bone) as it acts as a cofactor in hydroxylation of the lysine and proline. These two amino acids are important for cross-linking of triple helix of collagen. Defective collagen synthesis leads to impaired wound healing, fragile capillaries causing abnormal bleeding and defective bone formation.

CLINICAL PRESENTATION

The deficiency develops after 6–12 months of deprivation, so neonates generally get spared. Affected children usually are lethargic, anemic, having malaise and may come with bleeding spongy gums or with history of bleeding from alimentary tract. Wound healing is impaired in these children.

Orthopedic manifestations are characterized by exquisite bone pains due to subperiosteal hemorrhages mostly occurring beneath the periosteum of the metaphyseal growing ends of long bones of lower extremity. The child may minimally move the limb owing to extreme pain and the condition simulates a pseudoparalysis. Pathological

fractures may be reported but more commonly there occur epiphyseal separations.

X-RAY SIGNS OF SCURVY (FIG. 10.10)

- Pencil thin cortex
- *Subperiosteal hemorrhages*: Lower end of femur and tibia are most commonly involved. It is visualized in healing phase of scurvy.
- *White line of Frankel*: Dense zone of provisional calcification in metaphysis.
- *Wimberger ring*: Circular, opaque, dense band around the epiphysis of a long bone.
- *Pelkan spur*: Metaphyseal spurs leading to cupping of metaphysis.
- *Trummerfeld zone*: Lucent metaphyseal band underlying the Frankel's line.

HIGH-YIELD POINTS

- *Barton's disease*: It includes features of both rickets and scurvy.
- *Causes of white line of Frankel*:
 - Scurvy
 - Healing rickets
 - Lead poisoning
 - Growth arrest lines due to chronic diseases like bronchial asthma, cystic fibrosis
 - Methotrexate therapy
 - Healing in renal osteodystrophy

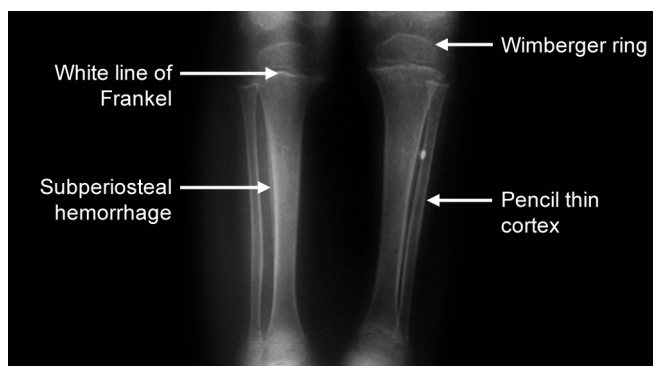


Fig. 10.10: X-ray showing characteristic signs of scurvy.

HYPERPARATHYROIDISM

Hyperparathyroidism is a condition of excessive secretion of PTH, either by the parathyroid glands or by an ectopic focus (generally a malignant tumor like breast, lung or pancreatic carcinoma) leading to multisystem manifestations. Bone disease occurs in approximately half of the patients with the disorder.

PARATHORMONE ACTION AND EFFECTS

The main effect of PTH is to increase the serum calcium concentration by increasing intestinal absorption of calcium, decreasing its renal tubular excretion and mobilizing calcium from bone to make it enter the circulation. While it elevates calcium concentration in blood, it decreases serum phosphate levels and increases phosphate excretion.

The mechanism by which the hormone mobilizes calcium from bone needs special mention. Osteoclasts, the bone resorbing cells, have RANK receptors on their surface while osteoblasts have the complimentary RANKL on their surface. PTH attaches to osteoblasts via its own receptors and makes the RANKL dissociate, that goes and attaches to its corresponding receptor RANK on osteoclasts, thereby activating them and causing bone resorption. So for bone resorption, PTH acts via the osteoblasts that further stimulate the bone resorbing cells, i.e. the osteoclasts.

TYPES

Hyperparathyroidism can be classified into three types:

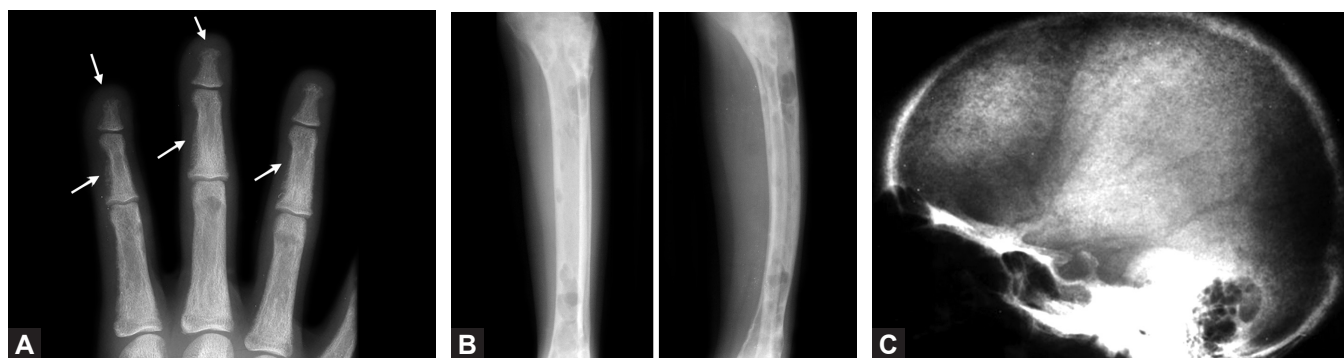
1. *Primary hyperparathyroidism* is due to adenoma (most common cause) or hyperplasia of parathyroid gland that leads to increased parathormone production. Most commonly it is seen in females (female: male 3:1) in middle age group (40–65 years). For long, patients may remain asymptomatic and hypercalcemia may be the only finding in blood tests. Due to hypercalcemia, patient presents with anorexia, nausea, depression, abdominal pain, muscle weakness and fatigue (not tetany). Increased glomerular filtration and tubular absorption of calcium causes kidney stone (nephrocalcinosis), polyurea, recurrent urinary infection and impaired renal function. Osteitis fibrosa cystica (replacement of bone marrow with fibrous tissue) and hemorrhages in this fibrous tissue producing brownish, fluid-filled cystic, tumor-like masses in bones, called Brown's tumors, are characteristic.
2. In *secondary hyperparathyroidism*, the elevated PTH levels result secondary to some disease that produces a persistent state of hypocalcemia in the body like vitamin D deficiency. Since the raised PTH levels are in reflex to the hypocalcemia, serum calcium is usually low (tetany can occur) and phosphate usually high, but the levels can be variable depending upon the cause.
3. In *tertiary hyperparathyroidism*, the parathyroid gland becomes autonomous, free from any inhibitory feedback control and produces excessive amount of the hormone into the circulation. In CRF, hyperphosphatemia and decreased renal production of 1,25-dihydroxycholecalciferol initially produce a decrease in ionized calcium. The parathyroid glands are stimulated (secondary hyperparathyroidism) and may enlarge, becoming autonomous (tertiary hyperparathyroidism). The bone disease seen in this setting is known as renal osteodystrophy (*see above*).

ORTHOPEDIC MANIFESTATIONS OF HYPERPARATHYROIDISM

- Generalized osteopenia secondary to diffuse bone resorption
- *Generalized bone pains*: The bones may even be tender to palpation.
- *Pathological fractures*: Generally involve the dorsolumbar spine, neck and shaft of femur and pubic rami.
- *Brown tumors*: In regions where bone loss is particularly rapid, hemorrhage, reparative granulation tissue, and vascular, fibrous tissue replaces the normal marrow, resulting in a brown tumor. Since hemosiderin is present in the area, it gives the characteristic brown color on histology. The lesion has a collection of osteoclasts and giant cells.

X-RAY FEATURES (FIGS. 10.11A TO C)

- Generalized osteopenia leading to diffuse rarefaction of bones
- *Brown tumors*: Appear as expansile cystic lytic lesions seen mostly in mandible, maxilla, ribs, clavicle and pelvis. Multiple brown tumors may be present in advanced stage leading to multiple cysts scattered throughout the skeleton, a condition referred to as osteitis fibrosa cystica/Von Recklinghausen disease of bone.
- Subperiosteal resorption of the phalanges is diagnostic (commonly seen on radial sides of middle phalanges). There may be resorption of the lateral ends of the clavicle.
- *Loss of lamina dura in teeth*: Lamina dura is a thin cortical shell of bone that surrounds the tooth socket. This may be resorbed in hyperparathyroidism.
- Diffuse stippling may be seen in the skull called the salt and pepper appearance. This is due to intermingling of areas of decreased radio-opacity and sclerotic radio dense areas.
- *Rugger jersey spine*: It refers to appearance of horizontal striped vertebrae seen as a result of alternate bands of bone loss and osteosclerosis in patients with renal osteodystrophy. The changes are also commonly seen at the base of skull apart from vertebrae.



Figs. 10.11A to C: X-ray features of hyperparathyroidism (A) X-ray of hand AP view showing subperiosteal resorption *Courtesy: Learning radiology.com.* (B) X-ray of skull showing salt and pepper appearance and (C) X-ray of leg AP and lateral views showing multiple Brown's tumor.

OTHER INVESTIGATIONS

Blood tests show increased serum PTH concentration, hypercalcemia, hypophosphatemia and increased serum ALK phosphatase level in primary variety. In secondary variety, the PTH and ALK levels are high but calcium and phosphorus levels are variable.

Renal investigations may be done to detect calculi.

Investigations are tailored to detect the cause of hypersecretion, to look for a parathyroid tumor or to locate any ectopic focus if suspected.

TREATMENT

Management is largely supportive. Adequate hydration is maintained and patient is advised to decrease calcium intake.

Surgical excision of the ectopic focus or a parathyroidectomy may be required in severe case of unresolved long-standing hypercalcemia, recurrent kidney stones and severe osteoporosis.

An important postoperative complication of parathyroidectomy can be the hungry bone syndrome. Hungry bone syndrome refers to the rapid, profound and prolonged hypocalcemia associated with hypophosphatemia and hypomagnesemia that result because of suppressed PTH levels, which follows parathyroidectomy. It is a relatively uncommon but serious adverse effect of parathyroidectomy. The severe hypocalcemia is believed to be due to increased influx of calcium into bone, due to the sudden removal of the effect of high circulating levels of PTH. Various risk factors have been suggested for the development of a hungry bone syndrome, including older age, weight/volume of the resected parathyroid glands, radiological evidence of bone disease and vitamin D deficiency. Treatment is aimed at replenishing the severe calcium deficit by using high doses of calcium supplemented by high doses of active metabolites of vitamin D. Adequate correction of magnesium deficiency is also essential. Preoperative treatment with bisphosphonates has been suggested to reduce postoperative hypocalcemia.



Fig. 10.12: Metacarpal sign (see small 4th and 5th metacarpals).

HIGH-YIELD POINTS

- Metacarpal sign describes a relatively short length of 4th and 5th metacarpals in relation to other metacarpals (Fig. 10.12). It is seen associated with Turner Syndrome, Albright's hereditary osteodystrophy, pseudohypoparathyroidism, pseudopseudohypoparathyroidism, sickle cell disease, hereditary multiple exostosis and homocystinuria.
- Hyperparathyroidism can be part of multiple endocrine neoplasia (MEN) 1, 2A and 2B.
- In hyperparathyroidism due to malignancy, the serum levels of PTH are low. Instead, one can detect high levels of PTH related peptide.
- Rugger jersey spine is seen in renal osteodystrophy and osteopetrosis (marble bone disease).
- Acro-osteolysis refers to bony erosions of terminal tufts of phalanges. Important causes include:
 - Primary acro-osteolysis (Hajdu Cheney syndrome)
 - Psoriatic arthritis
 - Hyperparathyroidism
 - Polyvinyl chloride exposure
 - Ergot poisoning
 - Thermal injury
 - Extreme cold; frost bite
 - Leprosy
 - Juvenile chronic arthritis
 - Raynaud disease
 - Scleroderma

PAGET'S DISEASE (OSTEITIS DEFORMANS)

Paget's disease is a disorder of abnormal bone turnover: There is increased osteoblastic activity followed by increased osteoclastic activity leading to deformed and brittle bones (osteitis deformans) that easily fracture. The common age group is more than 40 years, and males and females are equally affected.

Etiology of the disease is still unknown, although paramyxovirus and respiratory syncytial virus have been implicated.

DISEASE COURSE

The course of the disease is divided into three phases:

1. *First phase (osteolytic phase)*: Characterized by increased bone resorption and hypervascularization seen on radiograph as an advancing blade of grass appearance.
2. *Second phase (phase of bone formation)*: The resorbed bone is replaced by structurally weak bone that is brittle and breaks easily.
3. *Third phase (sclerotic/burnout phase)*: Bone resorption declines progressively resulting in hard, dense, avascular pagetic/mosaic bone.

CLINICAL PRESENTATION

Pelvis followed by tibia is the most commonly affected bone but other bones like femur, clavicle, spine and skull are also affected. Disease can be monostotic (affecting single bone) or polyostotic (multiple bones involved). Patients are usually asymptomatic and diagnosed incidentally with increased serum ALK phosphatase level. Pain is usually dull ache but still the most common presenting symptom. Patient presents with short neck because of flattened base of skull, kyphotic deformity and bowing of tibia and femur or at times with pathological fractures. Rarely, features of cranial nerve compression or spinal stenosis may also

be seen. Deafness results due to VIII nerve compression and otosclerosis. It has been postulated that sensorineural hearing loss in Paget's disease is due to loss of bone mineral density in the cochlear capsule. In patients with Paget's disease an increase in blood flow to extremities involved by Paget's disease can lead to vascular steal phenomenon, wherein blood is diverted from internal organs to skeleton leading to cerebral ischemia and spinal claudication.

DIAGNOSIS

Serum calcium and phosphorus levels are usually normal.

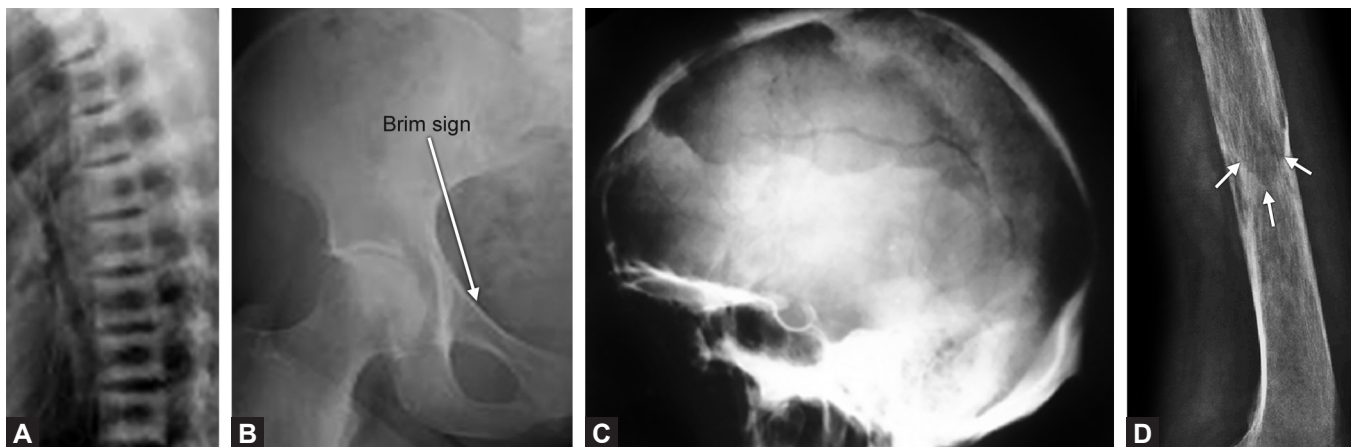
Markers of bone formation and bone resorption (page 9) shows elevated levels. Urinary N-telopeptide (bone resorption marker) is a sensitive marker and can be used to monitor response to treatment.

X-rays: Initially show flame-shaped osteolysis and later on bone becomes deformed and expanded with thickened and sclerotic cortex. Some characteristic X-ray signs of this disease include:

- Ivory vertebrae (diffusely sclerotic vertebrae)
- Picture frame vertebrae (Fig. 10.13A)
- Osteoporosis circumscripta/osteoporotic patch/cotton wool spots (Fig. 10.13C) seen in the skull
- *Brim sign* (Fig. 10.13B): Sclerotic iliopectineal line.
- *Blade of grass appearance*: It is "V" shaped radiolucency seen in diaphysis of long bones (Fig. 10.13D).
- Biopsy of bone characteristically shows the mosaic pattern but is rarely indicated.

Differential Diagnosis

All diseases with white sclerotic bones come under the differentials, viz. osteopetrosis, fluorosis, diffuse idiopathic skeletal hyperostosis (DISH).



Figs. 10.13A to D: Showing X-ray signs of Paget's (A) Picture frame vertebra (B) Brim sign (arrow) and (C) Osteoporosis circumscripta. (D) X-ray femur lateral view showing blade of grass appearance in Paget's disease (arrows).

Courtesy: Dr. Keith H. Wittenberg, (RSNA Radiology)

TREATMENT

Drug of choice in Paget's disease are bisphosphonates which reduce bone turnover and increase lamellar bone formation. Etidronate was first implied for the treatment but risedronate is more preferred. Calcitonin has been recently found to be very effective in relieving the pain in Paget's disease and decreasing bone resorption but effect is only temporary. Calcium and vitamin D should also be supplemented. Pathological fractures usually require surgery and internal fixation.

COMPLICATIONS

- Deafness occurs due to VIII cranial nerve compression and otosclerosis.
- Impaired vision, facial palsy and trigeminal neuralgia all can occur due to cranial nerve compression due to skull enlargement.
- High output cardiac failure can occur due to increased and prolonged blood flow to the bone.
- Osteosarcoma is seen in less than 1% of cases.

FLUOROSIS

Although fluoride is the most abundant element in nature, being highly reactive it is seldom found in abundance in free state. In very small amounts less than 1 parts per million (ppm), the mineral is essential for formation of dental enamel and for mineralization in bones. While inadequate ingestion leads to dental caries, overingestion is also characterized by serious problems.

Fluorosis is a state of chronic fluoride intoxication (>10 ppm in body tissues) seen in some parts of India (Punjab, Andhra, Tamil Nadu) and Africa, where the fluoride content of drinking water is high (2–4 ppm), as opposed to most other places where drinking water fluoride content is <1 ppm.

PATHOPHYSIOLOGY

High fluorine concentration in water is responsible for increase osteoblastic activity and deposition of fluoroapatite crystals in bones. They are not adequately removed by osteoclasts and this leads to osteosclerosis (white bones) evident in spine, ribs, pelvis and long bones (forearm and leg). Bony attachment of tendons, ligaments and fascia are also thickened due to new bone formation (hyperostosis).

CLINICAL FEATURES

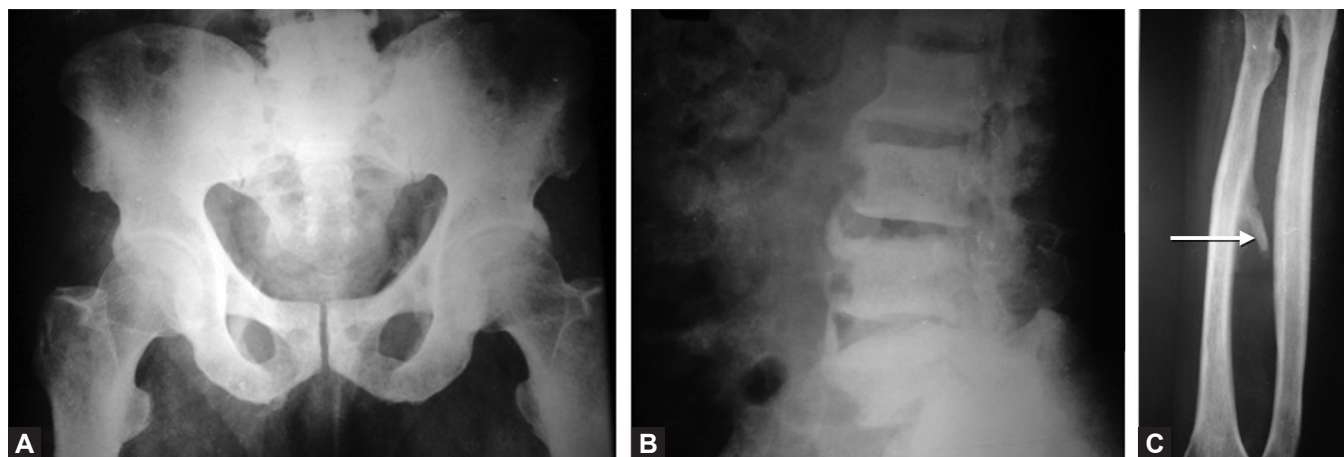
In human body, almost 95% of fluoride is contained in the bones and teeth. Thus, the symptoms of this disorder primarily span over these two systems.

Dental fluorosis: Teeth lose their shiny appearance and become chalk white. Over time, the white patches become yellow resulting in mottling of teeth. It is characteristically seen first up in the incisors of the upper jaw, and occurs only in permanent teeth when they are erupting. It is not seen after they are completely formed.

Skeletal fluorosis: Backache, joint pain and stiffness are common clinical features. Bone becomes weak and pathological fracture may occur and later on bones may deform and bowed. Calcification of the posterior longitudinal ligament occurs in spine and leads to narrowing the spinal canal. In advanced stages, this may lead to compression of the cord leading to spastic paralysis.

X-RAY FEATURES (FIGS. 10.14A TO C)

Thickening and sclerosis of bone (due to increased density), subperiosteal new bone formation and heterotrophic



Figs. 10.14A to C: X-ray features of fluorosis (A) X-ray of pelvis AP view showing calcification and sclerosis, (B) X-ray of lumbar spine lateral view showing calcification of spinal ligaments and (C) X-ray forearm AP view showing calcified interosseous membrane (arrow). Note intensely white bones.

ossification of ligament and tendons (especially posterior longitudinal ligament in spine and the pelvic ligaments) may be visible. Calcification of the interosseous membrane of forearm and leg is characteristic.

DIAGNOSIS

Elevated fluoride levels in blood, urine samples and in drinking water point toward the diagnosis. Otherwise, patient from endemic area with characteristic X-ray changes is enough to tell the tale.

Differential Diagnosis

All condition leading to osteosclerosis (white bones) come under the differential. These include Paget's disease, DISH, osteopetrosis, renal osteodystrophy, secondaries from prostate and Engelmann disease.

TREATMENT

No specific treatment is available and management has to be tailored to symptoms. In fact, prevention is the best treatment. Deflorination of the water is advocated. Patients improve markedly on using deflorinated water. Children less than 6 years should avoid fluoride tooth pastes (advised for prevention of dental caries). Affected patients should be advised to avoid fluoride-rich foods like fish, cheese and tea.

HIGH-YIELD POINTS

- *Nalgonda technique*: This is the deflorination method developed by National Environmental and Engineering Research Institute (NEERI).
- Bone disease in fluorosis is more severe in those with concurrent calcium deficiency.

DIFFUSE IDIOPATHIC SKELETAL HYPEROSTOSIS (DISH)

It is an idiopathic condition characterized by calcification and ossification of soft tissues, mainly ligaments and entheses. It generally affects people in their 5th or 6th decades and has predilection for thoracic spine although any joint of the body may be involved.

The calcification in this disorder tends to involve the anterior ligaments of spine (usually more than 4 contiguous vertebrae) characteristically giving the radiological appearance of melted candle wax dripping down the vertebral bodies (flowing calcification) (Fig. 10.15). The picture sometimes simulates ankylosing spondylitis and the two often need to be differentiated.

In DISH, lumbar spine and sacroiliac (SI) joint involvement is very infrequent. The condition is absolutely non-inflammatory and hence features like morning stiffness and reduced range of motion are not very severe and neither is the erythrocyte sedimentation rate (ESR)-raised. There is no human leukocyte antigen (HLA) B27 positivity, and on X-rays of DISH, osteophytes seen are nonbridging.

Mostly, the disease is discovered as an incidental finding and treatment is largely supportive. It includes nonsteroidal anti-inflammatory drugs (NSAIDs) for reducing pain and inflammation and physiotherapy for reducing stiffness.

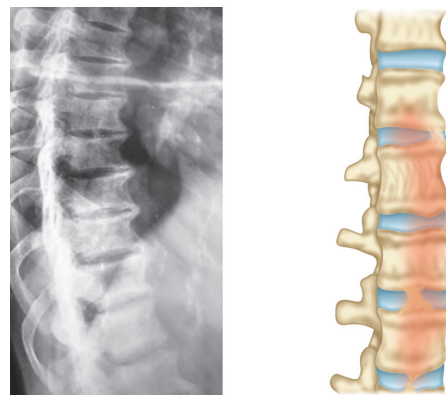


Fig. 10.15: Flowing calcification in DISH.

CHAPTER 11

Arthritis and Related Disorders



RELEVANT ANATOMY

The basic structure common to all synovial joints in the body is depicted in Figure 11.1. There are two articulating surfaces, with ends of each bone being covered by hyaline cartilage referred to as articular cartilage. A fibrous capsule encircles all around the joint. The inner side of the capsule is lined by special membrane called as synovium. The synovial membrane (made of Type I and III collagen) contains specialized cells called as synovial cells that secrete a viscous yellowish fluid called synovial fluid that lubricates the joint cavity. The synovial cells are of two types: Type A (macrophage like cells) are primarily involved in phagocytosis while Type B (fibroblast-like cells) possess a rich network of endoplasmic reticulum and secrete hyaluronic acid, proteins and prostaglandins present in synovial fluid.

SYNOVIAL FLUID

This specialized fluid is basically an ultradialysate of blood plasma to which hyaluronic acid has been added by the synovial cells. An absence of basement membrane in the synovium allows an easy passage of fluid from capillaries into the joint cavity. Normal average amount is 0–4 mL varying from joint to joint. The composition of fluid is relatively similar at all places with a water content of 96% and a pH of 7.3–7.6. Hyaluronic acid is the most important component that gives it its thixotropic properties (its viscosity decreases with increased rate of shear) and thereby allows it to follow non-newtonian kinetics (viscosity is shear rate-dependent). Synovial fluid does not clot on standing as there is no fibrinogen.

An aspiration of the synovial fluid sample and its analysis forms the corner stone in a number of conditions as shown in Table 11.1.

ARTICULAR CARTILAGE

Composition

The average thickness of articular cartilage is 1.5–3 mm. The exact composition is well depicted in Figure 11.2A. Chondrocytes constitute < 10% of the total volume of cartilage; consequently, the functional properties of cartilage, including stiffness, durability and distribution of load rely primarily on the extracellular matrix. However, the synthesis and maintenance of the extracellular matrix depends on the chondrocytes.

Zones

For the purpose of description articular cartilage is typically depicted in 4 zones (Fig. 11.2B).

The superficial zone (zone 1) is the thinnest and forms the gliding surface of the joint. The upper part of this layer

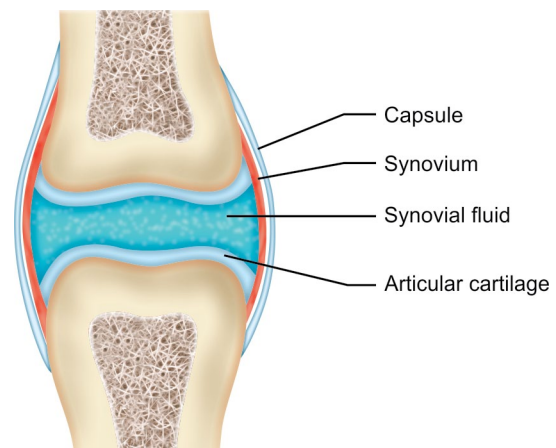


Fig. 11.1: Diagram depicting normal joint anatomy.

Table 11.1: Synovial fluid analysis

Parameters	Normal	Degenerative	Inflammatory		Infectious	
		Osteoarthritis	Gout	Rheumatoid arthritis	Pyogenic arthritis	Tuberculous arthritis
Appearance	Straw or clear Yellow	Clear yellow	Yellow to turbid milky	Yellow, cloudy	purulent	Yellow, turbid
Viscosity	Normal	Normal	Decreased	Decreased	Decreased	Decreased
Total WBC count	≤ 200	≤ 2,000	2,000–50,000	2,000–50,000	> 50,000	10,000–20,000
Polymorphonuclear leukocytes	< 20%	< 20%	60–70%	50–60%	90%	60%
Crystals	Negative	Negative	Urate crystals	Negative	Negative	Negative
Glucose level	A bit lower than plasma level	↓	↓	↓	↓↓	↓↓

in fact has no cells. It only has sheets of fine fibrils that make it look like a clear film and hence the name *Lamina splendens*. The deeper layer consists of flattened ellipsoid chondrocytes that are almost inactive. The collagen fibrils and chondrocytes here are organized with their axis parallel to the articular surface.

The next layer is the *transitional zone (zone 2)*. As the name suggests this layer indicates a transition whereby the collagen and proteoglycan content increases (least in superficial zone) while the water content goes down. The diameter of collagen fibrils of this zone is larger than that in the superficial zone. The chondrocytes are relatively more active and start assuming spheroidal shape. In this layer, collagen fiber orientation and chondrocyte arrangement transitions from parallel to columnar (arranged in columns).

Middle/deep/radial zone (zone 3) is the largest of all zones. It contains chondrocytes that are more spheroidal and are organized in a columnar pattern perpendicular to the joint surface. The cells here are synthetically most active having abundant cell organelles viz. golgi apparatus, mitochondria and hold large amounts of intermediate filaments and glycogen granules. Furthermore, the largest collagen fibrils of articular cartilage and the highest content of proteoglycans are also contained here. As the number of proteoglycans increases, the amount of water decreases from the superficial to the deep zone.

Tidemark: Tidemark is a basophilic line which forms the boundary between calcified and uncalcified cartilage. It's considered to be a part of Zone 4 i.e. calcified zone only although the exact reason for its existence is still unknown.

Calcified zone (zone 4) is the deepest zone of calcified cartilage that divides the softer cartilage from underlying subchondral bone. The cells from the deep zone bore directly into the calcified cartilage. These chondrocytes contain very little cytoplasm and almost no endoplasmic

reticulum (metabolically least active) but connect the articular cartilage to the underlying bone.

Age related changes in the articular cartilage include: Decreased number of chondrocytes, decreased water content, decreased proteoglycan content due to increased enzymatic degradation and accumulation of Pentosidine, an advanced glycation end product (AGE's).

ARTHRITIS

Arthritis (inflammation of the joint) practically refers to a condition where there is destruction of the articular cartilage of the joint (c.f. Arthralgia that refers simply to a painful joint from any cause). The articular cartilage is not visible on X-ray and manifests as clear space between the articulating surfaces on the radiograph. When this joint space is reduced, a radiological diagnosis of arthritis can be made.

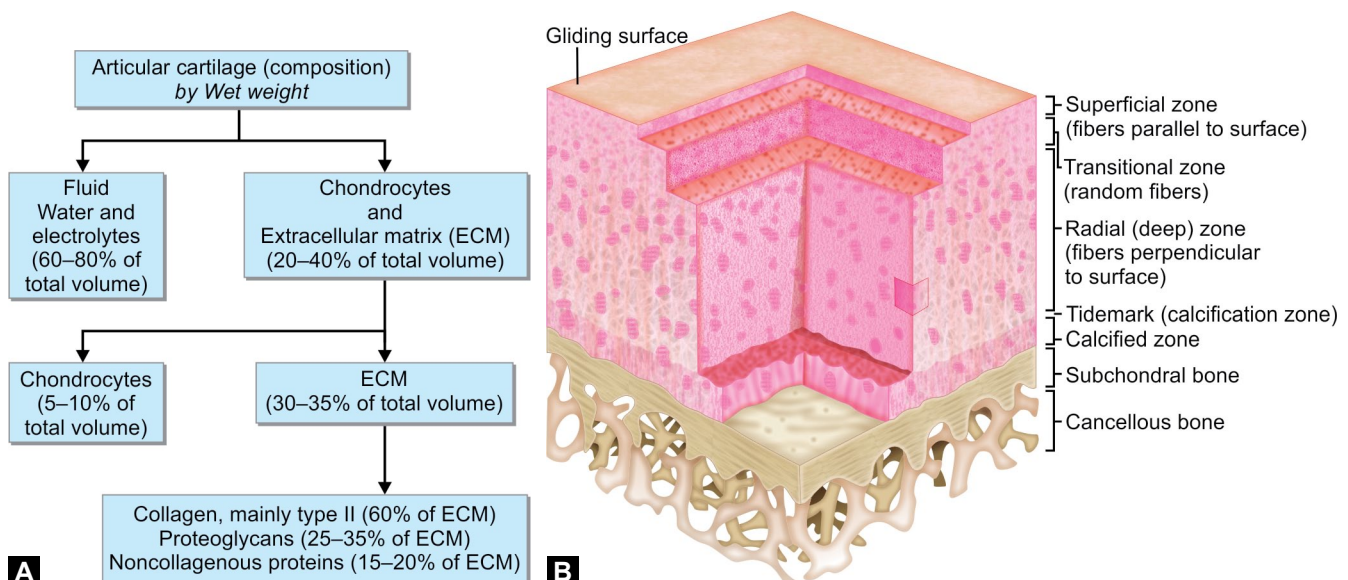
Based upon number of joints involved (Table 11.2) arthritis can be classified as monoarthritis (single joint involved), oligoarthritis (2–4 joints involved) and polyarthritis (5 or > 5 joints involved).

Based upon the etiology arthritis can be divided broadly into infective (septic/tubercular), noninfective inflammatory (i.e. rheumatoid arthritis) and noninflammatory (i.e. degenerative) categories. Infectious arthritis has already been discussed in detail in Chapter 5. In this chapter, we would discuss the degenerative and the inflammatory varieties of joint arthritis.

Table 11.2: Classifying arthritis on number of joints involved

Monoarthritis	Gout, Infective and Trauma
Oligoarthritis	Gout, SSAs, JIA and Reactive arthritis
Polyarthritis	RA, JCA, SLE and PsA

(SSAs: Seronegative spondyloarthropathies; JIA: Juvenile idiopathic arthritis; RA: Rheumatoid arthritis; JCA: Juvenile chronic arthritis; SLE: Systemic lupus erythematosus; PsA: Psoriatic arthritis).



Figs. 11.2A and B: (A) Composition of articular cartilage (B) Zones of articular cartilage.

INFLAMMATORY ARTHRITIS

Inflammatory arthritis comprises of two main categories of arthritis. The first category called Spondyloarthropathies, primarily encloses a group of autoimmune conditions which tend to produce erosive lesions in various joints that clinically manifest with cardinal signs of inflammation (erythema, tenderness, warmth and swelling) often with patient showing systemic manifestations and elevated white blood counts and acute phase reactants. Although called arthritis but in most situation, the autoimmune destruction starts as a synovitis which progresses on to involve the

articular cartilage, thereby culminating in arthritis. This group can further be divided into seropositive arthritis [rheumatoid arthritis (RA)] and seronegative spondyloarthropathies (SSAs). The former is seropositive as the patients with the condition tend to have rheumatoid factor (RF), an auto antibody detectable in their serum while the latter group lack the same and are called seronegative. The other category in the inflammatory group includes the crystal deposition arthropathies, where gout and pseudogout are the prime topics that merit a discussion.

SPONDYLOARTHROPATHIES (RA AND SSAS)

RHEUMATOID ARTHRITIS (RA)

Rheumatoid arthritis (RA) is an autoimmune multisystem disorder of young and middle aged adults characterized by an erosive chronic symmetric arthritis that mostly involves peripheral joints and at times axial skeleton (spondyloarthropathy) and may show extra-articular and systemic manifestations.

Incidence

Overall prevalence in general population is 0.8%.

Mostly affects young and middle aged adults (20–50 years) with male:female ratio 1:3.

Etiopathogenesis

The exact cause is unknown. The current hypothesis says that an initiating antigen (mainly viruses like rubella, Epstein barr and mycoplasma) triggers a self-perpetuating chronic inflammation in genetically predisposed individuals (associated with HLA-DR4) that leads to formation of immune complexes involving IgM antibodies. These immune complexes are deposited in the synovium, where they initiate inflammation and primary synovitis sets in which eventually causes synovial hypertrophy. The hypertrophied synovium surrounds the periphery of the articular cartilage and gives rise to an inflammatory mass called Pannus. Pannus buries into the junction between articular cartilage and subchondral bone and detaches the cartilage to expose raw bone that gradually gets eroded by the enzymatic products released in the inflammatory cascade. Adhesions develop between opposing areas leading first to a fibrous ankylosis that later transforms into bony ankylosis. In advanced disease the joint gets distended by hypertrophic synovium and increased amount of synovial fluid and the supporting ligaments get stretched and may spontaneously rupture causing a subluxation or dislocation.

Diffuse vasculitis, commonly affecting the arterioles is very often associated. Lymph nodes show hyperplasia. Muscles show nodular polymyositis. Subcutaneous nodules (rheumatoid nodules) form over extensor surfaces of limbs and show central area of fibrinoid necrosis surrounded by fibroblasts arranged radially and a surrounding fibrous capsule. Nerves show perineural fibrosis.

Clinical Presentation

This multisystem disorder is characterized by symmetrical polyarthritis that generally starts with the involvement of the small joints of hand (less commonly feet). The disease usually starts in the proximal interphalangeal (PIP) and metacarpophalangeal (MCP) joints with classical sparing of the distal interphalangeal (DIP) joints in a female who is in her thirties. Soon thereafter, the metatarsophalangeal (MTP) joints of the foot may be involved. Involvement of the large joints (knee, elbow, hip, shoulder) is not uncommon but occurs relatively later. Although most of the axial skeleton is generally spared, the cervical spine (especially C1-C2 articulation) may be at times involved, leading to subluxation in this area. The involved joints (*see* Table 11.3 for the list) are painful, swollen and stiff. In fact, morning stiffness especially of at least 1-hour duration is a characteristic feature of the disease.

The 14 specified joints (both sides) that are commonly involved in RA are:

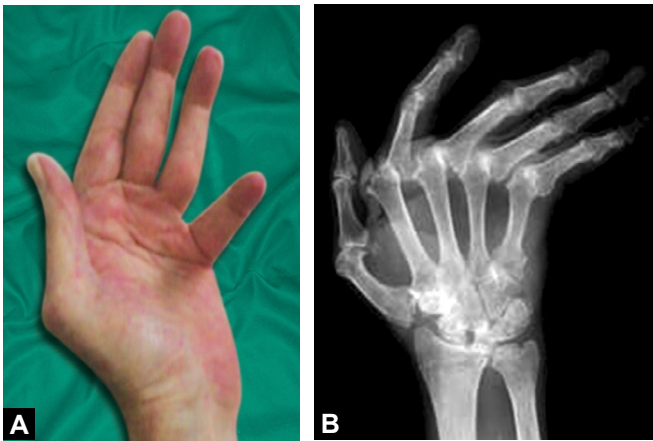
1. Proximal interphalangeal joint
2. Metacarpophalangeal joint
3. Wrist joint
4. Elbow
5. Knee
6. Ankle
7. Metatarsophalangeal joints.

Less commonly involved joints: Hip, temporomandibular, subtalar, atlantoaxial joints.

Joints not involved include: Distal interphalangeal, lumbar spine, sacroiliac (SI) joints.



Figs. 11.3A and B: (A) Boutonniere's deformity of middle finger and X-ray of same patient showing advanced arthritic changes of PIP joint of middle finger. (B) Swan neck deformity of little finger.
 Courtesy: Figure 11.3A: Dr. Charlie Goldberg, UCSD, California.



Figs. 11.4A and B: Z-deformity: Radial deviation of the wrist with ulnar deviation of the digits.



Fig. 11.5: Hallux valgus.

In RA, the inflammatory destruction is just not limited to the bone. The synovial linings of the tendon sheaths may be thickened and inflamed aggravating chances of tendon rupture especially in the hands and feet. Vaughan Jackson lesion refers to serial disruption of the digital extensor tendons. It begins from the ulnar aspect, first involving the extensor digiti minimi and progresses radially to involve ring, middle and index fingers subsequently. Mannerfelt syndrome refers to rupture of the flexor pollicis longus tendon from attrition caused by a bony spur in the carpal tunnel (scaphoid).

The disease course is characterized by remissions and exacerbations. Over years, the disease process may become less active but it generally leaves a number of joints damaged and permanently deformed. Following are the characteristic deformities of various joints seen in RA:

Hand

Boutonniere deformity (Fig. 11.3A): Flexion contracture of PIP joints and extension of DIP joint. It is due to rupture of the central extensor expansion of the fingers.

Swan neck deformity (Fig. 11.3B): Hyperextension of PIP joints with flexion of the DIP joint. It is due to rupture of the volar plate of the PIP joint.

Z-deformity (Figs. 11.4A and B): Radial deviation of the wrist with ulnar deviation of the digits.

Caput ulnae syndrome: It refers to the destructive process initiated by the synovitis of the distal radio ulnar joint (DRUJ) which includes stretching of the tendon sheath of wrist extensors and volar subluxation of the carpal bones.

Trigger finger and trigger thumb may result due to nodules over the tendons.

Foot

Hallux valgus (most common; Fig. 11.5), claw toes, hammer toes, bunion, callosities under PIP joints and over dorsum, flattening of longitudinal arch, Achilles tendinitis.

Knee

Genu valgum is more commonly seen in rheumatoid knees.

Windswept deformity (Fig. 11.6): Genu varum at one knee and valgum at the other.

Besides the articular manifestations discussed above, the disorder also has some characteristic extraarticular manifestations that rarely may be the presenting mode. These extraarticular features may be seen in up to one-third of the patients.



Fig. 11.6: Windswept deformity.

Extraarticular Manifestations

- **Systemic manifestations:** Generalized fatigue, low-grade fever, weight loss
- Diffuse osteoporosis is almost always associated.
- **Rheumatoid nodules:** These are the most pathognomonic extraarticular feature and appear as nontender subcutaneous nodules seen in around 25% of the cases. They present mainly over pressure areas or periarticular extensor surfaces with olecranon being the commonest site. Rarely, nodules may form in pleura and meninges.
- Rheumatoid vasculitis is widespread and can involve any organ. Vasculitis of vessels of vasa vasorum (vessels supplying nerves) leads to mononeuritis multiplex, an asymmetric asynchronous painful motor-sensory peripheral neuropathy involving at least two separate nerves.
- Nerve entrapment syndromes may be there (like carpal tunnel syndrome, cubital tunnel syndrome, tarsal tunnel syndrome, etc.)
- **Eye changes:** Keratoconjunctivitis sicca (most common eye manifestation), episcleritis, scleritis (most severe eye manifestation) and secondary glaucoma.
- **Cardiac manifestations:** Pericarditis (most common cardiac manifestation), cardiomyopathy, arrhythmias, heart block
- **Pulmonary manifestations:** Pleurisy, effusion, fibrosing alveolitis, pneumonitis and Caplan's syndrome.
- Pleural and pericardial effusions (with a very low glucose content)
- Anemia of chronic disorder, leukocytopenia, thrombocytosis, marrow hypoplasia, splenomegaly, generalized lymphadenopathy, pitting edema of foot and Felty's syndrome.

Investigations

Based on the characteristic clinical presentation, the diagnosis is suspected and further strengthened by making use of the following investigations:



Fig. 11.7: Knee X-rays of a patient with rheumatoid arthritis.

Routine blood investigations: Hb may be low; white cell counts are raised along with a raised erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) levels.

Rheumatoid factor (RF): The RF is an IgM autoantibody against Fc region of IgG, seen in almost two-third patients of RA. Its detection can suggest the diagnosis. However, early in the disease the levels are lower, therefore the sensitivity is lower and hence it is not useful for screening purposes. Neither is the presence of RF specific for RA as it can be seen in 5% of healthy population and in diseases like systemic lupus erythematosus (SLE), tuberculosis (TB), Sjogren's syndrome, syphilis, chronic liver disease, sarcoidosis, leprosy, infectious mononucleosis and malaria. However, it has a prognostic significance, as the levels often parallel disease activity with patients displaying high titers having more severe disease and extraarticular manifestations more commonly.

Anticyclic citrullinated polypeptide (anti-CCP): Anti-CCP antibodies are positive in up to 98% of cases. These are more specific than RA factor and may be positive very early in the course of the disease. Positivity indicates bad prognosis.

Antinuclear antibody (ANA) may also be raised in RA.

Radiological examination: The survey should include the X-rays of both hands and the affected joints. The classical features are (Fig. 11.7):

- Soft tissue swelling (earliest radiological feature)
- Juxta-articular osteopenia (an early feature)
- Symmetrical reduction of joint space
- Subchondral erosions and cysts (cf. subchondral sclerosis in degenerative arthritis)
- Deformities of hands and feet joints.

Synovial fluid in rheumatoid is yellowish green, cloudy, turbid due to high amounts of leukocytes (see Table 11.1) and its sugar content is low.

Synovial biopsy (gold standard) taken arthroscopically or by open methods confirms the diagnosis in cases of dilemma.

Diagnostic Criteria of Rheumatoid Arthritis (Table 11.3)

Differential diagnosis: Osteoarthritis, SLE, psoriatic arthritis, Reiter's syndrome, viral arthropathy

Treatment

Aims of Treatment

- Eliminate pain
- Stop inflammatory process
- Preserve joint mobility
- Preventing joint deformities
- Correction of existing deformities.

Medical Treatment

Nonsteroidal anti-inflammatory drugs (NSAIDs) and steroids are used mainly for induction of remission as both

these agents have a rapid onset of action. NSAIDs provide symptomatic relief (but not halt disease progression) from pain, especially in the prediagnosis stage when one is awaiting the results of investigations. Intra-articular steroids may be added in this situation in case the pain relief is partial. Once the diagnosis is established, the disease modifying antirheumatic drugs (DMARDs) are introduced to decrease the progression of the disease. However, DMARDs are very slow acting and take 3–6 months to reach their peak effect, so during this stage, oral steroids may be given to halt the inflammatory process. Steroids not only provide symptomatic relief early in the course but also significantly decrease the radiographic progression of the disease. But since long-term steroid therapy may be hazardous in terms of the likely side effects, the paradigm is to shift toward DMARDs for long-term control and taper the steroids over a 2–3 month period. However, high-dose glucocorticoids are the mainstay in cases where extra-articular manifestations like vasculitis (especially mononeuritis multiplex), scleritis, pericarditis or endocarditis are there.

Disease modifying antirheumatic drugs: Disease modifying antirheumatic drugs are slow-acting drugs for maintenance of remission and preventing acute exacerbations. These include:

- Methotrexate (drug of choice, most commonly used DMARD, hepatotoxicity is high)
- Leflunomide (relatively less hepatotoxic than methotrexate)
- Sulfasalazine
- Hydroxychloroquine
- Gold compounds (oldest known DMARD, given as intramuscular injections, slow onset of action, high toxicity, need close monitoring, not favored for use nowadays)
- Penicillamine
- Dapsone
- Minocycline
- Levamisole.

There are no fixed guidelines regarding treatment. It is usually preferred to start with a high-dose methotrexate (15–30 mg/week) under folic acid cover and give a combination therapy by adding on sulfasalazine and hydroxychloroquine initially. Once the disease has been controlled, the patient is generally maintained on low-dose methotrexate (7.5–10 mg/week) to prevent an exacerbation and keep the inflammatory process under check. In patients where there is fear of hepatotoxicity, instead of methotrexate, leflunomide is preferred which is relatively less hepatotoxic.

Recent additions to the treatment regimen have been the biological agents targeted against tumor necrosis factor (TNF) alpha and interleukin-1, the cytokines postulated to have a role in the pathophysiology of the disease. These include etanercept (TNF Type II receptor fused to

Table 11.3: Diagnostic criteria (2010 ARA)

Revised American Rheumatism Association Criteria for Diagnosis of RA 2010

• Joint involvement*	
– 1 large joint	0
– 2–10 large joint	1
– 1–3 small joints (with or w/o large joint involvement)	2
– 4–10 small joints	3
– > 10 joints (at least 1 small joint)	5
* <i>Large joints:</i> Shoulder, elbow, hips, knee, ankle	
* <i>Small joints:</i> MCP, PIP, 2nd–5th MTP, thumb, IP joints, wrists	
• Serology	
– Negative RF and negative anti-CCP	0
– Low positive RF or low positive anti-CCP	2
– High positive RF or high positive anti-CCP	3
• Acute phase reactants	
– Normal CRP and normal ESR	0
– Abnormal CRP and abnormal ESR	1
• Duration of symptoms	
– < 6 weeks	0
– ≥ 6 weeks	1
*With synovitis not better explained by another disease	

Result

*Score ≥ 6 positive

*Patients with score < 6/10 are not classified as having RA; their status can be reassessed and the criteria may be fulfilled cumulatively over time.

Target population

*Patients who have at least 1 joint with definite clinical synovitis (swelling)

IgG1), infliximab (chimeric mouse/human monoclonal antibody against TNF-alpha) and adalimumab (fully human monoclonal antibody against TNF) and anakinra (recombinant IL-1 receptor antagonist). Although they have shown promising result and a faster onset of action but their high cost and considerable risks of long-term toxicity (demyelinating diseases, reactivation of latent TB) remain the issues to be resolved. Currently, these agents are employed in patients who have failed response to standard therapy which means failure to respond/tolerate a therapeutic combination of two DMARDs one of which should be methotrexate for at least more than 2–6 months.

Orthopedic Treatment

Physiotherapy: To maintain joint mobility and muscle strength; use of splints to prevent and correct deformities; hot fomentation/wax bath for pain relief; lifestyle modification like use of western toilet, high chair, proper posture and avoiding squatting.

Surgical Options

Synovectomy: It has preventive role in joints where destruction is minimal and synovitis is the main cause of pain. It can be done arthroscopically assisted or by open methods. The synovectomy should be virtually complete so as to avoid recurrence of symptoms.

Osteotomy: It is indicated when a joint is partially destroyed. The goal is to shift the body's weight off the damaged articular surface for, e.g. high tibial varus osteotomy in genu valgum arthritic knees.

Arthrodesis: Surgical fusion of damaged joints gives good pain relief at cost of the joint function. So, it is commonly performed in the peripheral joints like wrist, ankle, IP joints of hands and feet where functional loss is less disabling and arthroplasty is less reliable.

Joint replacement surgeries: In advanced stages, arthroplasty remains the only way to alleviate pain and correct deformity.

Prognostic Factors in Rheumatoid Arthritis

Poor prognostic factors include:

- Young females have poorer prognosis than males.
- Family history of RA
- High titers of RA
- Positive serum anti-CCP
- Presence of HLA-DR4
- *Early erosive arthritis:* Presence of erosion on X-ray early in the course of disease carries poor prognosis.
- Persistent synovitis
- Presence of extraarticular manifestations
- Elevated ESR, CRP.

HIGH-YIELD POINTS

- *Ball Catcher's view (hands in ball catching position):* Special X-ray view to detect early erosive changes in RA of hand.
- Rheumatoid arthritis has a strong association with HLA DR-4. Other HLAs associated with RA include HLA DR1, DR9 and DR10. The HLAs that are thought to be protective against RA include HLA DR5, DR2, DR3 and DR7.
- *Caplan syndrome:* Rheumatoid arthritis associated with coal workers pneumoconiosis involving the upper lobes of lung. The multiple pulmonary nodules in these patients show cavitation and specks of calcification.
- *Felty syndrome:* It comprises a triad of RA, splenomegaly and neutropenia. It is seen in patients with severe seropositive disease. Treatment is focused on treating RA. If neutropenia is severe, splenectomy may be needed.
- Rheumatoid arthritis tends to spare the central nervous system (CNS). Neuropathies are generally due to vasculitis.
- Although mononeuritis multiplex is a common extra-articular manifestation of RA, the most common cause of the same in India is Leprosy.
- Rituximab (chimeric monoclonal antibody that binds to CD 20 antigen on B cells) has also recently been employed in treatment of RA.

JUVENILE RHEUMATOID ARTHRITIS/ JUVENILE IDIOPATHIC ARTHRITIS

It is an autoimmune, noninfective, inflammatory arthritis involving one or more joints, usually of more than 3-month duration in children less than 16 years of age. The term has been under considerable debate since very few children with the disorder test positive for the RF. In 1977, the European League against Rheumatism (EULAR) proposed the term juvenile chronic arthritis (JCA) for the same. However, the pathogenesis is quite similar to RA but with less marked cartilage erosion and joint destruction.

Although the disease commonly affects children less than 16 years of age, the peak occurs in two age groups 1–3 years and around 9 years. Girls are almost two times more commonly affected than boys.

Based upon the clinical presentation, juvenile rheumatoid arthritis (JRA) is classified into three varieties:

1. *Pauciarticular JRA:* Affects four or fewer joints (in half of these cases, only one joint is involved) in the first 6 months of illness. It is the most common clinical subtype (60%) and is commoner in girls. Knee joint is most commonly involved joint followed by subtalar and then elbow joint. Small joints of hand and feet are rarely involved. Cervical spine is also mostly spared. The involvement is generally not symmetric but a history of morning stiffness may be given. Children with

early onset are at high risk of developing a chronic iridocyclitis or an anterior uveitis. Approximately 70% of children with pauciarticular JRA demonstrate a positive ANA test.

2. *Polyarticular JRA (10%)*: Affects five or more joints in the first 6-month course of disease. Most of the features of this subtype are same as the above variety. However, in this subtype, the neck (cervical spine) and jaw (temporomandibular joint) as well as the small joints of hand and feet usually are affected.
3. *Systemic JRA/Still's disease (10–20%)*: Characterized by systemic features like fever, lymphadenopathy, hepatosplenomegaly and a salmon pink rash located over the trunk, face, palm and soles. Arthritis is just one manifestation of the generalized disorder. Pericarditis and pleural effusions are present in almost 10% of the children. Most children are less than 3 years' age and the variety has equal incidence in both boys and girls. Long-term prognosis is worst even though cardiac manifestations are transient and presence of pericarditis is not related to severity of disease.

Juvenile ankylosing spondylitis (seen mainly in boys, characterized by involvement of SI joints and hip with HLA B27 positivity) and juvenile psoriatic arthritis have also been recently added to the list.

Diagnosis

There is no single or definitive test. Rather, the diagnosis is made from clinical findings coupled with laboratory findings and analysis of aspirated joint fluid. Antinuclear antibody (ANA) is most commonly found positive immunological marker in JCA. Rarely HLA B27 and RF can also be positive.

EULAR Diagnostic Criteria

- Onset before age 16 years
- Arthritis in one or more joints
- Disease duration of at least 3 months
- A pattern of pauciarticular (fewer than five joints affected), polyarticular (more than four joints affected), and RF-negative arthritis or systemic arthritis with characteristic fever.

Treatment

The arthritis has a waxing and waning course with remissions and relapses. Symptomatic treatment is generally enough to tide over the exacerbations. Fortunately, most children with JRA recover from the arthritis and are left with only mild deformities. Only 5–10% would require a lifelong treatment. Those who are RF positive and have multiple joint involvement tend to land up with an adult rheumatoid like disease and a poorer prognosis. Management principles are almost same as for RA with methotrexate and DMARDs used in resistant cases.

SERONEGATIVE SPONDYLOARTHROPATHIES

It is a group of autoimmune disorders with onset usually below the age of 40 years characterized by inflammatory arthritis of predominantly axial skeleton with or without large peripheral joints, absence of RF in serum (hence seronegative) but having a strong association with HLA B27 with presence of uveitis in the patients.

The group includes (mnemonic: PEARS):

- Ankylosing spondylitis
- Reiter's syndrome
- Psoriatic arthritis
- Enteropathic arthritis (associated with ulcerative colitis/Crohn's disease)
- Synovitis, acne, pustulosis, hyperostosis and osteitis (SAPHO) syndrome.

ANKYLOSING SPONDYLITIS (MARIE STRUMPELL DISEASE/BECHTREW'S DISEASE)

Ankylosing spondylitis (AS) is a chronic progressive inflammatory seronegative spondyloarthropathy, involving mainly the axial skeleton (spine and the sacroiliac joints) with variable involvement of root joints (hip and shoulder).

Incidence

Age of onset is mostly 15–25 years.

Males are affected 2–10 times more commonly than females.

Etiopathogenesis

The primary site of pathology in ankylosing spondylitis is the enthesis (site of attachment of tendons and ligaments to bone). Autoimmune attack leads to enthesitis with edema in the adjacent bone that may result in erosive lesions in the affected joints. The joints involved undergo first fibrous and eventually bony ankylosis. Ossification also occurs in the ligaments that are ending up as enthesitis, especially the ligaments of the spine that gradually get ossified, progressively leading to stiffness.

The disease has been noted to have a striking association with the presence of a genetic marker HLA B27. This marker is present in 1–6% of general population but positive in almost 90% of the patients of ankylosing spondylitis (AS). Antineutrophil cytoplasmic antibodies (ANCA) are also associated with AS.

Clinical Features

The patient is usually a young male, presenting with gradual onset of pain and stiffness of the lower back and

often walks to the clinician with a straight stiff back. The symptoms are more prominent in the morning after getting from bed or after a period of inactivity and the pain is classically relieved by activity.

Sacroiliac (SI) joint is the first joint to be involved followed by the lumbar spine. Eventually, the whole spine may be involved in severe cases (cervical spine is involved late). In late stages, the patient's spine adopts a "question mark" posture due to hyperkyphosis of thoracic spine and straightening of lumbar spine (sniffing dog posture). Some patients may complain of pain over manubrium sterni, pubic symphysis and sternocostal joints. Rarely, the patient may present with involvement of shoulders or hip or peripheral joints first. Arthritis in the root joints (hips and shoulders) occurs in approximately 25% of patients while peripheral joint involvement may be seen in up to one-third of cases. In decreasing frequency peripheral joints involved are hip, shoulder, knee, wrist, MCP, MTP and PIP joints.

Not uncommon is to find a patient with a pathological fracture secondary to a minor trauma. Most acute spinal fractures in the AS population occur in the cervical spine, particularly at C5-C6 and C6-C7 levels. Vertebral fractures are four times more common while risk of cord damage is 11 times greater in patients with AS. The most common injury mechanism in such cases is hyperextension.

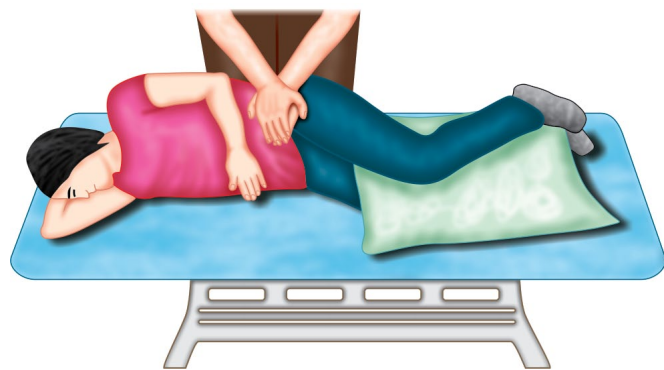


Fig. 11.8: Sacroiliac joint side to side compression test.

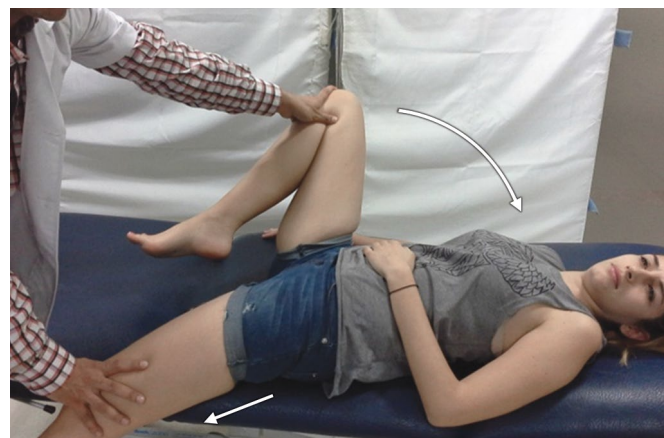


Fig. 11.9: Gaenslen's test.

A patient with AS may also have some extraarticular manifestations. Most common extraarticular manifestation is acute anterior uveitis (iridocyclitis) occurring in almost one-third of cases. However, the list is large and includes: pericarditis, aortic incompetence, pulmonary complications, bilateral apical lobe fibrosis, ulcerative colitis and Crohn's disease, generalized osteoporosis.

Examination

A thorough examination of these patients means evaluating for the involvement of SI joints, lumbar spine, thoracic spine and lastly cervical spine.

Tests for Sacroiliac Joint Involvement

- Tenderness localized to posterior superior iliac spine (PSIS) (as PSIS overlies SI joints)
- *SI side-to-side compression test* (Fig. 11.8): The patient is in the side lying position and the examiner's hands are placed over the upper part of the iliac crest, pressing toward the floor. The movement causes strain in the SI joint. Positive test is indicated by pain in the SI joint.
- *Gaenslen's test* (Fig. 11.9): The patient lies on his or her back, the examiner maximally flexes the hip on the normal side (by pushing the knee towards patient chest) and extends the affected hip (by allowing it to fall over the side of the table). The test is considered positive if the patient complains of pain over the SI joint.
- *Pump handle test* (Fig. 11.10): The patient lies supine, the examiner grasps the affected side knee of the patients with one hand and flexes the knee and hip and forces it toward the opposite shoulder across the chest. Pain over involved SI joints indicates a positive test.
- *Patric test/FABER test* (Fig. 11.11): The test is performed by keeping the limb flexed, abducted and externally rotated (FABER). If pain is elicited on the ipsilateral side anteriorly, it is suggestive of hip joint pathology of same side. If pain is elicited on the contralateral side posteriorly around the SI joint, it is suggestive of pain arising from SI joint.



Fig. 11.10: Pump handle test.



Fig. 11.11: FABER test.

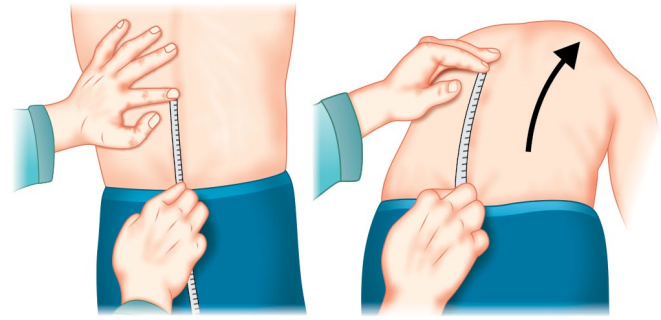


Fig. 11.12: Modified Schober's test.



Fig. 11.13: Fleche test.

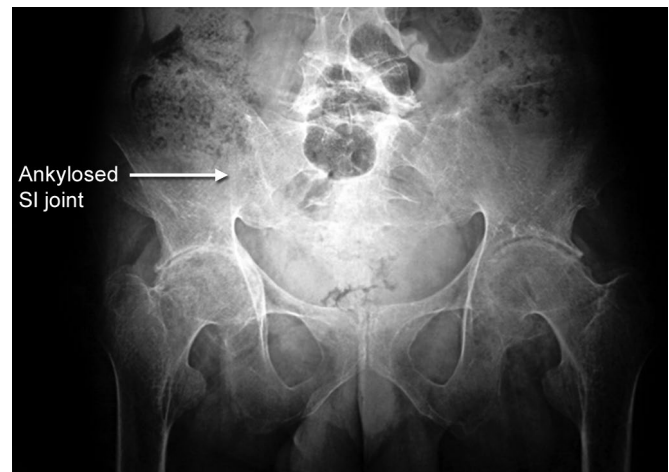


Fig. 11.14: X-ray pelvis anteroposterior view showing sacroiliac joint ankylosis in ankylosing spondylitis.

For Lumbar Spine Involvement

- Look for loss of lumbar lordosis.
- Check for restricted lumbar spine motion (*modified Schober's test*; Fig. 11.12): With the patient in standing posture, two bony points are marked in the lumbar spine 10 cm apart; the patient is asked to touch his toes with knees extended. Normally, the two points should be separated by more than 5 cm; if the lumbar excursion is less than 5 cm, it implies loss of lumbar flexion suggestive of ankylosing spondylitis.

For Thoracic Spine Involvement

Measure chest expansion: An expansion of less than 5 cm during full inspiration, at the level of nipples suggests involvement of the costovertebral joints.

For Cervical Spine Involvement

In severe cases, the cervical spine involvement may also be present. It can be detected by the Fleche test (Fig. 11.13). The patient is asked to stand against a wall and to simultaneously touch the heels, the back and the back of head against the wall. If the patient is unable to touch the

back of head against the wall, it indicates cervical spine involvement.

Investigations

Blood investigations show an elevated ESR, positive serum HLA B27 and mild anemia.

Radiographic Examination

Bilateral symmetrical sacroiliitis is the hallmark of AS. X-ray signs develop first on the iliac side of SI joint. Hazy and widening of SI joint due to subchondral erosions are the earliest X-ray signs. This is usually accompanied by variable osteoporosis around the SI joint. As the disease progresses sclerosis, new bone formation and calcification of SI and sacrotuberous ligaments around SI joint occurs leading to ankylosis (fibrous then bony) of the SI joint as the end result. (Fig. 11.14).

Radiographs of the lumbosacral spine show loss of lumbar lordosis, diffuse osteoporosis, calcification of anterior and posterior longitudinal ligaments, squaring of the vertebral bodies and bridging osteophytes (k/a syndesmo-phytes). Eventually, the spine in advanced stages gives the classical bamboo spine appearance (Fig. 11.15).



Fig. 11.15: X-ray lumbosacral spine AP and lateral views showing bamboo spine appearance in ankylosing spondylitis.

Role of MRI: Earliest diagnosis is made by MRI [short TI inversion recovery (STIR) sequence] or with gadolinium-enhanced MRI. (For active sacroiliitis, best is dynamic MRI with fat saturation).

Diagnosis

Modified New York criteria (Table 11.4) is used for diagnosis of AS.

Differential diagnosis: Diffuse idiopathic skeletal hyperostosis (DISH) (see Table 11.5) and other causes of low backache (see Chapter 3).

Treatment

Although no treatment modality exists to eradicate the disease process but a number of disabilities that the disease produces can be tackled by timely intervention.

Table 11.4: Diagnostic criteria—Modified New York criteria (1984)

Clinical criteria

- Low back pain and stiffness for more than 3 months that improves with exercise but not with rest
- Limitation of lumbar spine mobility in both the sagittal and frontal planes
- Limitation in chest expansion as compared with normal range for age and sex.

Radiologic criteria

- Unilateral sacroiliitis of grade 3–4 or
- Bilateral sacroiliitis of grade ≥ 2 (grade 1 is suspicious changes, grade 2 is minimal erosion or sclerosis, grade 3 is moderate to severe sacroiliitis with one or more of these—erosion, sclerosis, narrowing, widening and partial sclerosis. Grade 4 is total ankylosis).

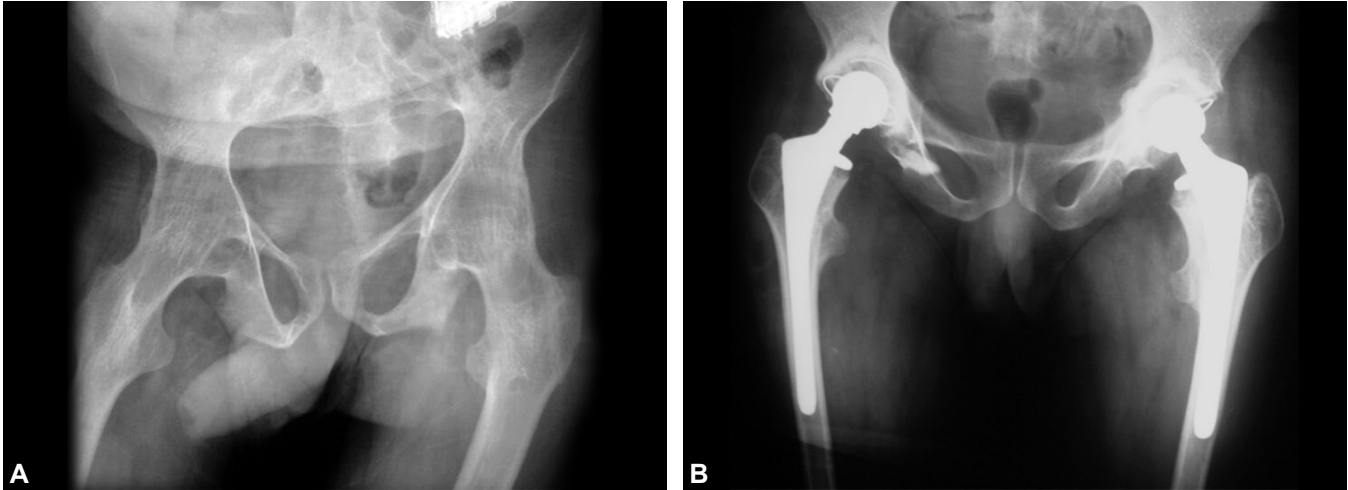
Grading

Definite ankylosing spondylitis if: The radiological criterion is associated with at least one clinical criterion.

Probable ankylosing spondylitis if: Three clinical criteria are present or the radiologic criterion is present without any signs or symptoms satisfying the clinical criteria.

Table 11.5: Comparison of ankylosing spondylitis and diffuse idiopathic skeletal hyperostosis

	<i>Ankylosing spondylitis</i>	<i>Diffuse idiopathic skeletal hyperostosis</i>
Sex/age	Common in males of 15–40 years of age	Common in males in 5th–6th decade
Etiology	It is chronic progressive inflammatory seronegative spondyloarthropathy.	It is a form of degenerative arthritis.
Pathogenesis	The primary site of pathology in ankylosing spondylitis is the entheses (site of attachment of tendons and ligaments to bone). Ossification also occurs in the ligaments that are ending up as entheses, especially the ligaments of the spine that gradually get ossified, progressively leading to stiffness.	Characterized by ossification at sites of tendon, ligaments and joint capsule insertion (enthesitis) anterior longitudinal ligament of spine is most commonly involved.
Distribution	SI joint, lumbar spine (eventually whole spine), hip joint are commonly involved.	Marked predilection to the axial skeleton; mainly involve thoracic spine
Course	All patients invariably present early with pain and stiffness of back.	It is usually asymptomatic and discovered incidentally.
SI joint	Bilateral, symmetrical involvement (sacroiliitis) In late cases, erosion may cause pseudowidening of SI joints.	Not involved
ESR	Elevated	Normal
HLA B27	Positive in 90% cases	Negative
Disability	Marked disability of spine and hip joints in advanced cases	Usually no disability
X-ray features	Bamboo spine, squaring of vertebrae, syndesmophytes	Candle wax appearance due to calcification along the anterior and lateral portion of vertebral bodies (separated from vertebral bodies)
Treatment	NSAIDs, TNF inhibitors	Usually not required



Figs. 11.16A and B: Total hip replacement (THR) for bilateral ankylosed hip joints.

General Measures

Patients are encouraged to do regular exercises and stay active so as to maintain joint mobility. They are educated to maintain a proper posture and advocated spinal extension exercises.

Medications

Nonsteroidal anti-inflammatory drugs form the first line of treatment. Indomethacin (most commonly used), phenylbutazone (most effective) and diclofenac provide relief from pain and stiffness. If NSAIDs need to be given for long or if toxicity symptoms develop, patient may be shifted to TNF inhibitors: infliximab and etanercept. Response is generally attained by 6–12 weeks but it is crucial to check for neurological side effects and go for a tubercular screening of the patient as these drugs may activate latent TB.

Evidence does not currently support the use of DMARDs, corticosteroids or radiotherapy in AS.

Surgical Management

Surgery is tailored to correct the debilitating deformities that form part of the spectrum of this disease. Spinal osteotomies are done to correct deformities of spine (e.g. Smith-Petersen osteotomy—an extension osteotomy to correct kyphosis of spine, pedicle subtraction osteotomy). Ankylosed joints are salvaged by joint arthroplasty (Figs. 11.16A and B).

HIGH-YIELD POINTS

- There is increased risk of heterotopic ossification after joint arthroplasty in ankylosing spondylitis. Radiotherapy has a prophylactic role in this situation.
- Some important MRI signs in AS (Figs. 11.17A and B):
 - *Romanus lesion (shiny corner sign)*: This is an early MRI finding and represents small erosions at the anterior margin of the superior and inferior

endplates (corners on lateral radiograph) of the vertebral bodies, with surrounding reactive sclerosis.

- *Anderson lesion (spinal pseudoarthrosis)*: Refers to inflammatory involvement of the intervertebral disks (spondylodiscitis) in AS.
- *Dagger sign*: This is a single central radiodense line in the AP radiographs of spine related to ossification of supraspinous and interspinous ligaments (Fig. 11.18).

REITER'S SYNDROME

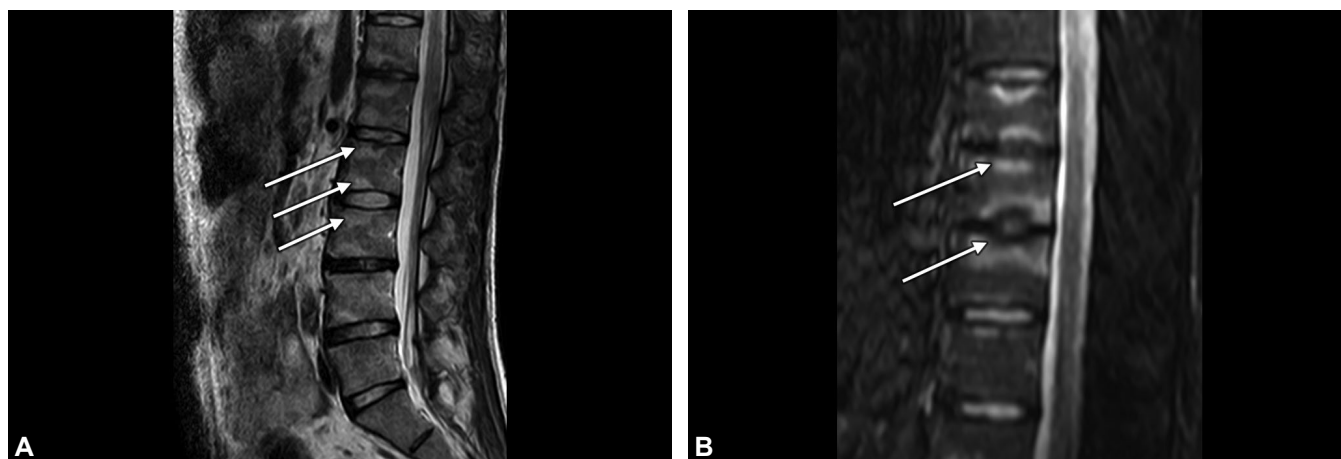
Reactive arthritis is an inflammatory polyarthritis that occurs after infection (nonpurulent) elsewhere in the body away from the affected joints. Two forms are recognized: a dysenteric form and a sexually transmitted form. The former occurs with infection after the *Shigella*, *Salmonella* and *Campylobacter* species while the latter is seen in cases of urogenital tract infections with *Chlamydia trachomatis*, *Mycoplasma genitalium* or *Lymphogranuloma venereum*. Most common triggering organism is *Chlamydia followed by shigella*. A strong association exists with HLA-B27 with almost 25% patients testing positive with the genetic marker (as opposed to 1% of general population who develop dysentery or urogenital infection).

Reiter's syndrome is a clinical triad (described by Hans Reiter in 1916) of nonerosive reactive arthritis, urethritis and conjunctivitis occurring generally after 1–3 weeks of gastrointestinal or genitourinary infection. The usual age of onset is 20–40 years with men being affected more commonly than women (10:1).

Pathophysiology involves initial immune system activation by the infecting organism triggering autoimmune reaction that involves the joints, eye, skin and the urinary system.

Clinical Features

- Asymmetric oligoarthritis commonly involving knee, ankle, subtalar, MTP and DIP joints
- Arthritis is additive in nature



Figs. 11.17A and B: Early MRI signs of AS: (A) sagittal section of MRI of lumbosacral spine showing shiny corner sign (arrows) (B) MRI of lumbar spine showing spondylodiscitis (arrows).

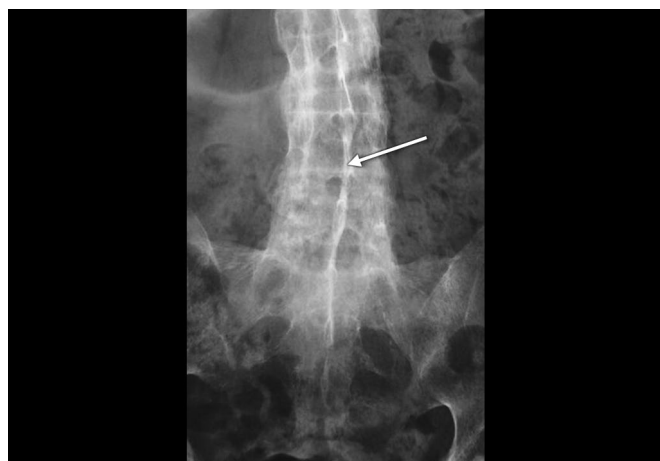


Fig. 11.18: AP X-ray of LS spine showing a central radiodense line due to ossification of interspinous and supraspinous ligaments.

- There are symptoms of associated enthesopathy (leading to plantar fasciitis, tendoachilles tendinitis) and dactylitis leading to swollen fingers (k/a sausage digits)
- *Keratoderma blennorrhagica*: Vesicular or pustular dermatitis of palm and sole
- *Circinate balanitis*: Vesicles over the glans penis
- Cystitis, cervicitis
- Ocular symptoms range from mild conjunctivitis to aggressive anterior uveitis.

X-rays usually show features of nonerosive arthritis of affected joints.

Treatment

Most patients can be managed with symptomatic treatment with NSAIDs. Rarely antibiotics are required to treat infections. DMARDs may have a role in chronic cases.

PSORIATIC ARTHRITIS

Psoriasis is an inflammatory skin disorder characterized by recurrent episodes of erythema and itching; thick, dry

and silvery scales on the skin along with nail abnormalities. Joint symptoms are seen in almost 10–30% cases of psoriasis and characterized by a seronegative polysynovitis that follows into an erosive arthritis, sacroiliitis and spondylitis. The usual age of onset is 30–50 years with an equal male-to-female ratio.

Pathophysiology is much similar to RA with initial lesion being a chronic synovitis with cell infiltration that leads to an erosive destructive arthritis. However, the destruction may sometimes be unusually severe (hence k/a arthritis mutilans). There is a strong genetic predisposition; family history of psoriasis is often present and almost 60% patients who have a concomitant sacroiliitis or spondylitis lesion are positive for HLA-B27. *HLA-Cw6* gene is also associated with the disorder.

Clinical Features

The skin lesions mostly precede arthritis but about 20% patients may present with an initial arthritis in one of the several patterns as described by Wright and Moll:

- *Distal arthritis*: Classic presentation involves DIP and the PIP joints. Erosion of the terminal tufts (acroosteolysis) in association with nail changes. Sausage like swelling of digits is seen.
- *Arthritis mutilans*: In this rare subtype extreme destruction of the phalanges and MCP joints is seen, giving rise to shortened digits that can be telescoped producing the opera glass deformity and classical “pencil in cup deformity” on X-rays (Figs. 11.19A and B)
- Symmetrical polyarthritis, resembling RA but milder than RA.
- *Asymmetrical oligoarthritis*: Less than 5 tender and swollen joints are involved. It involves small or medium-sized joints in an asymmetric distribution.
- *Spondyloarthropathy*: Almost in one-third of the cases, SI joint and spine involvement is seen. The predominance of cervical spine involvement over thoracolumbar spine distinguishes it from ankylosing spondylitis.



Figs. 11.19A and B: (A) Opera glass deformity of hand and (B) pencil in cup deformity (in circle).

Almost any peripheral joint can be involved in psoriatic arthropathy. The disease has greater tendency to produce ankylosis of the small joints of hand and feet as compared to RA. Shortening of the digits producing telescoping due to underlying osteolysis is characteristic of the disease.

Associated nail changes that may be seen in 90% patients with psoriatic arthropathy include: pitting, horizontal ridging, yellowish discoloration of the margin, subungual hyperkeratosis and onycholysis (separation of the nail from the nail bed).

Eye symptoms may be present in up to one-third cases and may include uveitis, blepharitis, blepharoconjunctivitis and dry eye (keratoconjunctivitis sicca).

Radiography

Some characteristic features of this erosive arthropathy include:

- Distal interphalangeal involvement with the classical “pencil in cup” deformity
- Small joint ankylosis
- Severe osteolysis of the phalanges and metacarpal bones (arthritis mutilans)
- Periostitis and proliferative new bone at sites of entheses.

Treatment

Antipsoriatic medicines form the mainstay of treatment. Methotrexate is the drug of choice. Retenoids, psoralens

and psoralens and ultraviolet A (PUVA) therapy all have a role in management. For orthopedic lesions, NSAIDs provide the pain relief. Anti-TNF drugs have recently shown promising results even in resistant cases with skin lesions. Surgery (arthrodesis or arthroplasty) is primarily indicated for unstable or painful joints. Arthrodesis of DIP joint helps in relieving pain and improving function.

HIGH-YIELD POINT

Arthritis mutilans is seen in Psoriatic arthritis, RA, JCA, diabetes, leprosy, neuropathic arthropathy and Reiter's syndrome.

ENTEROPATHIC ARTHRITIS

It occurs in association with both ulcerative colitis and Crohn's disease and presents either as peripheral arthritis or sacroiliitis and spondylitis. In about 15% patients with inflammatory bowel disease (IBD), this peripheral arthritis is seen. Extraarticular features like iritis, skin lesions such as erythema nodosum and pyoderma gangrenosum may be present. About 10% of patients with IBD present with sacroiliitis/spondylitis—AS-like symptoms. DMARDs are useful in this condition, particularly sulfasalazine because of its additional effect on IBD. NSAIDs should be avoided as they can exacerbate IBD.

CRYSTAL DEPOSITION ARTHROPATHIES

GOUT

It is a disorder of purine metabolism characterized by hyperuricemia (>7 mg/dL) that leads to deposition of monosodium urate crystals in joints and periarticular

tissues and thereby precipitates recurrent attacks of acute synovitis and eventually leads to arthritis. The disorder is predominantly seen in middle-aged alcoholic men or at rare times in postmenopausal women.

The hyperuricemia in gout may be due to:

- *Underexcretion of uric acid (90%)*: Patients on drugs like thiazide diuretics, cyclosporine, salicylates, pyrazinamide, ethambutol; hypertensive or diabetic patients
- *Overproduction of uric acid (10%)*: Patients having condition like lymphomas, leukemias, Paget's disease, hemolytic anemia, hypoxanthine-guanine phosphoribosyltransferase (HGPRT) deficiency (Lesch-Nyhan syndrome)
- *Both overproduction and underexcretion*: Alcohol abuse cases.

Factors predisposing to gout:

- Obese, alcoholic middle-aged (usually over 30 years) male patient
- *Dietary excess of purine-rich foods*: Meat, beans, peas, cauliflower, lentils, spinach, mushrooms, alcohol.
- Trauma, post-surgery
- Chronic inflammatory diseases
- Hemolytic disorders, myeloproliferative disorders
- Long-term use of aspirins, diuretics.

Pathogenesis

Central to the pathogenesis of gout is the high body total urate levels that cause deposition of monosodium urate crystals (called as tophi) into the synovium of joints. When there are fluctuations in uric acid levels, the micro tophi break apart and liberate the crystals into the synovial fluid. This incites a foreign body kind of reaction inviting the macrophages. The macrophages ingest the crystals and initiate an inflammatory synovitis that produces the acute exacerbation. Recurrent attacks lead eventually to destruction of joint cartilage that culminates in chronic tophaceous gouty arthropathy.

Although hyperuricemia is a *sine qua non* for the development of gout, all patients with the disease may not have raised uric acid levels. Hyperuricemia is present even in 5% of normal population but they don't ever develop gout. What has been seen the gouty attacks seem more to be associated with fluctuations in the uric acid levels (either increase or more often decrease) rather than on absolute levels. So it is quite possible that the measured levels of uric acid at the time of attack may well be in normal limits. Nevertheless, occurrence of gout is directly related to magnitude and duration of hyperuricemia. The higher the serum urate levels, the more likely an individual is to develop gout. And moreover, measuring uric acid levels is a good way to monitor the effect of treatment therapy.

Clinical Presentation

The disease course is characterized by recurrent acute attacks that end up into the stage of chronic gouty arthropathy. On an average, it takes about a decade between initial acute attack and the development of chronic arthropathy.



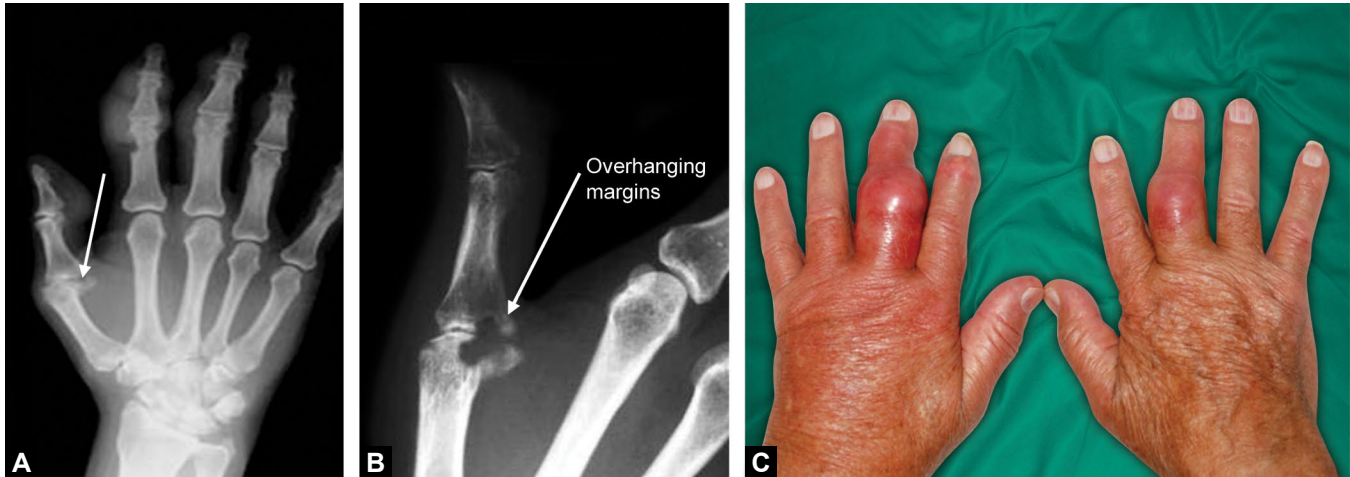
Fig. 11.20: Acute attack of gout at great toe (also called as Podagra).

Acute gout: It is characterized by sudden onset, severe joint pain with red, hot, swollen, shiny overlying skin that mimics septic arthritis. The attack may be precipitated by local trauma, intermittent illness, unaccustomed exercise or alcoholic binge. Most common site of involvement is the MTP joint of the great toe (podagra; Fig. 11.20). Other joints like the ankle, small joints of hand, knee and elbow may be involved.

Chronic gout: Recurrent acute attacks in due course lead to chronic gout. It is asymmetric and polyarticular. Joints become eroded, painful and eventually stiff and deformed. Uric acid crystals deposited in and around the joints (over synovium, articular cartilage, tendons, ligaments and bursae to form clumps of chalky material called "tophi" (Figs. 11.21A to C). They vary in size from 1 mm to several centimeters in diameter and are commonly seen around MTP joint of big toe, Achilles tendon, olecranon bursae and pinnae of ears. Although muscles and skin are spared from the deposition, large tophi can ulcerate through the skin and discharge the chalky material. Prolonged hyperuricemia by this time often leads to uric acid nephropathy secondary to formation of stones, due to precipitation of uric acid in urine.

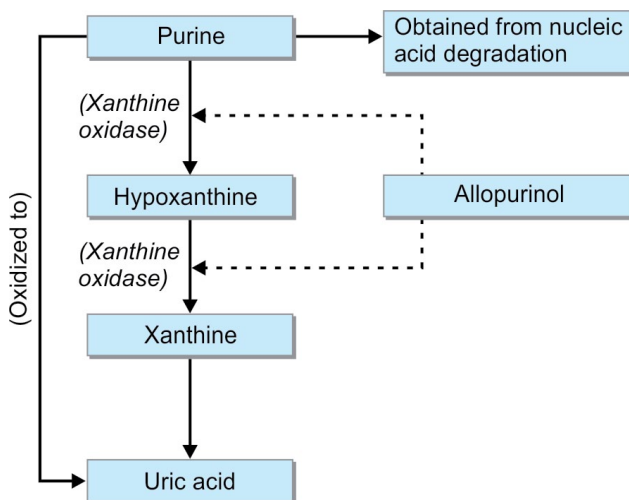
Investigations

- *Serum uric acid*: It may or may not be raised. Nevertheless, it should be documented to monitor the treatment effect.
- 24-hour urinary uric acid excretion of greater than 800 mg/day indicates overproduction of uric acid
- X-ray changes include:
 - Soft tissue swelling (may be the only sign during acute attack)
 - Periarticular deep erosions
 - Joint space narrowing
 - *G sign/Martel sign (Fig. 11.21B)*: Punched out lesion of bone with overhanging bony edges.
 - Conspicuous absence of osteoporosis.



Figs. 11.21A to C: (A) X-ray of hand showing gouty tophi (arrow). (B) X-ray of foot AP view showing Martel sign in gout. (C) Gouty tophi. Courtesy: Figure 11.3A: Dr. Charlie Goldberg, UCSD, California.

Flowchart 11.1: Flowchart showing mechanism of action of Allopurinol.



Joint aspiration and synovial fluid analysis (see Table 11.1) is the gold standard to confirm the diagnosis by demonstrating characteristic strongly negative birefringent, needle-shaped urate crystals on polarizing microscopy.

Treatment

Asymptomatic hyperuricemia: No treatment is needed.

The acute attack: It is treated with rest to the joint, ice fomentation and NSAIDs (naproxen, indomethacin are very effective) for acute pain relief. The fastest acting drug to halt the acute attack is colchicine but nausea, vomiting, abdominal cramps and bloody diarrhea remain dose-limiting side effects and hence it is not preferred now. Rather in such patients, corticosteroids are preferred. Urate-lowering drugs are contraindicated in acute attack of gout as sudden changes in uric acid levels in serum may itself precipitate gout.

Chronic gout (with or without renal complications): Any drug causing hyperuricemia should be withdrawn. General measure like reduction of weight, good hydration, avoiding alcohol and a low purine diet should be advocated.

Urate-lowering drugs (started under the cover of NSAIDs) remain the mainstay of therapy. The drug of choice is allopurinol or febuxostat—xanthine oxidase inhibitors. The mode in which they bring the therapeutic effect has been depicted in Flowchart 11.1.

Uricosuric drugs (probenecid, sulfinpyrazone) for underexcretors can be used if renal functions permit.

Surgery: Curettage may be needed for ulcerating tophi not responding to conservative treatment.

HIGH-YIELD POINTS

- Renal manifestations are seen in 10–25% of gout patients at some time of their life.
- Although the incidence of nephrolithiasis correlates with serum uric acid levels, the level of uric acid in urine is a stronger predictor.
- Even though majority of calculi in gout are predominantly composed of uric acid, even calcium-containing stones are more common in gout patients than in general population arthritis mutilans is seen in both psoriatic arthritis and RA.

CALCIUM PYROPHOSPHATE DIHYDRATE ARTHROPATHY

This disorder is characterized by deposition of calcium pyrophosphate crystals in the articular tissue. Pyrophosphate that shows elevated intra-articular concentrations is most likely generated by abnormal cartilage which combines with calcium ions in the matrix and leads to crystal nucleation on collagen fibers.

Calcium pyrophosphate dihydrate (CPPD) deposition disease includes three overlapping conditions:

1. **Chondrocalcinosis:** It is asymptomatic appearance of calcific material in articular cartilage, intervertebral disks and knee menisci. The condition is generally seen in elderly people and is mostly incidental finding on X-rays. A number of disorders are there where chondrocalcinosis is an associated finding: Hemochromatosis, hyperparathyroidism, hypothyroidism, hypophosphatasia, hypomagnesemia, hepatolenticular degeneration (Wilson's disease) and alkaptonuria (ochronosis).
2. **Pseudogout:** This is acute synovitis due to CPPD crystals, typically affecting middle-aged women. Larger joints like knee (most common site), wrist, shoulder, ankle and elbow are commonly involved. The involved joint is tense and tender and the diagnosis is often confused with acute gout. Confirmation comes by demonstration of positively birefringent, rhomboid-shaped crystals in the synovial fluid on joint aspiration.
3. **Chronic pyrophosphate arthropathy:** Usually, patient is an elderly female, presenting with chronic arthritis of joints like hip, knee, ankle, shoulders, elbows, and wrist. It resembles osteoarthritis, but the X-ray features are distinctive.

Blood Investigations

Evaluation of serum calcium, urate, phosphorous, alkaline phosphatase, magnesium, iron/transferrin, TSH and PTH levels is done to know the etiology.

Radiological Features

The characteristic X-ray feature is chondrocalcinosis—calcification of articular cartilage in joints, menisci in knee, pubic symphysis, intervertebral disks (Fig. 11.22) and at times tendons and bursae around joints.

In chronic stages, degenerative changes (joint space narrowing, subchondral sclerosis, osteophytes) are seen

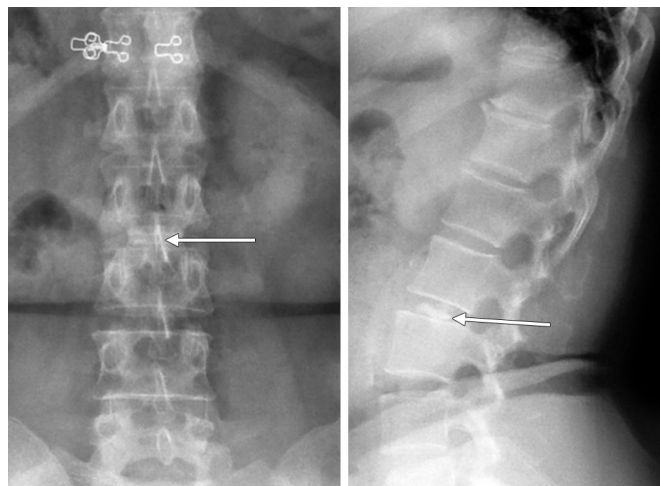


Fig. 11.22: Intervertebral disk calcification (arrows).

but notably involving the unusual site like the patellofemoral compartment of the knee, talonavicular joint. In advanced stages, marked joint destruction with loose body formation may be seen.

Treatment

Rest to the joint, ice fomentation in acute attacks, aspiration in cases of tense joint swelling, NSAIDs/coxibs for pain relief, oral/intra-articular steroids are the treatment modalities used.

Surgical treatment (arthrodesis/arthroplasty) may be needed for advanced arthritis.

CALCIUM OXALATE DEPOSITION ARTHROPATHY

It is a rare crystal deposition disorder seen mainly in patients either with a metabolic enzyme defect (primary hyperoxaluria) causing increased oxalate production or with end stage renal failure leading to decreased oxalate excretion. Other rare causes include short bowel syndrome, thiamine or pyridoxine deficiency, diet rich in spinach and ascorbic acid etc. patients present with mono or oligoarthritis affecting mainly joints of hand and feet. Other features include milium cysts, skin calcium oxalate deposits, synovial calcification and vascular calcifications of hand and feet vessels. Diagnosis can be confirmed by identifying the crystals of oxalate (bipyramidal, positively birefringent) in synovial fluid. Rest to joint and NSAIDs are mainstay of treatment.

HIGH-YIELD POINTS

- **Tumoral calcinosis:** It is a familial condition of dysfunction of phosphate metabolism (not a tumor) that results in periarticular extracapsular soft tissue deposition of inorganic calcium phosphate. Commonly seen in young black males, it commonly affects the shoulders, hips and elbows (Fig. 11.23) and rarely even knees. On knee X-rays, one finds ossification around the knee but not in joint menisci. The condition is frequently seen in patients undergoing renal dialysis. The depositions are clinically painless but result in swelling around joints. These masses have tendency to enlarge and may even ulcerate through the overlying skin and extrude. Treatment involves normalizing the serum phosphate levels.
- The most reliable means of distinguishing inflammatory from noninflammatory arthritis is by analyzing the cell count of the synovial fluid.
- Pain and stiffness in inflammatory arthritis generally improves with activity while in degenerative arthritis it settles with rest. Commonly involved joints in different forms of arthritis are summarized in Table 11.6 while differences between rheumatoid and seronegative spondyloarthropathies are given in Table 11.7.



Fig. 11.23: X-ray showing extracapsular calcification around elbow in a case of tumoral calcinosis.

Courtesy: Learningradiology.com.

Table 11.6: Different joints involved in various forms of arthritis (Fig. 11.24)

Disease	Commonly affected joints
Gout	MTP joint of great toe
Pseudogout	Knee
Rheumatoid arthritis	MCP, PIP, wrist Not involved: DIP
Osteoarthritis	Knee, hip, PIP, DIP, 1st CMC Not involved: MCP, wrist
Ankylosing spondylitis	Sacroiliac joints > Lumbar spine
Hemophilic arthritis	Knee: most common
Septic arthritis	Knee: most common
Charcot arthropathy	Foot (mid tarsal joints): most common
Reactive arthritis	Knee
Psoriatic arthritis	DIP and PIP joints

- **Parvo virus arthropathy:** Human parvo virus arthropathy in young adults is characterized by transient sudden onset polyarthropathy involving multiple small joints and absence of rashes. In few patients it can lead to chronic arthritis.

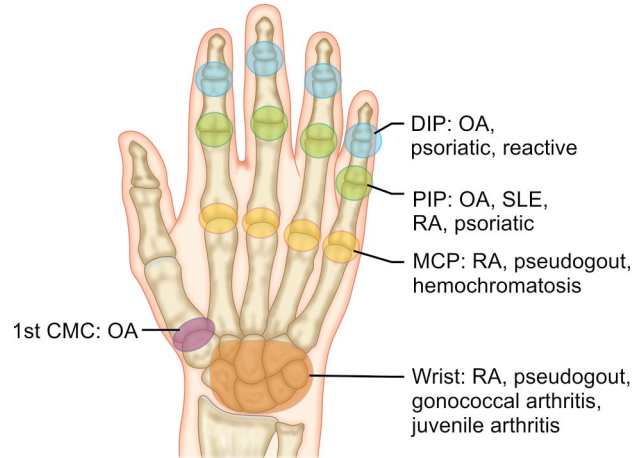


Fig. 11.24: Involvement of various joints in different arthritis types.

Table 11.7: Differences between rheumatoid arthritis and seronegative spondyloarthropathies (SSA)

Features	RA	SSA
No. of joints involved	Polyarthritis	Oligoarthritis
Enthesitis	No	Yes
Limbs	Both upper and lower limbs	Predominantly lower limbs
Spine	Cervical spine	Lumbar spine and SI joints
Lesions in skin and mucus membrane	Palmar erythema, Subcutaneous nodules	Oral ulcer, genital ulcer, keratoderma blenorrhagica, psoriasis
Lung lesions	Interstitial lung disease, pleural effusion, nodules	Apical fibrosis
Eye lesions	Scleritis, episcleritis, scleromalacia performance	Conjunctivitis, uveitis
Rheumatoid factor	+ve	-ve

- Pseudo-Ankylosing spondylitis and Pseudo-Rheumatoid arthritis are presentations of chondrocalcinosis that mimic the native disorders respectively.

DEGENERATIVE ARTHRITIS

OSTEOARTHRITIS

Osteoarthritis (OA) is a chronic, age related degenerative disorder of joints in which there is progressive softening and destruction of articular cartilage accompanied by new growth of bone at the joint margins (osteophytes), cyst formation in subchondral area, sclerosis in the subchondral bone, mild synovitis and capsular fibrosis. Although there are some signs of inflammation it's not primarily an inflammatory arthritis.

Etiopathogenesis

There is imbalance between normal cartilage repair mechanisms and its degradation which leads to net loss of cartilage. The cartilage loss is "asymmetric", greater where the stress on the joint is greatest (E.g. in knee, medial compartment being more commonly effected than the lateral compartment). Once the cartilage is lost, the denuded bone surfaces rub against each other, the process is called "eburnation". Subchondral cysts form in

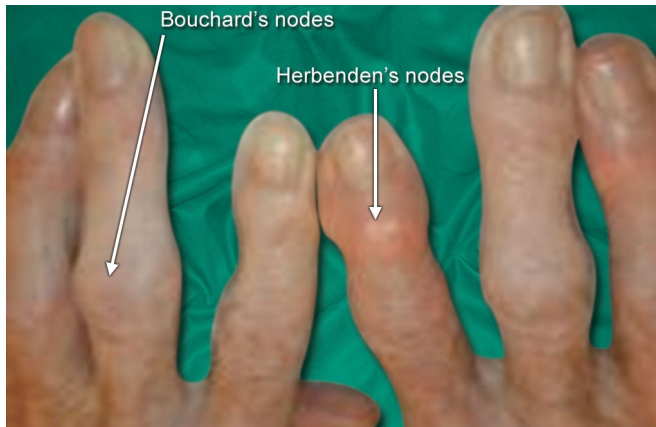


Fig. 11.25: Bouchard's and Heberden's nodes.

areas beneath the eburnated surfaces. The subchondral bone shows marked osteoblastic activity and manifests as subchondral sclerosis in the most stressed part of the joint. *Risk factors for OA:* Advanced age, trauma to the joint (old malreduced intra-articular fracture), occupation (footballers are more prone to have OA knee, baseball pitchers are more prone for OA shoulder), obesity, smoking and a positive family history.

Joints commonly involved: Knee (most common), hip, DIP, PIP, first CMC, first MTP, facet joints of cervical spine and lumbosacral spine.

Clinical Features

Patients usually present after middle age, the weight-bearing joints are commonly involved (knee > hip). Characteristically, symptoms of OA show a waxing and waning course. Pain is the usual presenting complaint. The pain is typically aggravated on exertion and relieved on taking rest unlike rheumatoid and other inflammatory arthritis. Possible cause of pain are synovial inflammation, muscle spasm, medullary hypertension and microfractures in subchondral bone, stretching of periosteal nerve endings by osteophytes and distension of fibrosed capsule by joint effusion. Stiffness is also a common presenting complaint, which occurs with period of inactivity.

On examination, crepitus may be felt around the involved joint. Deformities are seen in late stages due to capsular fibrosis or joint instability, e.g. genu varum in OA knees. Sometimes, the joints appear deformed/swollen because of excessive osteophyte formation around joint margins, e.g. Bouchard's nodes (PIP joint) and Heberden's nodes (DIP joint) (Fig. 11.25). Irregular joint space narrowing and marginal osteophytes of IP joints resemble a flying seagull (called as "seagull wings sign") Bony ankylosis is uncommon except in IP joints of fingers where it may be the end result.

Investigations

X-ray of the knee joint orthogonal views (AP and lateral) are sufficient to make diagnosis.

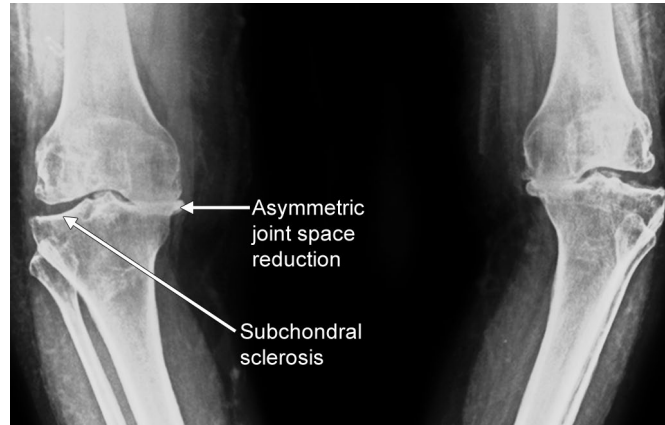


Fig. 11.26: X-ray knee showing signs of osteoarthritis.

Hallmark radiological features (Fig. 11.26) are:

- Decreased joint space (asymmetric, medial > lateral)
- Subchondral sclerosis
- Subchondral cysts
- Marginal osteophytes
- Loose bodies
- *In late stages:* Deformities of the joint and joint subluxations.

Erythrocyte sedimentation rate, CRP and serum uric acid are usually normal. Elevated homocystein levels have recently been documented and may have a role in pathogenesis.

Treatment

Principles of management are to provide pain relief, to maintain joint mobility and muscle strength and to protect joint from eccentric loads (unloading joint) by modification of lifestyle and advising specific precautions. Treatment is best guided by grading the disease.

Ahlback Grading for OA Knee

- Joint space narrowing
- Joint space absent
- Bone attrition/loss

Treatment as per the stage:

Stage I

Treatment is primarily conservative. Options include: Lifestyle modification includes avoiding climbing stairs and sitting cross-legged and squatting to off load the joint from excessive forces. Weight reduction and use of walking aids also assists in the process.

Physiotherapy is advised to improve muscle strength around the joints. Hot fomentation and TENS may provide pain relief.

NSAIDs: Advised for pain relief on short term basis. Acetaminophen is recommended by most guidelines as the first-line therapy although NSAIDs (diclofenac) have

been shown to provide better improvement in pain and function. Selective Cox-2 inhibitors (etoricoxib) are generally preferred by clinicians because of their better side effect profile and almost a matchable efficacy. Opioids (tramadol) can be given where NSAIDs are not suitable.

Viscosupplementation to delay the progression: Diacerin, chondroitin sulphate, glucosamine can be given orally. Intra-articular hyaluronic acid injections are the other option.

Surgical options: In this stage, the nonresponders can be taken up for arthroscopic lavage and debridement, removal of loose bodies or impinging meniscus if any and removal of cartilage tags to smoothen the articular cartilage but effects are generally short-lived. High tibial osteotomy is an excellent option in cases where only medial joint space is lost and lateral and patellofemoral compartments are preserved.

The osteotomy changes the bony alignment and redistributes weight from the medial to the lateral compartment.

Stage II and Above

Total knee replacement is generally the best option once the cartilage loss is complete. Arthrodesis can be opted in small joints of hand and feet.

HIGH-YIELD POINTS

- The most common bone involved in OA knee is the patella.
- The most common muscle weakness seen in OA knee is of Quadriceps.
- The first sign on X-ray diagnostic of OA is reduction of joint space.

MISCELLANEOUS ARTHRITIC AFFECTIONS

NEUROPATHIC JOINT (CHARCOT JOINT)

Neuropathic joint was first described by Charcot in tabes dorsalis in 1868. It is a progressive destructive (but painless) arthritis that arises from loss of pain and proprioceptive joint sensations.

The site of involvement varies depending upon the cause (Table 11.8).

Miscellaneous causes: Amyloidosis, multiple sclerosis, peripheral nerve disorders, Intra-articular steroid injections in weight-bearing joints and Charcot Marie tooth disease.

Pathogenesis

The basic factor seems to be lack of appropriate sensory input from the joint. Abolition of proprioceptive and/or

sensory impulses from the joint leads to it being exposed to unusual trauma for a prolonged time. Repetitive trauma leads to fragmentation and destruction of the joint cartilage, loose body formation and pronounced bone destruction along with attempted evidence of new bone formation (osteophytosis) in abnormal sites.

Clinical Presentation

The classic diagnostic Charcot's triad includes gross joint swelling, exaggerated movements and painless presentation (Fig. 11.27).

The patient initially comes with a single joint involvement. The affected joint is markedly swollen, deformed, may be subluxated or have gross instability, but is classically minimally painful. Crepitus may be felt on moving the joint owing to presence of multiple loose bodies. Patient may exhibit features of underlying disease.

Table 11.8: Neuropathic joints—site predilection varies with disease

	<i>Joints involved</i>
Diabetes (most common cause)	Midtarsal (most common) Tarsometatarsal Metatarsophalangeal Ankle joint > knee and spine
Tabes dorsalis (2nd most common cause)	Knee (most common) Hip Ankle Lumbar spine
Leprosy	Interphalangeal (hand) Metatarsophalangeal (feet) Lower limbs
Syringomyelia	Shoulder (glenohumeral) Elbow Wrist Cervical spine
Myelomeningocele	Ankle Intertarsal joint



Fig. 11.27: Clinical photo of patients with Charcot joints (knee).

X-Ray Features (Fig. 11.28)

- Marked destructive changes with periarticular erosions
- Joint space narrowing
- Osteophyte formation
- Subchondral sclerosis
- Loose bodies.

The changes simulate osteoarthritis but absence of pain is diagnostic.

Management

The principle in the management of neuropathic joint consists of minimizing the trauma to which the unstable and insensitive joint is exposed, by efficient bracing, weight-relieving calipers or leather corset. Large effusions may be aspirated and in troublesome cases joint debridement (arthrocentesis) and arthrodesis may be necessary, although the results are often disappointing. Joint arthroplasty is relatively contraindicated in Charcot's disease.



Fig. 11.28: Knee X-ray showing destructive changes in Charcot's disease of knee.

HIGH-YIELD POINTS

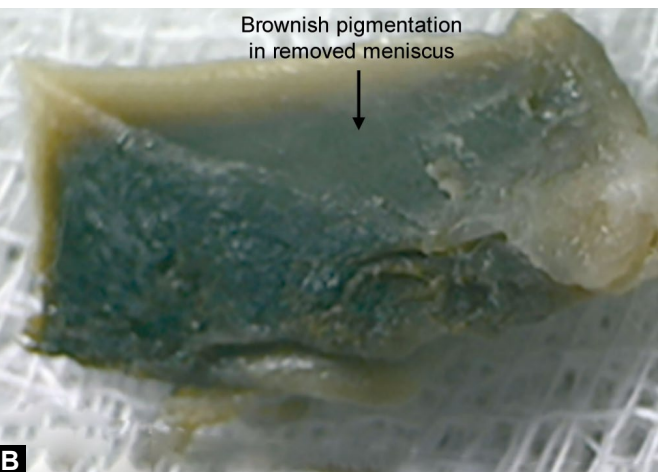
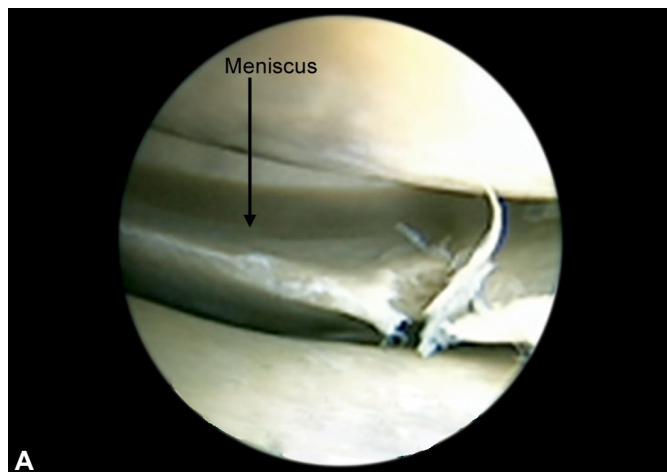
Some terms in relation to neuropathic joint disease	
Term	Definition
Bag of bones	Clinical term to describe the palpable signs of an advanced neuropathic joint
Charcot's joints	Physical appearance of a neuropathic joint of any cause owing to disorganization, debris and distension
Clutton's joints	Physical appearance of bilateral nonpainful swelling, usually in the knees owing to congenital syphilis
Licked candy stick	Generalized pencil-like tapering of a long bone toward a joint owing to atrophic resorption
Tumbling building block spine	Multisegmental subluxated vertebral bodies simulating falling building blocks
Jigsaw vertebra	Fragmented appearance of a vertebral body owing to multiple fractures

ALKAPTONURIC ARTHRITIS (OCHRONOSIS)

It is an inherited disorder of tyrosine metabolism occurring due to deficiency of enzyme homogentisic acid oxidase characterized by increased excretion of homogentisic acid in urine (urine turns black on standing, due to oxidation of homogentisic acid) and deposition of homogentisic pigment in the soft tissues (ochronosis).

Orthopedic Manifestations

Joint symptoms occur usually after the age of 40 years. The pigment deposits (Figs. 11.29A and B) in articular cartilage, synovium, menisci and intervertebral disks causing periarticular and intervertebral disk calcifications. Spine and shoulder joints are common sites of affection. Symptoms simulate osteoarthritis.



Figs. 11.29A and B: (A) Degenerative meniscal tear due to ochronotic arthritis (arthroscopic view) and (B) Black pigment deposition in removed meniscus.

Courtesy: Dr JVS Vidyasagar, Global hospital, Hyderabad.

Management

Arthropathy is treated on symptomatic basis. Later stages may need joint replacement. Vitamin C supplementation and nitrosone therapy may have a role.

HEMOPHILIC ARTHRITIS

Hemophilia is an X-linked recessive disorder that manifests generally in males (females are carriers) and is characterized by the deficiency of clotting factors VIII (hemophilia A, 80% cases) and IX (hemophilia B, Christmas factor). The deficiency results in spontaneous hemorrhages into the joints that initiate a chronic synovitis that eventually culminates in progressive destructive arthritis.

Orthopedic Manifestations

Patients with plasma clotting factor levels more than 40% tend to lead a normal life while those with levels less than 5% have prolonged bleeding after an injury or surgery. Those with severe hemophilia (level < 1%) form the main clinical spectrum as they are the ones prone to spontaneous joint and muscle hemorrhages.

Following problems may be encountered in these patients:

Intramuscular Bleeding

Although bleeding into muscles is relatively less common than joint bleeding, it can lead to muscle necrosis, fibrosis and development of contractures. In the lower limb, most common site is quadriceps followed by triceps surae while in the upper limb, bleeding generally occurs into the deltoid. In abdomen hemorrhages into iliopsoas may occur mimicking appendicitis while retroperitoneal hemorrhages may simulate renal colic.

Intra-Articular Bleeding (Hemarthrosis)

These are the more common manifestations that bring these patients to the doctor. Weight bearing joints are commonly involved. In decreasing frequency the joints involved are knee, ankle, elbow, shoulder and hip joint. Involved joints are intensely swollen and warm and may simulate an infective etiology. Recurrent hemorrhage precipitates the hyperplasia and fibrosis of synovium causing chronic synovitis. Articular cartilage is damaged by pannus formation and by action of proteolytic enzymes.

Hemophilic Pseudotumors

Uncontrolled bleeding in a confined place of musculoskeletal system produces cystic swellings which can cause pressure changes of surrounding structures. Pseudotumor can develop within the muscle fascia without producing bony changes or may cause cortical thinning but more

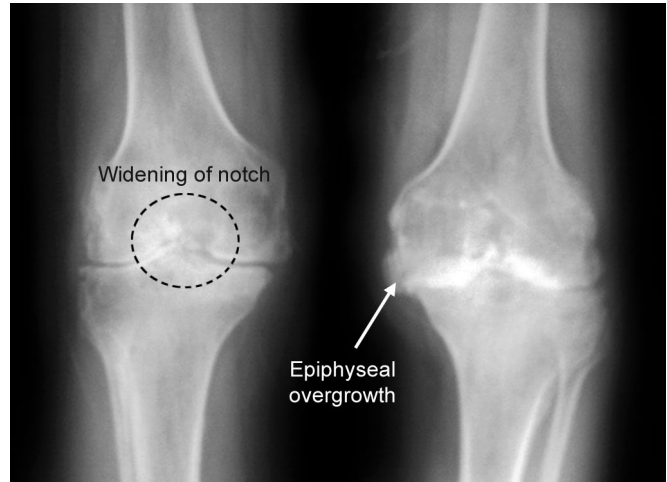


Fig. 11.30: Anteroposterior X-ray view of both knees showing signs of hemophilic arthropathy.

commonly they are caused by subperiosteal hemorrhages. Thigh is the most common site of pseudotumor formation followed by abdomen and pelvis. Quadriceps is the most common muscle to develop pseudotumor.

Nerve Palsies

Hematomas may cause compression neuropathies (generally transient). Femoral nerve followed by median nerve is the most common nerve involved. Not uncommon is bleeding into the peripheral nerve's sheath that causes peripheral neuropathy.

X-ray Features (Fig. 11.30)

X-ray features are diagnostic and include:

- Soft tissue swelling
- Juxta-articular erosions (no sclerosis) and subchondral cysts
- Narrowing of the joint space
- Epiphyseal overgrowth
- Widening of the intercondylar notch and squaring of the patella in knee
- Enlargement of the proximal radius.

Management

Medical management of hemophilia aims at factor VIII or IX replacement. Factor level should be raised to 30% to 40% of normal to control intramuscular and soft tissue bleeding. NSAIDs should be used cautiously in these patients. Pseudotumor should not be aspirated or biopsied. Management of the acute hemarthrosis involves factor replacement primarily and institution of RICE therapy (involves rest to the limb, ice fomentation, compression by applying crepe bandage and elevation of the affected part to reduce swelling). Aspiration is performed only in severe distension; it is usually avoided. Traction is effective in relieving muscle

spasm and maintaining range of motion. Joint is temporarily immobilized in correct position and active ROM is encouraged. For disabling hemophilic arthropathy synovectomy, arthrodesis or arthroplasty may be required.

During surgery factor level should be maintained at 100% of normal value. Synovectomy may be arthroscopic, open or by radiation. Yttrium is most commonly used for radio-synovectomy (radiation synoviorthesis).

CHONDROMALACIA PATELLAE AND OSTEOCHONDROSIS

CHONDROMALACIA PATELLAE

The term chondromalacia coined by Alleman basically refers to “softening of cartilage”. Chondromalacia patellae is an idiopathic disorder affecting mostly young females. It is characterized by degeneration of the articular cartilage on the back of the patella producing patellofemoral pain. The disease results due to decrease in sulfated mucopolysaccharides (ground substance) in deep layers of patellar articular cartilage (as opposed to osteoarthritis where the superficial layers of cartilage is affected). Central ridge area at the back of patella is the classically involved area. Although the exact etiology is unknown, the most important predisposing factor seems to be malalignment of the extensor apparatus (patella alta, etc.). Overuse and trauma may have a role.

These patients classically present with anterior knee pain. The pain occurs on squatting, climbing stairs and after getting up from periods of prolonged sitting (theater/movie sign). X-rays initially are normal although a skyline view is more informative. MRI may be useful in moderate-to-severe cartilage loss but arthroscopic examination is considered the gold standard for establishing the diagnosis.

Treatment is largely conservative as the lesions seldom progress to frank osteoarthritis. Patients are advised physiotherapy to strengthen the knee muscles. In cases where cartilage loss is severe, arthroscopic debridement or cartilage transplant surgeries may be required.

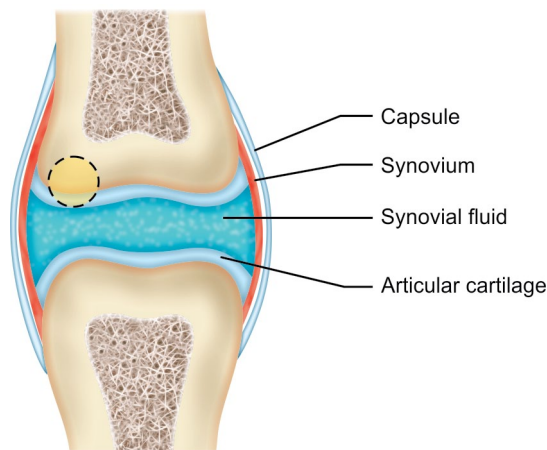


Fig. 11.31: Osteochondritis.

OSTEOCHONDROSIS/EPIPHYSITIS

Osteochondrosis includes a group of conditions that are disorders of the growing epiphysis and hence also called as epiphysitis. Technically, it refers to inflammation of the osteochondral (bone-cartilage) part of the joint as shown in Figure 11.31.

As per the probable etiology, the lesion in different locations is named differently:

Crushing Type

- *Freiberg's disease*: Metatarsal heads
- *Kohler's disease*: Navicula (Fig. 11.32)
- *Kienbock's disease*: Lunate
- *Panner's disease*: Capitulum
- *Scheuermann's disease*: Ring epiphysis of vertebrae (See Chapter 3)
- *Calve's disease*: Central bony nucleus of vertebrae.
- *Theeman's disease*: Phalangeal epiphysis.

Traction/Pulling Type

- *Tibial tuberosity*: Osgood-Schlatter's disease (Fig. 11.33)
- *Calcaneal epiphysis*: Sever's disease
- *Patellar ligament (at its lower pole patellar attachment)*: Johanssen-Larsen syndrome
- *Base of 5th metatarsal*: Iselin's disease.
- *Medial epicondyle of humerus*: Adam's disease.

Splitting Type

Osteochondritis dissecans (see below).

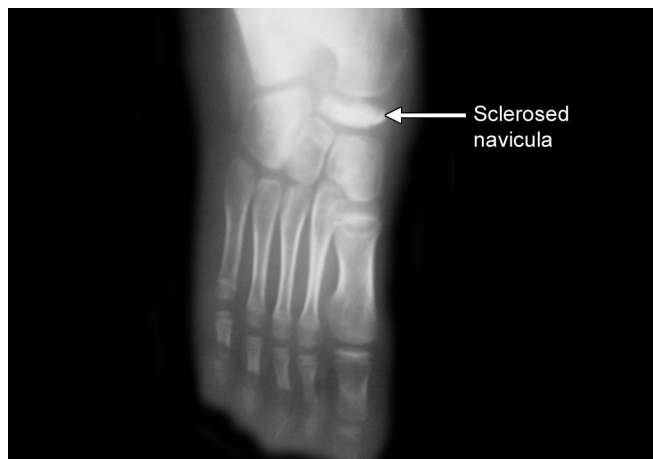


Fig. 11.32: X-ray of foot showing sclerosed navicula in a patient with Kohler's disease.



Fig. 11.33: X-ray both knees lateral view in an adolescent showing Osgood-Schlatter's disease.

KIENBOCK'S DISEASE

It is osteochondritis of lunate that occurs possible due to a chronic stress injury. Approximately 70% of these patients have a negative ulnar variance (ulna ending far short of radius) that tends to stretch the ulno-lunate ligament causing a chronic stress injury to lunate (Fig. 11.34) that eventually starts degenerating, collapsing and fragments, the condition culminating in secondary osteoarthritis of wrist.

Affected patients are in the age group 15–40 years, mostly being manual laborers who present with pain usually in the dominant wrist. On examination, one may find tenderness over lunate. X-rays are done that initially may be normal but later on show increased density of lunate (Fig. 11.35) followed by evident collapse and fragmentation. MRI provides the earliest diagnosis and is the investigation of choice.

Management in early stages (before collapse) involves radial shortening/ulnar lengthening procedures to correct ulnar variance along with a vascularized pronator quadratus-based muscle pedicle graft to increase vascularity. In advanced stages with collapse, arthrodesis of the wrist is performed.

OSTEOCHONDritis DISSECANS

This is a special type of osteochondritis in which an osteochondral fragment separates from rest of the bone and forms a loose body in the joint. The disease is two times more common in males and occurs generally during adolescence (10–20 years). Approximately 30% cases are bilateral.

Knee (lateral surface of medial femoral condyle) is the commonest site affected but a few other areas can also be involved like talus (anteromedial corner), femoral head (superomedial part), elbow (capitulum) and first metatarsal head.

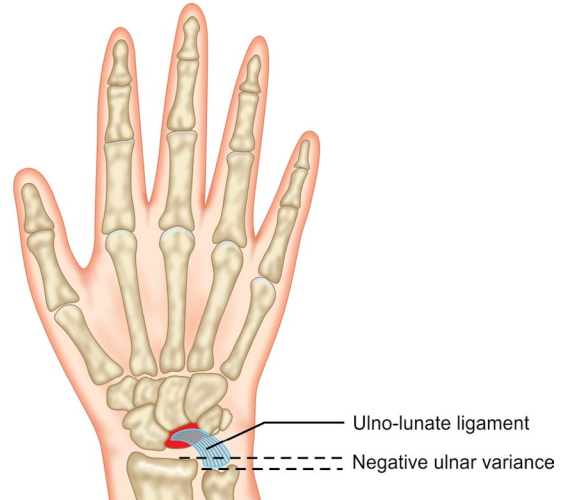


Fig. 11.34: Negative ulnar variance in pathogenesis of Kienbock's disease.



Fig. 11.35: X-ray hand AP view showing increased sclerosis of lunate (Kienbock's disease).

Patients generally tend to come with a vague aching discomfort in the knee present for months. When these patients are made to sit on a couch with legs hanging, there is pain on internal rotation of leg which disappears as leg is externally rotated (Wilson's test).

X-rays classically reveal a loose body or may show a loosely attached osteochondral fragment (Fig. 11.36) in the joint that clinches the diagnosis. An intercondylar/tunnel view is more informative. Bone scan can provide early diagnosis but MRI is the investigation of choice, provides earliest diagnosis and also aids in management.

Management depends upon the size of the defect created by separation of the fragment. In smaller lesion multiple drilling of the crater is performed. Drilling leads to fresh pool of bleeding from marrow and the inflow of growth factors that cause the lesion to heal. In larger defects, a mosaicplasty or osteochondral autologous transplantation surgery is performed wherein an osteochondral graft is harvested from non-weight-bearing area of knee and transplanted into the crater (Fig. 11.37).



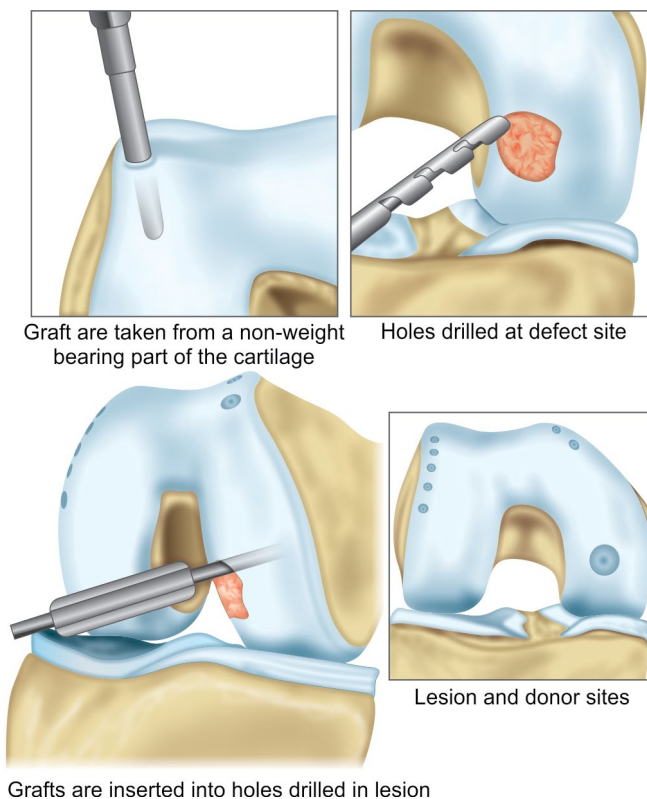
Fig. 11.36: X-ray of knee joint AP view showing osteochondral fragment loosely attached to medial femoral condyle (white arrow). MRI (coronal section of knee joint) further confirms the diagnosis (black arrow).



Fig. 11.38: Synovial chondromatosis knee.

HIGH-YIELD POINTS

- *Finsterer's sign*: Diagnostic for Kienbock's disease. The patient is asked to make a fist. There is tenderness at base of third metacarpal on tapping and its normal prominence is absent in patient with the disease.
- Osteochondritis dissecans is the most common cause of loose bodies in the knee joint. Loose bodies in the knee joint can also result from synovial chondromatosis,



Grafts are inserted into holes drilled in lesion

Fig. 11.37: Mosaicplasty.

Charcot's joints, broken osteophytes, fractured articular surfaces and damaged menisci.

- *Synovial chondromatosis* (Fig. 11.38): In this condition, there occurs cartilage metaplasia in the synovium of joint leading to formation of multiple loose bodies (may be more than 50). Knee followed by hip is the most common site of affection and this disease is the most common cause of multiple loose bodies in knee.
- The term "Snow storm appearance" is used to describe the appearance of this condition on arthroscopic evaluation of knee.
- Negative ulnar variance is associated with Kienbock's disease whereas positive ulnar variance is associated with ulnar impaction syndrome and injury to TFCC (triangular fibrocartilage complex).

AVASCULAR NECROSIS OF HEAD OF FEMUR (CHANDLER'S DISEASE)

Femoral head is prone to avascular necrosis (AVN) that might occur after a dislocation or after a fracture of neck of femur, due to its precarious blood supply, as already discussed in Chapter 2. However, apart from traumatic causes, a number of cases present with spontaneous osteonecrosis (AVN) of the femoral head without any antecedent traumatic event or fracture and without any evident

infection/sepsis. Femoral head is the most common site for atraumatic AVN.

ETIOLOGY

Although a number of factors have been implicated as shown in Table 11.9, the most common cause still remains

idiopathic. Steroids and alcohol intake are next common causes for AVN.

PATHOPHYSIOLOGY

The factors mentioned above either lead to intravascular thrombosis of sinusoidal vessels or produce an extravascular marrow swelling (like steroids), that eventually causes ischemia. The subarticular areas lie at the most distant part of bone's vascular territory and are largely enclosed by cartilage, restricting their access to local blood supply. Thereby even on minimal insult, the subchondral trabeculae get affected (generally anterolateral part of superior weight bearing zone of femoral head in the subchondral region involves first), followed by changes occurring in other compromised areas eventually leading to deformation of bone, collapse and fragmentation which if untreated ends in secondary osteoarthritis.

CLINICAL PRESENTATION

Mostly, the disease is seen in young individuals (20–40 years age), and it is one of the commonest causes of painful hip in a young adult. Pain in the groin area initially may be there on activity but later on even rest pain develops. Bilateral involvement is common and seen in about 75% cases. Range

of motion also gets affected during the course. Internal rotation is the first movement to be restricted followed by abduction. Collapse of head causes shortening of the limb. Over time, a fixed pelvic deformity may eventually develop.

INVESTIGATIONS

X-ray is usually the first investigation ordered that may be normal in the initial stages. As disease progresses, one may find patchy areas of increased density/sclerosis in the superolateral part of femoral head (as decalcification does not occur in avascular bone that appears white). As the disease progresses irregularity of the head, fragmentation and collapse may be noted (Fig. 11.39). In the end stages, the joint space is lost and the hip ends up in secondary osteoarthritis.

Bone scan can provide an early diagnosis. Initially, there may be a hot spot and in later stages a cold spot.

Magnetic resonance imaging is the investigation of choice and provides the earliest diagnosis. In the initial stages, there may be edema in the marrow but as disease progresses, subchondral fracture lines (crescent sign) and eventually fragmentation and collapse may be noted.

Other investigation tailored to cause may be needed.

DIFFERENTIAL DIAGNOSIS

The disease has to be differentiated from all possible causes of chronic arthritis of hip like TB, primary and secondary osteoarthritis.

MANAGEMENT

Management is dictated by the presence of collapse of bone.

In the precollapse stage, preferred treatment is a surgery called core decompression (Fig. 11.40). The sclerotic focus is reamed to decompress the marrow and relieve pressure in an attempt to improve vascularity and a fibular bone graft is inserted in the reamed area.

Table 11.9: Causes of avascular necrosis

- Idiopathic (most common cause)
- *Coagulation disorders:* Familial thrombophilias, hypolipoproteinemia, thrombocytopenic purpura, nephrotic syndrome
- *Thrombosis:* Hemoglobinopathies (Sickle cell disease), storage disorders (Gaucher's disease), pancreatitis, pregnancy, polycythemia, anticancer drugs, postrenal transplant
- *Embolic occlusion of vessels:* Caisson's disease
- *Vasculitis:* Irradiation, SLE (antiphospholipid antibodies)
- *Miscellaneous:* High-dose steroid therapy, i.e. more than 2 g of prednisone or its equivalent for 2–3 months (occlusion of vessels by fat emboli and increased marrow pressure due to fat accumulation), alcohol intake, HIV, etc.



Fig. 11.39: X-ray pelvis AP view showing fragmentation and collapsing of head of both femurs due to avascular necrosis.

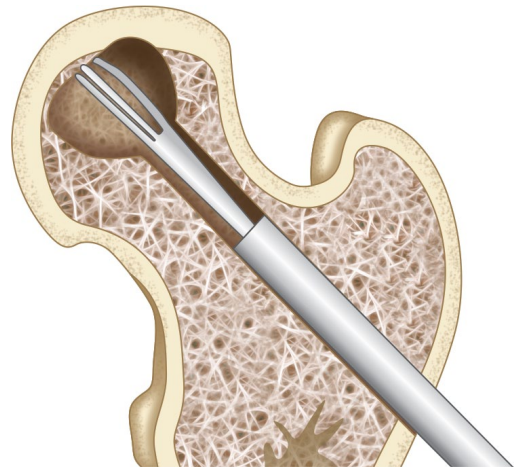


Fig. 11.40: Schematic representation of core decompression for non-traumatic AVN of femoral head.

If the collapse has started but is in only a patchy area, then one can go for a vascularized fibular/muscle pedicle grafting or a realigning osteotomy (abduction/adduction hip osteotomy) to make the affected area become non-weight-bearing. In case there is advanced collapse or superimposed arthritic changes then replacement arthroplasty remains the preferred choice.

HIGH-YIELD POINTS

- *Positive sectoral sign:* In AVN of head of femur, the range of internal rotation is less in hip flexion compared to when in hip extension.
- *Transient osteoporosis in pregnancy:* Transient osteoporosis of pregnancy is a rare condition of unknown etiology that affects otherwise healthy pregnancy

in the third trimester. Patient presents with sudden onset of pain with mild restriction of hip range of motion. Radiological investigations show bone marrow edema and transient osteoporosis of the hip. Radiological findings and symptoms usually resolve within weeks of labor.

- *Ahlback's disease:* It is spontaneous avascular necrosis of the femoral condyles (knee) in an adult
- AVN changes classically starts in the sub chondral area of femoral head.
- In HIV patients incidence of AVN of femoral head is higher than general population. Anti retroviral therapy (mainly protease inhibitors), steroid intake, I.V. drug abuse, alcohol intake, smoking and hyperlipidemia all have been implicated in causation of AVN of femoral head in HIV patients.

CHAPTER 12

Soft Tissue Disorders



ADVENTITIOUS BURSITIS

INTRODUCTION

True or anatomical/synovial bursae are connective tissue sacs lined by synovium, containing a viscous fluid. They are interposed between two moving structures to reduce friction or shear or they may be present at sites of unusual pressure like many bony prominences.

Adventitious bursa refers to a bursa that is not normally present at that site. Adventitious bursae typically develop in areas of chronic frictional irritation.

Following are the important sites of adventitious bursitis:

- *Student's elbow*: Olecranon bursitis (Fig. 12.1A)
- *Tailor's ankle (bunionette)*: Lateral aspect of fifth metatarsal head (Fig. 12.1B)
- *Weaver's bottom*: Ischial bursitis
- *Clergyman's knee*: Infrapatellar bursitis
- *Housemaid's/coal miner's knee*: Prepatellar bursitis
- *Baker's/popliteal cyst*: Semimembranosus bursitis.

RETROCALCANEAL BURSITIS (FIG. 12.2)

It refers to inflammation of the retrocalcaneal bursa that lies between the posterior aspect of calcaneum and Tendo-Achilles. The likely etiology is the back of the heel

repeatedly rubbing against the shoes. It commonly occurs in females in their twenties and thirties. Pain is aggravated by running or walking and relieved by rest.

When this is associated with bony outgrowth of the posterosuperior part of calcaneum causing a visible swelling, it is known as Haglund deformity (pump bump) (Fig. 12.3).

Treatment of retrocalcaneal bursitis consists of non-steroidal anti-inflammatory drugs (NSAIDs), modification of activity, changing to soft footwear or backless shoes and local ice application or a contrast bath (hot and cold fomentation alternatively in a ratio of 3:1, starting from hot fomentation). Haglund deformity can also be treated with such conservative measures, but when refractory, it may require surgery in the form of resection of the superior aspect of the tuberosity.

MORRANT-BAKER'S CYST (POPLITEAL CYST) (FIG. 12.4)

Popliteal cyst is formed due to egress of fluid through the normal communication between knee joint and the semimembranosus bursa or the bursa beneath the medial head of gastrocnemius.



Figs.12.1A and B: (A) Student's elbow. (B) Bunionette.



Fig. 12.2: X-ray showing heavily calcified retrocalcanal bursa.

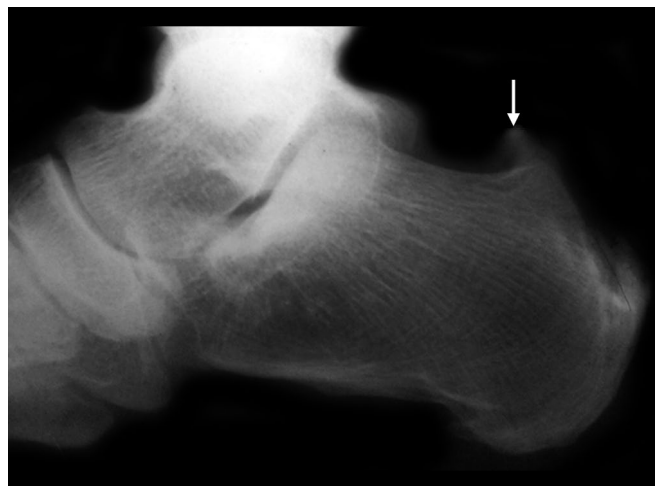


Fig. 12.3: Haglund deformity (arrow).



Fig. 12.4: Clinical picture showing Baker's cyst in popliteal fossa.

In adults, the cyst is usually associated with some intra-articular pathology (e.g. tear in posterior one-third of medial meniscus) and can recur if the pathology is not dealt with during surgery. In children however, intra-articular pathology is rare and cyst infrequently communicates with knee joint and even incomplete excision affects cure.

Transillumination test is positive but can be negative at times due to thick muscle cover at the back. In these cases ultrasonography (USG) can establish the diagnosis and distinguish effectively between popliteal cyst and other lesions in the location such as lipoma, fibrosarcoma, vascular tumors, xanthomas etc.

Radiology: X-rays are not of much use. CT can effectively delineate the extent of cyst, but MRI is best and can also elucidate associated intraarticular pathology.

Treatment: In children, prolonged neglect is wise as many

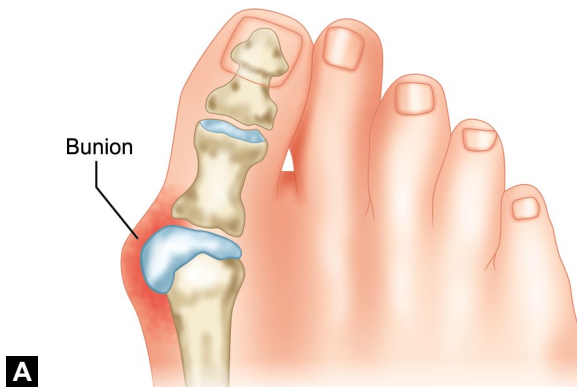
cysts spontaneously regress. In non-resolving cysts, aspiration and injection of steroid is effective. Surgery is rarely required. On the other hand in adults, arthroscopic decompression of cyst along with correction of associated intra-articular pathology is indicated. If no significant pathology is found, an open excision can also be performed.

HIGH-YIELD POINTS

- The most common site of bursitis is shoulder (sub-acromial)
- The most common patellar bursitis is the Pre-patellar bursitis.
- Swellings around the knee:
 - In front of knee—Prepatellar and infrapatellar bursitis
 - Medial side of knee—Pes anserine bursitis
 - On back of knee—Baker's cyst.
- *Bursas around the knee that communicate with the knee joint:* Suprapatellar bursa, popliteal bursa, gastrocnemius bursa and pes anserine bursa.
- The infrapatellar bursa is divided into superficial and deep bursa. Clergyman's knee is inflammation of the superficial infrapatellar bursa.

BUNION

A bunion is a bony bump that forms over the dorsal surface of the first metatarsal head (Figs. 12.5A and B). It mainly results due to imbalance between two tendons—peroneus longus (that depresses the first metatarsal) and tibialis anterior (that elevates the first metatarsal). It can also result from paralysis of gastro soleus. In this situation the long toe plantar flexors exert more force to give added strength to plantar flexion as gastro soleus is weak.



Figs.12.5A and B: Bunion.

WRIST AND HAND AFFECTIONS

GANGLION

It is a cystic degeneration of the tendon sheath or joint capsule. It presents mostly as a unilocular cystic structure filled with thick gelatinous fluid. Dorsum of the wrist is the most common site (Fig. 12.6) and it usually develops from the dorsal aspect of scapholunate ligament. The swelling becomes more prominent on flexion of the wrist. Mostly it is a painless mass but rarely may it become painful. Treatment initially involves aspirating the cyst and injecting steroid/hyaluronidase). Recurrent cases may need surgical excision.

HIGH-YIELD POINTS

- Ganglion is the most common swelling of the hand.
- The most common tumor of the hand is Squamous cell carcinoma while enchondromas are the most common primary bone tumor of hand.
- Compound Palmar ganglion (page 238) is due to chronic inflammation of common sheath of flexor tendons both above and below the flexor retinaculum causing an hour-glass like swelling in front of the wrist. Both rheumatoid arthritis and tuberculosis are common causes.

BOWLER'S THUMB

It is digital nerve neuroma (strictly speaking, it is perineural fibrosis and not a true neuroma) of thumb seen in those involved in spin bowling. Thickening of the nerve occurs due to constant friction as the ball rubs against the lateral thumb surface during bowling. Ulnar digital nerve of thumb is involved.

SKIER'S/GAMEKEEPER'S THUMB

Gamekeeper's thumb is the most common injury pattern at the first metacarpophalangeal (MCP) joint and refers to

injury to ulnar collateral ligament (UCL) of the metacarpophalangeal joint of thumb. It is named so because it was a common injury in gamekeepers who used to scarify small games such as rabbits by breaking the animal's necks between the thumb and index finger and the ground. Tenderness is on the medial aspect of the MCP joint of thumb. Hyperabduction or extension of thumb is the usual event causing injury. The most common cause now a days is a skier's hand landing on a ski pole, causing a valgus force on the thumb and injury to UCL. Thus skier's thumb is an acute injury whereas gamekeeper's thumb is more of chronic nature.

X-ray may show avulsion fracture at the ulnar corner of the base of the proximal phalanx and widening of MCP joint on stress views.

Note: Stener's lesion is the avulsion of UCL from the base of proximal phalanx with or without bony attachment and its displacement above the adductor pollicis aponeurosis. Adductor pollicis aponeurosis gets interposed between retracted ligament and proximal phalanx of thumb thus prevents its healing with closed treatment.

Clinical features and treatment: Patient presents thumb valgus instability with pain and swelling of the MCP joint particularly at the ulnar aspect. In partial rupture (intact palmar plate) when only ulnar collateral ligament proper is torn thumb is unstable in flexion and treated with immobilization in thumb spica for 4 weeks. For complete tear (thumb is unstable in both extension and flexion) operative repair is required.

DE QUERVAIN'S DISEASE

Tendons in the body are enclosed in double walled sheaths with an inner visceral layer and an outer vaginal layer. Inflammation of the complete tendon sheath is called tenosynovitis while isolated involvement of the outer layer is called tenovaginitis.

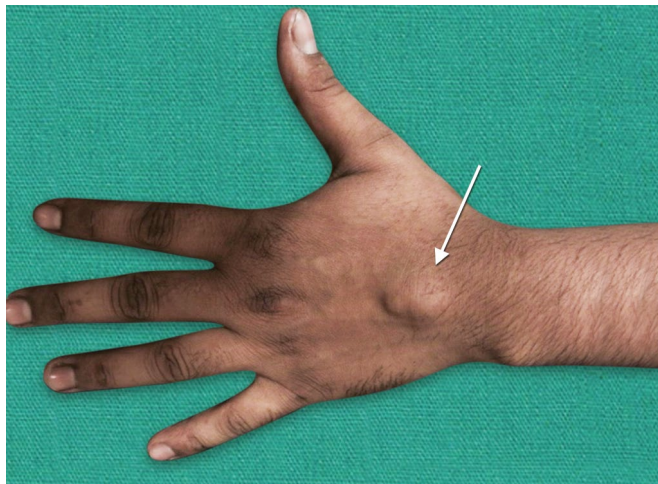


Fig. 12.6: Ganglion cyst.

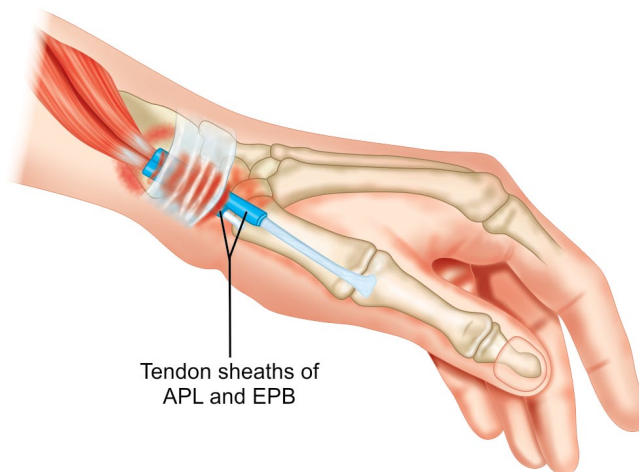


Fig. 12.7: De Quervain's disease.



Fig. 12.8: Finkelstein test.

De Quervain's disease is tenovaginitis affecting the common tendon sheaths of the extensor tendons of the first extensor compartment of the forearm, viz., abductor pollicis longus and extensor pollicis brevis (Fig. 12.7). Common age group is 30–50 years with women affected 6 times more frequently than men. The cause is almost always related to overuse, working with the wrist in ulnar deviation as in inflating a BP cuff, lifting a heavy pan off the stove, etc.

On examination, these patients classically have tenderness at the radial styloid process. The pathognomonic (not diagnostic) clinical test is Finkelstein's test (Fig. 12.8). In this test, on grasping the patient's thumb and pulling it ulnarward, excruciating pain is felt over the styloid tip.

X-rays are usually normal and clinical examination and history point the main diagnosis. However, one must rule out arthritis at the base of the thumb, superficial radial nerve entrapment or neuroma and intersection syndrome

(tenosynovitis at the crossing of the extensor pollicis brevis and abductor pollicis longus over the extensor carpi radialis longus and brevis). Tenderness and crepitus in intersection syndrome is felt 4–6 cm proximal to the extensor retinaculum.

Management: Initially conservative. Activity may be restricted by giving a thumb spica splint. Nonresponders may be given local heat therapies and steroid injections into the tendon sheaths. Recalcitrant cases may need surgery to release the first dorsal compartment to relieve pressure (splitting open the thickened tendon sheaths).

TRIGGER FINGER/THUMB

It is a stenosing tenosynovitis of the flexor tendon sheaths of the fingers/thumb that mostly affects people older than 45 years of age. The flexor tendon sheath is thickened and constricted so that free gliding of the tendon in the sheath does not occur freely. Often the constriction is present at the mouth of the tendon sheath (i.e. at the level of metacarpophalangeal (MCP) joint/at the level of A1 pulley), so that the tendon becomes trapped right at the point of entry into the sheath (Fig. 12.9). This produces the characteristic snapping of the finger on trying to flex and extend it, referred to as triggering. Triggering is more pronounced in the morning time.

Although the condition is idiopathic, important predisposing factors include: local trauma, rheumatoid arthritis, gout and diabetes.

The middle and ring fingers are the most commonly involved areas and constriction is most commonly found in front of the MCP joints in trigger finger and IP joints in trigger thumb. On examination, one may palpate a tender nodule in front of the MCP joints.

Initial treatment usually is nonoperative and includes stretching, night splinting, and ultrasonic heat therapy. Corticosteroid injections are also effective. Patients with diabetes mellitus may be more refractory to nonoperative management, in all such cases surgical release reliably relieves the problem.

DUPUYTREN'S CONTRACTURE (PALMAR FIBROMATOSIS)

Dupuytren's disease is a proliferative fibrometaplasia of the subcutaneous tissue of the palm. Palmar fascia is replaced by fibrous tissue in the form of nodules and cords that may result in secondary progressive and irreversible finger joint flexion contractures. Usually it starts in ring followed

by little finger and goes on to involve other fingers (Figs. 12.10A and B). Flexion contractures most commonly occur at the MCP joints, followed by proximal interphalangeal (PIP) joints and then distal interphalangeal (DIP) joints.

Associations: 5% of patients with Dupuytren disease have similar lesions in the medial plantar fascia of one or both feet (Ledderhose's disease), and 3% of patients have plastic penile induration (Peyronie's disease).

Predisposed individuals: The condition is commonly seen in men of Scandinavian and Celtic origin (Male:Female = 10:1) in their fourth to sixth decade of life. People those who are diabetics, alcoholics, smokers and who are on anti-epileptic drugs are at greater risk of affection. Although the exact cause remains unknown, hand trauma and heavy manual labor performed by an individual may be contributing factor. Hereditary predisposition is present in some families.

Clinical presentation: The involvement is commonly bilateral (45%), but it is rarely symmetrical. In the early stages, thickening of palmar aponeurosis or nodules may be felt at the base of ring or little fingers while in later stages flexion deformity of the fingers develops. Nodules are typically painless, although larger ones may be painful due to associated tenosynovitis. Garrod nodules or "knuckle pads" are common on the dorsum of the PIP joints in these patients.

Treatment: An elderly patient with minimal deformity needs no treatment. But when flexion contractures of fingers at PIP joints exceed 15 degrees and at MCP joints exceed 30 degrees then contracted fascia has to be resected (total/partial fasciectomy). An amputation also rarely is indicated in case incorrecable recurrent flexion contractures have made the finger non useful.

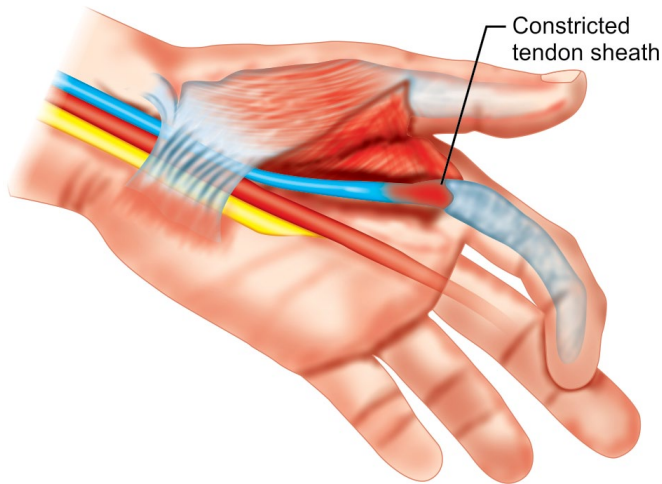
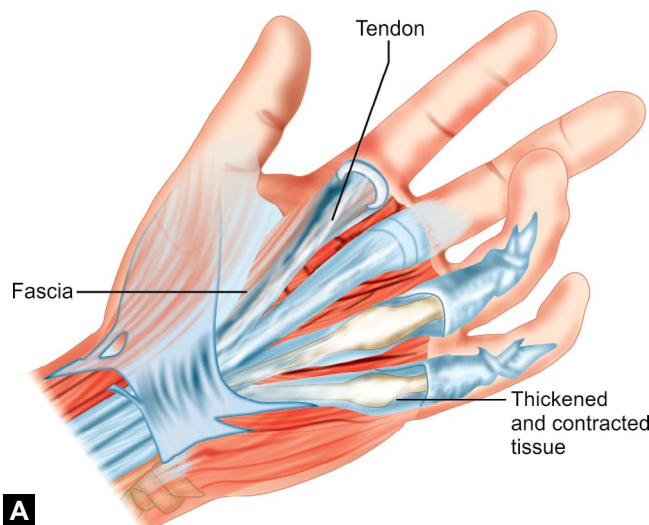


Fig. 12.9: Trigger finger.



A



B

Figs. 12.10A and B: (A) Dupuytren's contracture; (B) Dupuytren's contracture developing in the ring finger.
Courtesy: Figure 12.10B: Dr Charlie Goldberg, UCSD, California.

HIGH-YIELD POINTS

- Hallux Saltans is palpable triggering of Flexor hallucis longus tendon in foot along the medial wall of calcaneum.
- In Dupuytren's contracture structures contracted in fingers can be remembered by mnemonics: "**No GPS-Location**" (Natastary ligament, **G**rayson ligament, **P**retendinous band, **S**piral band and **L**ateral digital sheath)
- *Mallet/baseball finger* (for details see chapter 2): Rupture of the extensor tendon (EDC) from the base of distal phalanx (Fig. 12.11)
- *Jersey finger*: Rupture of the flexor tendon (FDP) from base of distal phalanx
- *Symphalangism*: Congenital ankylosis of proximal interphalangeal joints of hands and feet
- *Kirner's deformity*: Palmo-radial curvature of the middle phalanx
- *Camptodactyly*: PIP joint flexion deformity.

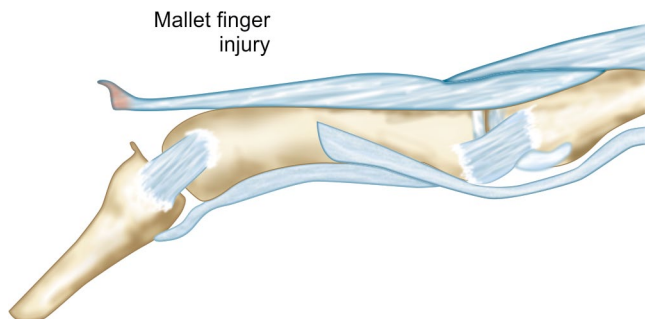


Fig. 12.11: Mallet finger.

- *Clinodactyly*: Curving of little finger towards ring finger due to a wedge shaped middle phalanx.
- Congenital Trigger Thumb is also a known entity. In this triggering in the thumb resolves mostly by the age of one year. However, an important differential to exclude is Congenital clasped thumb (absence of extensor tendons of thumb).

ELBOW AFFECTIONS

TENNIS ELBOW

Tennis elbow, also called lateral epicondylitis, is chronic tendinitis of common extensor origin [more specifically extensor carpi radialis brevis (ECRB)], seen mostly in patients between 30 and 50 years of age. It is hypothesized that chronic stress (overuse) causes small tears (micro-tears) that lead to fibrocartilaginous metaplasia, calcification and painful vascular reaction in the tendon fibers close to the site of origin on lateral epicondyle. Most commonly it affects individuals (male and female ratio almost equal) whose work profile involves repetitive wrist extension against resistance and twisting activities. It may be seen in tennis players (those using the back hand stroke) or at times even in nonplayers as those involved in activities like hammering, squeezing clothes, carrying loads like a bucket or suitcase in hand, etc.

Clinical Testing

One may classically find tenderness localized to lateral epicondyle of humerus or just distal to it. The important diagnostic tests are:

Cozen's test: Pain in the region of the lateral epicondyle during resisted extension of the wrist (Fig. 12.12).

Maudsley's test: Pain in the region of the lateral epicondyle during resisted extension of the middle finger (Fig. 12.13).

Mill's maneuver: Patient's elbow is extended and wrist is flexed to 90 degrees and then the patient is asked to narrate

any pain at lateral epicondyle region, presence of which is considered a positive test for tennis elbow (Fig. 12.14).

X-Ray

X-ray is usually normal. Rarely one may find calcification adjacent to the lateral epicondyle.

Differential Diagnosis

Radial tunnel syndrome (*see* Page 217)

Management

Initially management is conservative (NSAIDs and activity modification). A wrist strap may be given to provide local support and restrict activities. Local heat therapies and intralesional steroid injections are useful in resistant cases. Some other treatment options involve injecting blood at the site to cause fibrosis or injecting platelet rich plasma (PRP) to provide growth factors and promote healing of lesion. Only in recalcitrant cases is surgery needed where the origin of ECRB is debrided and if needed released.

GOLFER'S ELBOW

This condition, much less common than tennis elbow, is just its medial counterpart, where chronic overuse



Fig. 12.12: Cozen's test.



Fig. 12.13: Maudsley's test.



Fig. 12.14: Mill's maneuver.



Fig. 12.15: Triceps tendinitis with calcification at triceps insertion.

tendinitis involves the common flexor pronator origin (especially flexor carpi radialis). The tenderness in these cases is localized to medial epicondyle of humerus. The affected people generally have a work profile that involves squeezing actions or swinging actions of forearm (like golfers, cricketers, baseball players, etc.) or frequently have to perform overhead motions (like persons involved in racket sports). The diagnostic and management aspects are basically the same as in the above condition.

HIGH-YIELD POINTS

- Even in Golfer's, the more common epicondylitis is lateral (Tennis elbow)

- In nonresolving cases of epicondylitis the end resort remains epicondylectomy (but no more than 25% of the epicondyle should be removed)
- *Baseball pitcher's elbow/little leaguer's elbow*: (Medial epicondylar apophysitis)—these are counterparts of the Golfer's elbow seen in young players before or around the age of puberty.
- Little Leaguer's shoulder—This is a Salter Harris Type I injury of the proximal humerus.
- *Javelin throwers elbow*: Painful elbow in a javelin thrower. Two etiologies are described:
 - Sprain of ulnar collateral ligament of elbow
 - Tendinitis of triceps insertion at olecranon (Fig. 12.15).

SHOULDER AFFECTIONS

IMPINGEMENT SYNDROME/PAINFUL ARC SYNDROME

This is a clinical condition characterized by pain anteriorly over the shoulder in 60–120 degrees of shoulder abduction. During shoulder abduction the greater tuberosity slides under the acromion, the movements being smoothed by presence of subacromial bursa in the space between the opposing bony surfaces. Also present in the space is the tendon of supraspinatus that inserts on the greater tuberosity. Any condition that compromises this space may result in painful arc syndrome like (Fig. 12.16):

- Subacromial bursitis
- Supraspinatus tendinitis or partial tears of the tendon

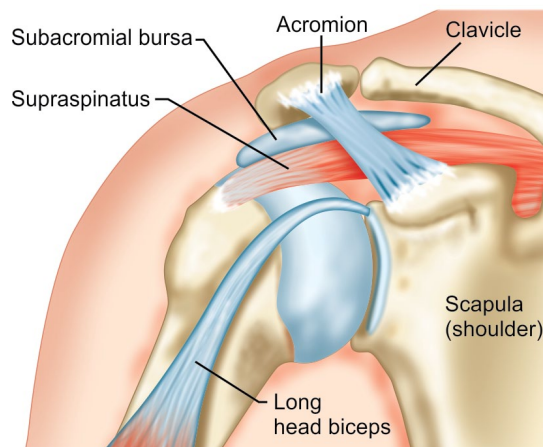


Fig. 12.16: Causes of impingement syndrome.

- Calcific tendinitis (calcifications in supraspinatus)
- Fracture of greater tuberosity
- A hook shaped acromion.

Clinical Testing

Following clinical tests may help in reaching the diagnosis:

Neer's impingement sign: Passively raise the arm in forward flexion while stabilizing the scapula (to prevent scapulothoracic movement) (Fig. 12.17). This causes pain.

Neer's impingement test: 5 mL of 1% lidocaine is injected into subacromial space. After several minutes, Neer maneuver is again performed and this time pain is absent or significantly reduced, indicating that subacromial impingement was the cause of pain.

Hawkins-Kennedy test: Forward flexion of shoulder to 90 degrees with forcible internal rotation reproduces the impingement pain. This test is sensitive, but not very specific (Fig. 12.18).

Imaging

X-rays may show calcific deposits or fracture. MRI is the investigation of choice and reveals bursitis or tendinitis in the region.

Treatment

Initial treatment is conservative with anti-inflammatory medicines and restriction of overhead activities. Local heat therapies may be added to provide relief. Steroids may be



Fig. 12.17: Neer's impingement test.



Fig. 12.18: Hawkins-Kennedy test.

given as local injections. In recalcitrant cases surgery in the form of arthroscopic decompression and debridement (acromioplasty) is usually indicated.

ROTATOR CUFF TEAR AND ARTHROPATHY

Relevant Anatomy

Rotator cuff comprises of four tendons that surround and stabilize the shoulder joint (Fig. 12.19). These include:

Subscapularis: It originates from the costal surface of scapula and goes laterally crossing the humeral head anteriorly to insert on lesser tuberosity of humerus. It is mainly an internal rotator of shoulder.

Supraspinatus: Originates from supraspinous fossa, travels under the acromion and attaches to greater

tuberosity. Involved in first 15 degrees of shoulder abduction (15–90 degrees of shoulder abduction is by deltoid and above 90 degrees of abduction is by trapezius and serratus anterior).

Infraspinatus and teres minor: Both these muscles come from the lower part of dorsal surface of scapula and go laterally on posterior aspect of shoulder to insert on the greater tuberosity. Both are primarily involved in external rotation.

Trauma to shoulder during unaccustomed athletic activity at times may lead to tears in these muscles, most commonly to supraspinatus. In older individuals age related fatty degeneration may result in spontaneous ruptures in these tendons. Long standing cuff tears then give rise to degeneration of the shoulder joint referred to as cuff arthropathy.

Clinical Testing

For Subscapularis

Belly-press test (Gerber)/Napoleon sign: Place the hand on the belly and press the abdomen or against the examiner's hand. If subscapularis is normal, patient presses the abdomen with hand by internal rotation of shoulder and elbow remain in front of the trunk. If the subscapularis is weak, the internal rotation can not be maintained and patient presses the abdomen by extending the shoulder or by flexing the wrist and elbow drops back behind the trunk (Fig 12.20A).

Lift-off test (Gerber): Arm is internally rotated with dorsum of hand touching the back. If the patient is able to lift hand off the back, test is positive, implying a normal subscapularis (Fig. 12.20B).

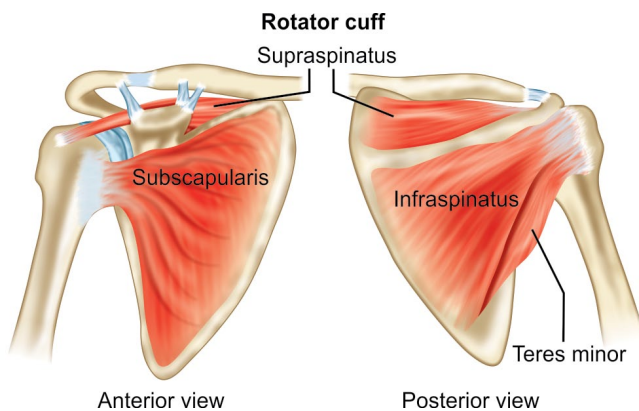


Fig. 12.19: Rotator cuff.



Figs. 12.20A and B: Belly-press test and the lift-off test.

For Supraspinatus

Jobe's empty can sign: Place shoulder in 90 degrees abduction and, 30 degrees forward flexion and, internally rotated so that thumb points toward the floor. Patient is asked to elevate the arm against resistance. Weakness suggest tear of supraspinatus (Fig. 12.21).

For Infraspinatus and Teres Minor

Drop sign: Patient's arm is held in abduction and full external rotation, with elbow in 90 degrees flexion and palm facing forward. The examiner then supports elbow and releases the wrist. If patient is not able to maintain this position actively (remember both these muscles are

external rotators), the arm drops and this suggests weakness mainly of infraspinatus (Figs. 12.22A and B).

Diagnosis

Magnetic resonance imaging (MRI) is the investigation of choice. Arthroscopy is the gold standard and is a diagnostic tool as well as treatment.

Management

Treatment is mainly conservative in old people and in those with low demand. NSAIDs for pain relief along with stretching and cuff strengthening exercises are instituted. If not much pain relief is noticed in 6 weeks, one may proceed to surgery. There is an increasing trend toward early surgical repair of tears in young high demand patients, especially athletes. However, there may be some late presentations in all age groups where the patient comes late and the torn cuff has retracted and is unreparable. In such cases, in patients less than 70 years of age treatment is appropriate tendon transfers (donors being pectoralis major, latissimus dorsi, trapezius etc) while in older patients a reverse shoulder arthroplasty is the recommended treatment (see Chapter 14).

PERIARTHRITIS SHOULDER/FROZEN SHOULDER

Adhesive Capsulitis

Adhesive capsulitis also known as frozen shoulder refers to a situation where the patient has painful restriction of shoulder motion in all planes but on X-ray everything



Fig. 12.21: Empty can sign.



Figs. 12.22A and B: Drop sign.

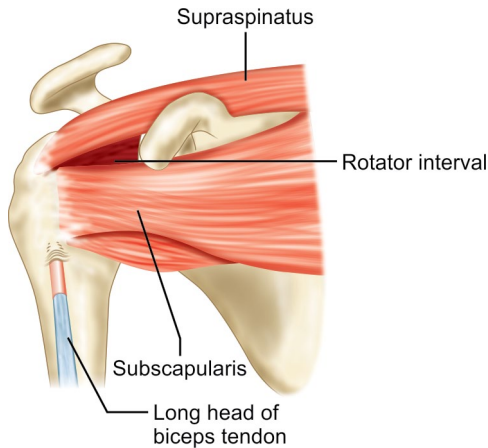


Fig. 12.23: Rotator interval.

seems to be normal. The pathology in such cases is attributable often to a condition called periarthrititis or more appropriately adhesive capsulitis. In this condition there is fibroblastic proliferation in the shoulder joint capsule that leads to adhesion formation and consequent stiffness and pain on attempted movement. The changes more severely involve an area in the anterior part of capsule called the rotator interval (Fig. 12.23) and coracohumeral ligament. Rotator interval is a triangular space bounded above by the supraspinatus tendon, below by the subscapularis and, medially the apex is formed by the coracoid process of scapula. It contains the coracohumeral ligament that is most prominently involved.

Associations

The condition generally affects people of 40–60 years age and is almost five times more common in diabetics. It is bilateral in 20–30% cases. Other important associations include hyperthyroidism, hypothyroidism, Parkinson's disease, myocardial infarction and stroke.

Clinical Presentation

Patients present with severe pain and stiffness in the affected shoulder. There is global restriction of movements in all directions affecting both passive and active range of motion (unlike cuff arthropathy where only active movements are lost). The first movement to be lost is external rotation then abduction.

Course of the Disease

The disease is self-limiting with a chronic course that spans over a period of 6–12 months passing through three characteristic phases:

- Painful phase (few weeks to months)
- Phase of progressive stiffness/freezing phase (4–12 months)
- Resolution/thawing phase (few weeks to months).

Diagnosis

Diagnosis is mainly clinical. Radiographs are mostly normal. MRI may show thickening in the area of rotator interval.

Differential Diagnosis

Caries sicca (tuberculosis of shoulder, see page 249).

Treatment

Disease is self-limiting and initial treatment is thus conservative. NSAIDs can relieve pain. Physiotherapy is advised to prevent stiffness. Local heat therapies and steroid injections may be used in nonresponders. Manipulation under general anesthesia to break adhesions may be tried in those where conservative therapies fail. Manipulation must not be very aggressive as fracture of proximal humerus can result. Recalcitrant cases may need arthroscopic rotator interval release and adhesiolysis. Diabetic status should be controlled.

HIGH-YIELD POINTS

- Bear Hug test is a clinical test described for subscapularis.
- The most common rotator cuff muscle to tear is the Supraspinatus.
- Now a days, arthroscopic repair of Rotator cuff muscles is the surgical treatment of choice.
- The forgotten muscle of the rotator cuff is the subscapularis.
- Codman's paradox method is used for manipulation under GA in frozen shoulder that is effective in preventing a damaging rotational torque to humerus
- Cumulative trauma disorders—These are disorders of musculoskeletal systems and nerves resulting from repetitive stress to the involved body part. These can involve bone, muscle, tendons, ligaments and nerves. Examples of cumulative trauma disorders include—De Quervain tenovaginitis, tennis elbow, carpal tunnel syndrome, impingement syndrome, stress fracture, shin splints, athletic pubalgia etc.

FOOT AFFECTIONS

MORTON'S NEUROMA

It is basically a neuritis and perineural fibrosis of common digital nerves of foot. The term is a misnomer as histopathologically it is not a neuroma. Third interspace is most commonly affected, followed by second.

Typical symptoms are pain and paraesthesia in web space and adjoining toes. Compression of interspaces by compressing the foot results in a palpable click (Mulder's click).

A trial of conservative treatment which includes wide toe box shoes, metatarsal bars or pads, local steroid injections should be tried at first, but they are commonly not very effective. Surgery includes decompression or resection of nerve, which gives complete relief.

PLANTAR FASCIITIS

This condition results due to inflammation of the plantar aponeurosis at its attachment site on the calcaneum. Patients classically present with heel pain that is worst in the morning when patient takes the first few steps. Pain reduces as the day goes by. Obesity is a risk factor. On examination there is tenderness usually localized to the medial aspect of the calcaneal tuberosity.

X-rays are usually normal, but may reveal a spur on the under surface of the calcaneum, the significance of which is doubtful (Fig. 12.24). Calcaneal spur is not considered to be the cause of heel pain. Diagnosis is mainly clinical.

Management involves oral anti-inflammatory medications, use of heel pads to relieve pressure, local ice application and ankle stretching exercises. Extracorporeal shock-wave therapy and ultrasonic therapy are also beneficial. Nonresponders may benefit from local steroid injections while in recalcitrant cases, excision of the calcaneal spur or release of fascia may be opted.

HIGH-YIELD POINTS

- **Causes of heel pain:** Plantar fasciitis and calcaneal spur, retrocalcaneal bursitis, achilles tendinitis, Sever's disease (osteochondritis), tarsal tunnel syndrome, bone tumor or osteomyelitis of calcaneum, gout and rheumatoid arthritis.
- Plantar calcaneal spurs are also sometimes seen in Rheumatoid arthritis and in sero negative spondyloarthropathy cases (like Ankylosing spondylitis, Psoriatic arthropathy etc.).



Fig. 12.24: X-ray showing calcaneal spur.

METATARSALGIA

It refers to pain in forefoot region due to increased stress over metatarsals, mainly the head region. It is a symptom which has multiple etiologies. Common causes include Morton's neuroma, stress fracture, foot deformities (hammertoes, hallux valgus), poor footwear, intense training, arthritis etc. Investigations include X-rays to rule out stress fracture and arthritic changes, inflammatory markers (Erythrocyte sedimentation rate, C-reactive protein, rheumatoid factor) to rule out rheumatoid arthritis or an inflammatory pathology. MRI is more specific and sensitive for stress fractures. Treatment is based on underlying cause. If no cause can be found general measures include changing footwear, using metatarsal bars in foot, weight loss and reducing activity.

HIGH-YIELD POINTS

- **Ainhum (*dactylolysis spontanea*):** This is a condition classically seen in people of African descent where a constriction spontaneously forms at the base of a toe (most commonly 5th toe) and over few months or years it progresses to lead to an auto-amputation of the digit. The condition is likely to be genetic and in around 75% cases it is bilateral.
- **Turf Toe:** This refers to sprain of the metatarsophalangeal joint of the great toe occurring due to hyperextension classically seen in professional American footballers who have been playing on the recently introduced artificial turf (a more rigid surface as compared to the natural grass).

IMPORTANT TENDON AFFECTIONS AND MISCELLANEOUS CONDITIONS

IMPORTANT TENDON AFFECTIONS

Rupture of a tendon is not an uncommon injury especially in elite sports men. The most common site for a tendon rupture in the body is the Supraspinatus (part of Rotator cuff, already discussed above) followed closely by the Tendo Achilles, while rupture of biceps, quadriceps mechanism/patellar tendon, pectoralis major have also been reported.

Most commonly these ruptures are secondary to an overuse injury although purely traumatic ruptures can also occur. Some general risk factors for all tendon ruptures include an increasing age, history of smoking, comorbidities like diabetes, SLE, gout, uraemia due to any cause and drugs (steroids, fluoroquinolones etc.). Few important tendon ruptures are as follows:

Tendo Achilles (TA) Rupture

Although TA is the longest and strongest tendon in the body, it is also a very frequently ruptured tendon. The rupture is mostly seen in 30-40 years aged athletes who have excessive hind foot valgus/varus, sub-talar hyperpronation, increased femoral anteversion, a limb length discrepancy, high body mass index or have a stretched running schedule or when they are training on unfamiliar running surface.

The classical site of rupture is generally 3 cm proximal to its insertion into the calcaneal tuberosity, as there is a hypovascular zone present in this area of tendon. Clinically these patients present with a weak plantar flexion causing difficulty in the push off phase of the gait cycle. Simmonds

test (Fig. 12.25) is mostly employed for clinical detection of this rupture. Normally, squeezing the calf irritates the gastrosoleus and the muscle contracts causing visible plantar flexion of foot; however, when TA is torn, this maneuver is not followed by any noticeable plantar flexion of the foot. Other clinical tests that may be employed include the O'Brien's needle test and the Matles knee flexion test. Radiographs can also guide the diagnosis.

Important radiological signs include- decrease in size and obliteration of Kager's triangle (a space filled with fatty tissue, bordered by margins of the anterior surface of the Achilles tendon, the upper part of the calcaneus, and the posterior surface of the deep flexor tendons.), decreased Toygar angle (angle of the posterior skin surface adjacent to the tendo achillis; less than 150° is indicative of tendo-achillis rupture) and thickened Tendo Achilles. USG is another useful investigation to make the diagnosis in doubtful cases but MRI is the investigation of choice.

Treatment of fresh ruptures (<8 weeks old) is a primary repair, however, in neglected cases one needs to go for a Modified Teuffer's operation (reinforcement of torn TA with peroneus brevis). If one TA ruptures, chances of contralateral TA rupture also increases.

Biceps Tendon Ruptures

The ruptures of the biceps tendon (see Fig. 12.26 for biceps anatomy) most commonly involve the long head of biceps



Fig. 12.25: Simmonds Thompson test.

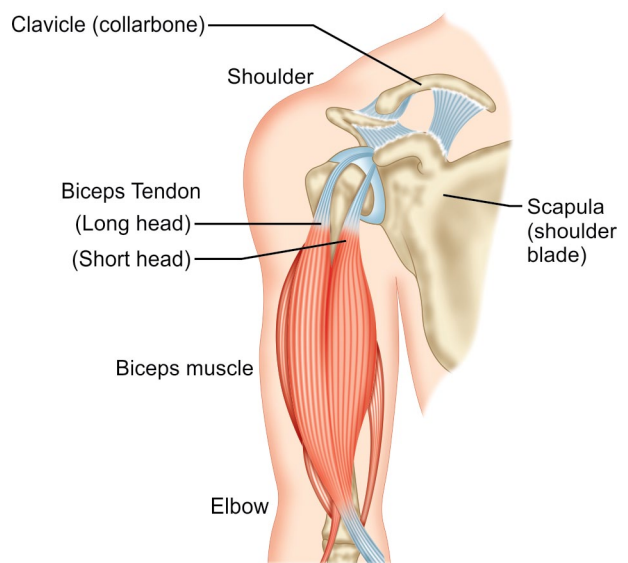


Fig. 12.26: Diagrammatic depiction of the biceps anatomy.

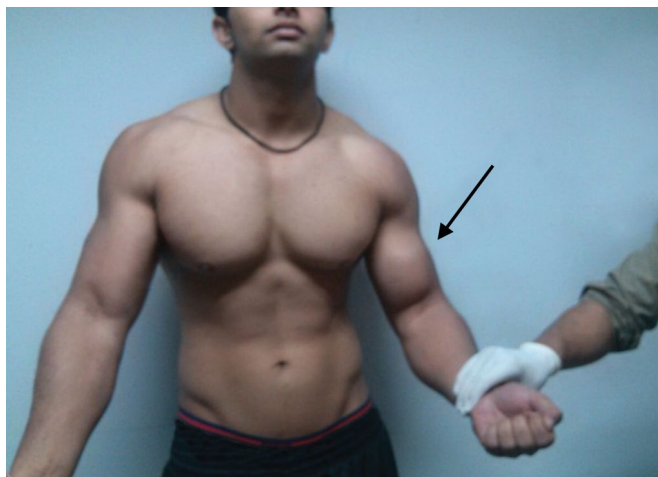


Fig. 12.27: Left biceps of patient is torn at distal attachment and has retracted and bunched up in the arm (Popey sign) (arrow).

with most common site of rupture being inter tubercular sulcus followed by myotendinous junction and glenoid attachment site. Hence, proximal tendon ruptures are far more common than distal tendon ruptures. Most of the tears are either traumatic injuries or overuse injuries in people who are in professions involving heavy overhead work or an overuse of shoulder.

The proximal tendon ruptures are more common in fourth to sixth decade of life and are clinically almost indistinguishable from rotator cuff tears presenting with pain around shoulder. The distal tendon ruptures are particularly common in young weight lifters and may present with the classical Popey sign (Fig. 12.27). The tendon ruptures near the distal attachment and retracts and bunches up in the arm. Distal tendon ruptures may present with significant loss of supination strength (40-50% loss).

Treatment is generally tenodesis (fixation to bone) of the torn tendon in case of low demand/aged patients but in high demand sportsmen the ruptures mostly need to be repaired surgically.

Bicipital Tendinitis: This refers to inflammation of long head of biceps tendon seen mostly in patients involved in overhead activities. Most of these patients present with pain anteriorly in the shoulder and tend to have concomitant rotator cuff disease or labral tears in the shoulder. Two important clinical tests that are used in identifying this pathology are the Speed and the Yergason's test. Speed's test (Fig. 12.28) is performed by asking the patient to resist the downward pressure at the wrist while the arm is in 60-90 degrees forward elevation, elbow extended and forearm supinated. The maneuver produces pain in shoulder in cases with the pathology. In Yergason's test (Fig. 12.29) patient's elbow is flexed to 90 degrees and the patient is asked to supinate the forearm against resistance while examiner looks for pain along the proximal biceps.



Fig. 12.28: Speed's test.

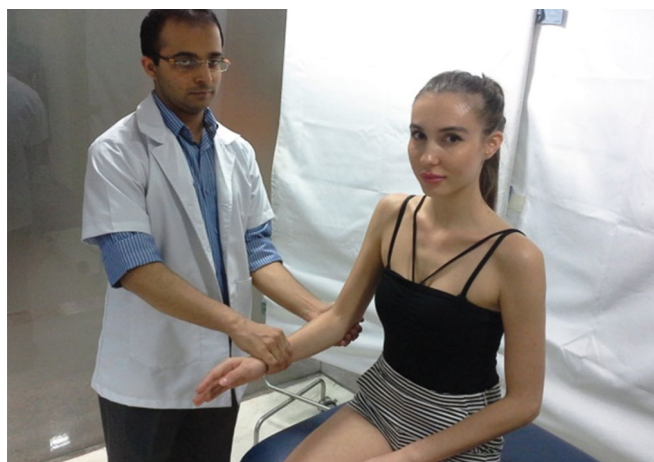


Fig. 12.29: Yergason's test.

Iliopsoas Tendinitis and Bursitis

These both conditions are closely interrelated and present with similar signs and symptoms.

Iliopsoas tendinitis is inflammation of the iliopsoas tendon resulting from acute trauma or more commonly from overuse injury (sports which requires repetitive hip flexion). Iliopsoas tendinitis is usually seen in ballet dancers, runners, jumpers and other athletes. Patients present with activity related groin pain following running, walking, etc. There may be complaint of snapping about the hip joint. On examination passive hip extension and active hip flexion (supine patient raises the heel 15 degree off the bed) are painful. Ludloff test (In sitting position on the chair, patient raises his thigh against resistance) often exacerbates pain. Treatment is almost always conservative with rest, ice and NSAIDs. Recalcitrant cases may require corticosteroid injection in bursa or tendon sheath or rarely tendon release.

External Coxa Saltans (Snapping hip/Dancer's hip)

This is characterized by audible or palpable snap about the hip with movement, with or without pain. Snapping of hip is divided into extra-articular and intra-articular snapping based on the etiology. Common causes of Intra-articular snapping are labral tear, loose bodies, and osteochondral fragments. Patients often complain of catching and locking sensation into the hip joint with movement.

Extra-articular snapping is further divided into internal and external forms. In internal form snapping usually occurs anterior to the hip joint and is commonly attributed to movement of iliopsoas muscle or its tendon against iliopectineal eminence. In external form snapping occurs lateral to the hip joint and is attributed to movement of Iliotibial band (ITB) over the greater trochanter.

Snapping commonly occurs in persons who demand heavily on their hip joint (Ballet dancer and athletes requiring repetitive and extreme hip flexion and abduction). Snapping may be associated with pain if underlying tendon gets inflamed. Snapping may be reproduced by some provoking movements like internally and externally rotating the extended and adducted hip, flexing the extended hip and extending the flexed hip or a combination of these movements. Diagnosis is mainly clinical in extra-articular snapping but dynamic ultrasound and MRI are helpful in making diagnosis of intra-articular snapping and to reveal the tendon and iliotibial band pathology in extra-articular snapping.

Conservative treatment in form of Ice, rest, NSAIDs, ultrasonic and interferential therapies along with stretching of iliopsoas and ITB is effective in majority of cases. Injection of a local anesthetic with a corticosteroid into the involved bursa or around the tendon sheath is also useful. Resistant cases may require lengthening of iliopsoas tendon and ITB. Intra-articular snapping due to labral tear and loose body often requires arthroscopic repair of labrum or removal of loose body.

RUPTURES OF KNEE EXTENSOR MECHANISM

Knee extensor mechanism includes the Quadriceps femoris (the rectus femoris and the three vasti) inserting on the patella, the patella and the ligamentum patella inserting into the tibial tuberosity. The most common cause of disruption is actually a fracture of patella followed by quadriceps tendon (ruptures mostly at myotendinous junction especially in older people) and then by the patellar tendon (ruptures mostly in young people).

Quadriceps and patellar tendon may rupture following a violent and forceful contraction of the quadriceps in flexed knees in a jump or fall from a height.

Patients present with pain and tenderness around distal or proximal pole of patella. On examination there is an extension lag. A hemarthrosis may be present and if painful it should be aspirated. Plain X-ray may show avulsion fracture of patella or tibial tuberosity. In patellar tendon rupture patella may be abnormally high (patella alta) due to unopposed pull of quadriceps. Similarly it may be low lying (patella baja) in quadriceps rupture. Diagnosis is confirmed on ultrasonography or MRI.

Management

Partial tear with full active knee extension can be effectively managed conservatively with extension bracing/cast. Limb is immobilized in cylindrical cast/ brace with full knee extension for 4-6 weeks followed by range of motion and strengthening exercises. Operative repair is required in all cases of complete tear with extension lag.

Jumper's knee (Patellar tendinitis): It is tendinitis of the knee extensor mechanism usually occurring at the tendo-osseous junction of the lower pole of patella. On X-rays one may find Tooth sign (periosteal reaction of the anterior patellar surface).

HIGH-YIELD POINTS

- *Tennis leg:* This refers to tear of the medial head of the gastrocnemius at the junction of the muscle belly and the aponeurosis.
- The most common congenitally absent muscle is the Pectoralis Major.
- Longest muscle in the body: Sartorius
- Strongest muscle in the body: Gluteus Maximus
- Strongest ligament in the body: Illo femoral ligament (Ligament of Bigelow)
- Strongest tendon in the body: Tendo Achilles
- Largest bursa in the body: Iliopsoas bursa
- Most common cause of tendon ruptures is overuse.
- Most common tendon to rupture is supraspinatus followed by Tendo Achilles.
- Dancer's tendinitis is tendinitis of flexor hallucis longus in dancers.
- Hoffa syndrome: Inflammation in Infra-patellar fat pad leading to anterior knee pain.

SPORTS HERNIA/ATHLETIC PUBALGIA GILMORE'S GROIN

This condition refers to strain at the insertion site of rectus abdominis (an abdominal muscle) on the pubic bone. Partial tear occurs in the muscle and when abdominal organs press against this muscle, it causes pain. The conjoint tendon insertion and the adductor longus insertions on the pubis may also be involved.

The patient is usually an athlete who presents with pain in groin region noted mostly on exertion. There is no visible swelling, compared to the more common inguinal hernia, although uncommonly in late cases a true herniation might occur. Hip movements mostly are unaffected but one may find tenderness localized to pubic tubercle.

Management is usually conservative with strengthening exercises and rest. Resistant cases may need Nesovic's operation (Inguinal myorrhaphy).

MEDIAL TIBIAL STRESS SYNDROME (SHIN SPLINTS)

This is a condition where the patients complain of exertion related pain in shins, mostly bilateral. It is believed to be a repetitive stress injury of posterior tibial or soleus muscle, seen mostly in runners and athletes in response to repetitive muscle contractions causing a tibial strain. Patients present with exertional pain located at posteromedial aspect of leg (mostly distal 1/3rd of leg). At times there may be stress fractures evident in the posteromedial cortex of tibia. X-rays are usually negative. Technetium pyrophosphate bone scan help to differentiate periostitis (seen in medial tibial stress syndrome) from stress fracture. Treatment is mainly conservative and involves a strict activity modification, stretching and aerobic training.

FIBROMYALGIA (FIBROSITIS)

It is a chronic musculoskeletal pain syndrome of unknown etiology that is classified under nonarticular rheumatism. It affects all age groups and is more prevalent in females of middle age. Patients present with gradual onset widespread pain (pain in all four limbs and trunk for at least

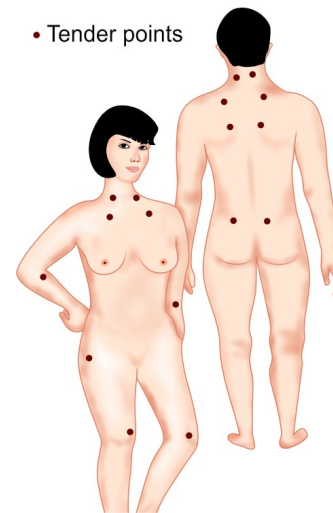


Fig. 12.30: Tender points in fibromyalgia.

3 months), tenderness [multiple tender points, (Fig. 12.30)] and other frequently associated symptoms (generalized fatigue, sleep disturbances, depression, anxiety, bowel upset, etc.). Tenderness on digital palpation over tender points is a characteristic feature.

Treatment

Patients usually fail to respond to one form of therapy so multimodality treatment is required for fibromyalgia. Patient education, physical therapy for pain (interferential therapy, transcutaneous electric nerve stimulation) and exercise program is mainstay of treatment. Patient may need psychological or psychiatric treatment. Analgesics and antidepressants are often helpful.

CHAPTER

13

Amputations, Prosthetics and Orthotics



INDICATIONS AND PRINCIPLES OF AMPUTATIONS

INTRODUCTION

Amputation is an iatrogenic or a traumatic removal of all or part of a limb when its blood supply is irreversibly compromised by a disease or severe injury. Overall, most common indication of amputation is peripheral vascular disease while in young patients trauma remains the most common cause. In children most common cause of amputation is congenital limb deficiency followed by trauma.

INDICATIONS

The absolute indication for an amputation is irreversible ischemia in a diseased or traumatized limb due to any cause. At times amputation is needed in malignant neoplasms and fulminant infections (like clostridial gas gangrene) in view of saving the patient's life over the limb. A rare but important situation is congenital anomaly in a child that has a severely mal formed limb that needs amputation for improving cosmesis and function.

However, one must exercise caution in some special situations:

- *Crush limb injury*: Mangled extremity severity (MES) Score (see Chapter 2) is the best predictor of limb salvage in such situations
- Frostbite is an indication for amputation, but one should delay amputation until viable tissue is clearly demarcated
- Clostridial infection of limb causes severe myonecrosis that spreads rapidly within 24 hours and has a typical mousy odor. Such limbs may better be amputated to prevent a fulminant life-threatening toxemia.

TYPES

It can be either "guillotine/open" when skin over the stump is not closed or "closed" when the skin over the stump is sutured. In open amputations the skin closure is performed after a few days once adequate granulation tissue has formed (secondary closure). In amputation, bone is cut at desired level and stump is covered with surrounding muscles and skin flaps.

Types of skin flaps are:

- *Skewed* (when there is long posterior flap, commonly preferred for below knee amputation)
- *Scandinavian* (equal medial and lateral flaps, mainly for peripheral vascular disease).
For stabilization of muscles the two methods include:
- Myodesis, (here the muscles are attached to bone end by drill holes; preferred method but contraindicated in patients with severe ischemia)
- Myoplasty, (Muscle is sutured to periosteum/fascia/muscle of antagonist group). Muscles should be divided preferably 5 cm distal to bony resection level.

One must also know how to handle the neurovascular bundle. The blood vessels must be doubly ligated with nonabsorbable sutures to prevent any accidental bleeding postoperatively. Nerves are gently pulled and transacted with a sharp knife to ensure the end retracts proximal to bone ends thereby preventing the formation of a painful neuroma at the stump. Large nerves like sciatic nerve carry their vasa vasora along and hence should be ligated before transacting.

USE OF TOURNIQUET

The use is desirable as it lessens the blood loss and provides a clear surgical field. However, the limb must be properly exsanguinated before inflating the tourniquet.

Caution: The use is contraindicated in cases where indication is infection or malignancy for the fear of spreading the pathology proximally.

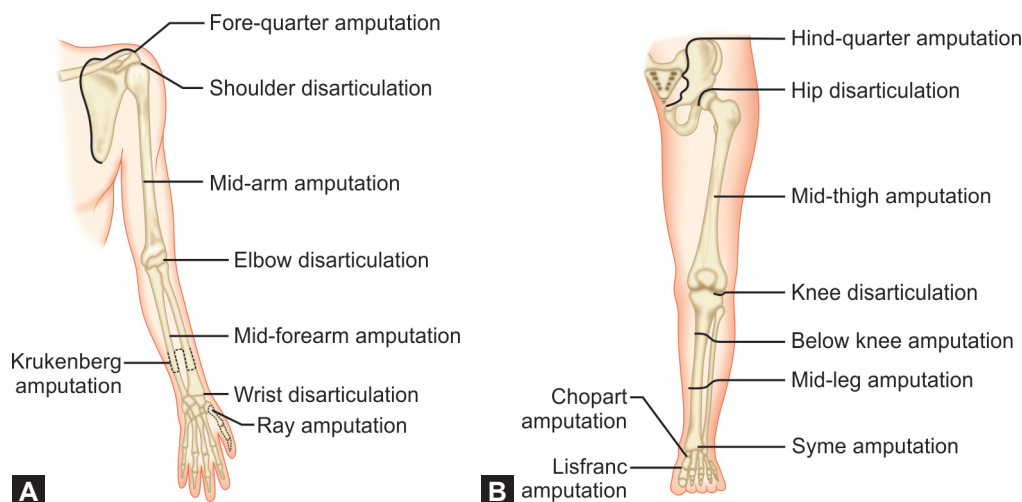
RECOMMENDED LEVELS IN VARIOUS AMPUTATIONS

Above knee amputation: 18 cm below the tip of greater trochanter or 12 cm from the medial joint line.

Below knee amputation: 15 cm from the medial joint line (ideally at the musculotendinous junction of gastrocnemius)

Above elbow amputation: 20 cm from the acromion

Below elbow amputation: 18 cm from the tip of olecranon.



Figs. 13.1A and B: Levels of various amputations. (A) Upper limb and (B) Lower limb.

AFTER TREATMENT

Once the amputation has been completed, the stump is dressed. Two types of dressings are in use. A soft dressing is the traditional dressing with gauze, cotton and bandage. A rigid dressing involves application of a molded plaster of Paris (POP) slab over the conventional dressing to cover the stump. This helps in restricting blood loss and also enhances wound healing. Another major advantage is that a temporary prosthesis can be fitted to the stump and patient can be mobilized immediately.

Wrapping a crepe bandage over the stump is also advisable to promote shrinkage and maturation. Stump exercises are immediately started to maintain range of motion (ROM) of adjacent joints and build up strength of muscles controlling the stump. Prosthetic fitting and gait training can be accomplished in about 2–3 months time after the amputation.

Nomenclature for Some Specific Amputations (Figs. 13.1A and B)

LOWER LIMB AMPUTATIONS

Hind quarter amputation: Whole of lower limb with half of ilium is removed

Lisfranc amputation (Lisfranc, France; 1815): Amputation at tarsometatarsal junction

Chopart amputation: Midtarsal joint amputation

Syme's amputation: Talus and calcaneus are removed with rotation of heel pad to close the stump through the dome of ankle. Distal tibia and fibula 0.6 mm proximal to the periphery of ankle joint are also removed along.

- Modifications of Syme's amputation:
 - **Sarmiento's amputation:** Distal tibia and fibula are cut 1.3 mm proximal to the ankle joint with excision of medial and lateral malleoli.

- **Boyd's amputation:** In Boyd's amputation, after teleotomy calcaneus is shifted forward and calcaneotibial arthrodesis is done.
- **Pirogoff's amputation:** Vertical section of calcaneus is performed through middle and calcaneus is rotated forward to fuse to tibia. Teleotomy is performed as well.

Basically, both Boyd and Pirogoff's amputation involve calcaneotibial arthrodesis.

UPPER LIMB AMPUTATIONS

Fore quarter amputation: Removal of scapula along with a portion of clavicle and whole of the upper limb.

Krukenberg amputation: It is done in below elbow amputation to provide a pincer grasp. It is primarily indicated in blind bilateral hand amputee. This amputation separates the radius and ulna in a shape of forceps (motored by pronator teres muscle) to be used as a makeshift pincer (Fig. 13.2).

Ray amputation: Removal of a finger/toe with respective metacarpal/metatarsal

*Knee disarticulation and Syme's amputation have end bearing stumps. End bearing stumps are those stump where bone ends are metaphyseal and weight can be taken through the end of stump.

Special Considerations in Children

For performing an amputation in children, Krajchik principles are often looked at. In children aim should be to preserve the growth plates and all length possible. In lower limb amputations, where ever Possible knee joint should be preserved. Disarticulation is preferred over transosseous amputation. The most common issue that bothers in most cases is the terminal bone growth that sometimes needs revision. One way of dealing with this problem is to use epiphyseal caps to cover medullary canals.

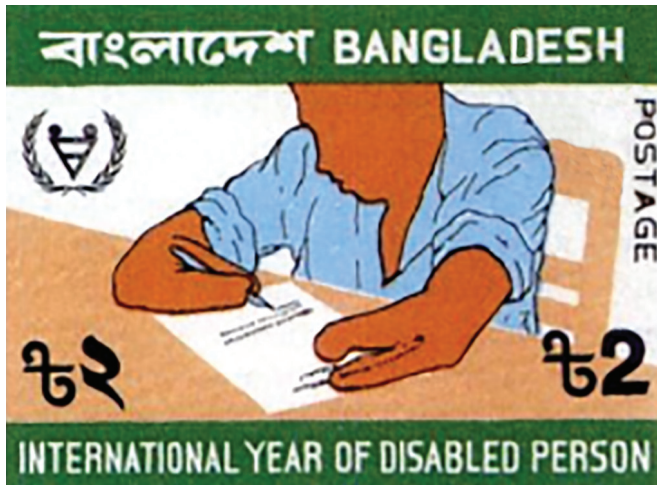


Fig 13.2: Stamp published by Bangladesh government showing Krukenberg amputation.

COMPLICATIONS

Bleeding: Bleeding from stump can occur due to inadequate hemostasis achieved during surgery or slipping of a ligature. Exploration may be done if needed, else aspirate to prevent infection and give a pressure bandage.

Skin flap necrosis: Suture line tension must be low to prevent this. Small areas may heal while large area of necrosis mostly needs revision flaps.

Infection: Mostly seen in diabetic patients or in cases with peripheral vascular disease (PVD). One must always prefer a secondary skin closure whenever there is doubt about the viability of soft tissues around the stump. Any discharge from wound must be handled seriously. Excessive periosteal stripping during the procedure should be avoided as if this gets complicated further by infection, a ring sequestrum may form at the stump.

Postamputation neuroma: To prevent postamputation painful neuroma the nerves are generally pulled before cutting them during amputation and in case it forms, the best treatment is excision. Pulsed radiofrequency ablation, interferential therapy (IFT) and transcutaneous electrical nerve stimulation (TENS) may also have a role. TENS is most preferred and works by inhibiting pain gate pathway.

Phantom sensations: It refers to a situation where the patient feels that the amputated part is still present and he is getting discomforting sensations from that part. Phantom sensations are extremely distressing and are present in 30–80% patients. More proximal is the amputation, more are the sensations felt. The problem tends to diminish with time. By the end of first year phantom limb gradually shortens to stump end (known as Telescoping). Treatment is difficult and antidepressants, opioids, ketamine, TENS

and increased prosthetic use all have been reported to provide some benefit.

Joint contractures: These result from improper positioning of stump and inadequate physiotherapy. Contractures preclude the appropriate use of prosthesis and hence must be prevented.

HIGH-YIELD POINTS

- Most common amputation: Transtibial
- Risk of complications is increased with a low total lymphocyte count (TLC) level and a low serum albumin level.
- In diabetics a below knee amputation is relatively contraindicated due to vascular issues.
- Lisfranc and Chopart amputations have severe tendency to go into equinus.
- Amputees are advised to walk slow and take longer steps rather than taking several short steps to lower their energy consumption
- Ultrasound has least role in treatment of postamputation neuroma.
- *Jactitation*: distressing phantom limb pain with involuntary jerking of stump
- There is no phantom limb sensation in congenital limb deficiencies and patients with brain damage
- Energy expenditure with amputation at various levels is inversely proportional to length of remaining limb
 - Long below knee amputation: 10%
 - Medium below knee amputation: 25%
 - Short below knee amputation: 40%
 - Average above knee amputation: 65%
 - Hip disarticulation: 100%
- Syme's Amputation (Edinberg; James Syme; 1843)
 - It is more energy efficient than mid-foot amputation even though it is more proximal
 - Stable heel pad is most important factor in Syme's amputation as migration of the heel pad is the most important complication. It has been used successfully to treat forefoot gangrene in diabetics but patent tibialis posterior artery is a prerequisite.

INTERESTING HISTORICAL FACTS

- Amboise Pare, a French military surgeon, introduced the use of ligatures in 1529. He is called Father of amputation surgery. He also performed the first elbow disarticulation.
- First hip disarticulation was performed by William Kerr of England in 1774.
- Antiseptic techniques (Father of antiseptic surgery) were introduced by Joseph Lister (1867).

PROSTHETICS AND REHABILITATION OF AN AMPUTEE

INTRODUCTION

For an amputee the duty of a surgeon extends way beyond performing the procedure. Infact, a much bigger challenge is rehabilitation of these patients. It is imperative to integrate emotionally with the patient, provide him physcological counseling and make his disability socially acceptable by providing an appropriate replacement for the lost part.

Prosthesis (A greek word meaning an addition, application or attachment) is an artificial device (metallic or non-metallic) that replaces a body part. It is a functional replacement for an amputated or congenitally malformed or missing limb. A prosthesis can replace an internal body part (e.g. hemiarthroplasty prosthesis) or replaces the part externally (e.g. artificial limb). It is easier to design a prosthesis for a lower limb but in upper limb considering the dexterity, functional demand and cosmesis, still a lot of advancement is needed to achieve satisfactory designs.

TYPES

A prosthesis may be provided at times only for a cosmetic problem while at most other times the aim is to improve functional performance. Since the prosthesis lacks proprioception and muscle power, the power forces are

provided to the prosthesis by movement of either the residual limb or the normal limb on other side. Such prostheses are called as body powered prosthesis. In other cases one can opt for an externally powered prosthesis (battery-operated prosthesis or myoelectric prosthesis).

PARTS OF PROSTHESIS (FIG. 13.3)

Socket: It is the part of the prosthesis that contacts the stump. These could be end bearing sockets where whole weight is borne by the end of the stump or total contact sockets where weight is distributed throughout the surface of the socket. They are custom made to fit the stump.

Suspension: It holds the socket in contact with the stump.

Prosthetic extension with substitutive joints: Some prosthesis may have additional joints depending upon the length of the prosthesis and parts of the limb to be replaced.

Terminal device: This is the distal most part of the prosthesis. The traditional terminal device for lower limb prosthesis has been the solid ankle cushion heel (SACH) foot (introduced by University of California in 1995).

SACH foot: It has a compressible heel cushion wedge that provides “pseudo-plantar flexion” after heel strike and a rigid keel (Fig. 13.4). Ankle action is provided by the soft rubber heel which gets compressed under load during the early part of the stance phase of walking (Figs. 13.5A and B).

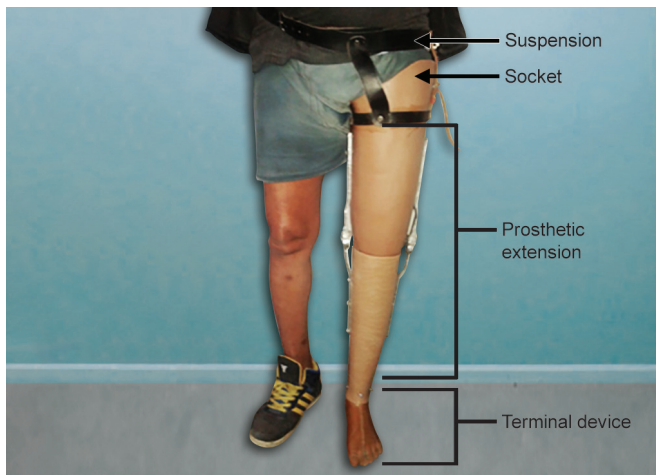


Fig. 13.3: Parts of a prosthesis.

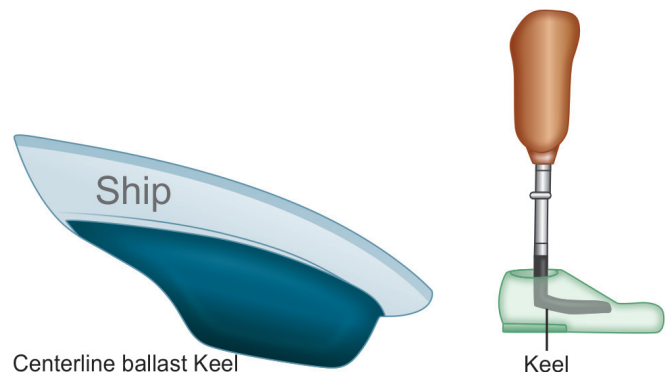
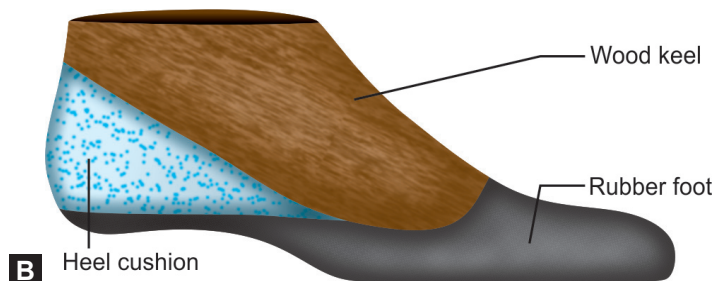


Fig. 13.4: Keel of a ship compared with keel of foot.



Figs. 13.5A and B: Solid ankle cushion heel (SACH) Foot.



This SACH foot has been modified by an Indian doctor, Dr PK Sethi, to make it suitable for barefoot walking. The same has been named as Jaipur foot (Fig. 13.6), (for differences see Table 13.1).

SAFE foot: The solid ankle-flexible-endoskeletal (SAFE) foot has the same principle as the SACH foot with the ability for the sole to conform to slightly irregular surfaces and thus makes it better suited for the amputee to walk over uneven terrain. Feet of this type make walking easier because of the flexibility, and are sometimes called “flexible keel” feet (Fig. 13.7).

Most recent developments include the dynamic response feet, which are indicated where the gait patterns generate enough energy to be worth storing. For this reason, they are called “energy storing feet”. They incorporate elastic keel structures that absorb energy during midstance and terminal stance, and then “release” it during pre-swing and initial swing.



Fig. 13.6: Jaipur foot.

Some Commonly used Prosthesis

Above knee prosthesis: Quadrilateral socket prosthesis

Below knee amputation: Patellar tendon bearing prosthesis

Syme's amputation: Canadian Syme's prosthesis

Partial foot amputations: Shoe fillers.

WALKING AIDS

Walking aids are used for ambulation of injured or disabled patients who are not able to bear body weight on their lower limbs. Walking aids enable the patients to bear some body weight on their upper limbs. Examples of walking aids are sticks, crutches, walking frames and parallel bars.

Adjustment of height of walking aids

1. If axillary crutches are of proper height they should extend from a point 5 cm or three finger breadths below the axillary fold to a point on the ground 15 cm in front of and lateral to the tips of the toes.
2. Height of crutches and walking frames should be adjusted so that patient's shoulder are depressed over the crutches and elbows are in 30 degrees flexion when patient holds the hand grips of walking aid.

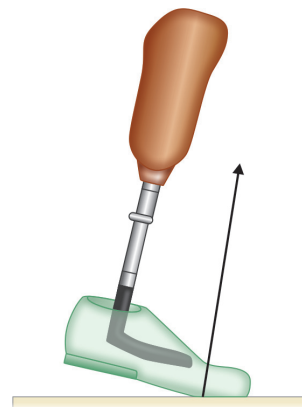


Fig. 13.7: Flexible keel.

Table 13.1: Differences between Jaipur and SACH foot

Jaipur Foot	SACH Foot
It looks like a normal foot so patient does not need to wear shoe over it. However amputee can use shoe satisfactorily over it. For the same reason bare foot walking is possible.	It requires a shoe over it for walking and also to hide it. Bare foot walking is not possible.
It has metallic keel which is confined to ankle only and allows for dorsiflexion and plantar flexion to take place and thus allowing for squatting.	It has rigid wooden keel which does not allow for dorsiflexion and plantar flexion and thus squatting is not possible.
Jaipur foot allows for adequate inversion and eversion of terminal piece so walking on uneven and muddy surface is comfortable.	Walking only on level ground is comfortable as it does not allow for inversion and eversion at “sub tarsal” level.
Cross-legged sitting is possible due to adequate forefoot adduction and transverse rotation of foot	Cross-legged sitting is not possible.
It is very cheaper than SACH foot. It can be made by locally available material by rural artisan.	It is very costlier than Jaipur foot. Modern technology with skilled personnel is required to manufacture it.
Shock absorbing capacity is less than SACH foot.	Shock absorbing capacity is more than SACH foot.
It meets the socio-cultural needs (bare foot walking, cross legged sitting) of Indian and many Asian populations.	It does not meet such needs.

ORTHOTICS

INTRODUCTION

Orthosis is a device that aids/supports a body part and enhances the structural and functional characteristics of the skeletal system.

They can be classified as “static” or “dynamic” types. Static orthosis is rigid and gives support without allowing any movements. It basically supports a fractured limb, a painful joint or is used to prevent joint contractures by keeping limbs in functional position. A Dynamic orthosis device allows movements in some directions.

NOMENCLATURE OF ORTHOTICS

Earlier various orthoses were called by different names, viz., braces, calipers, splints, corsets etc. To avoid confusions a systematic nomenclature was developed in 1972 to name the orthoses. This terminology uses the first letter of each joint crossed by the orthosis in sequence, with letter “O” fixed at last (signifying orthosis). For example, an orthosis for foot drop crosses the ankle and is called ankle-foot orthosis and designated as AFO, a

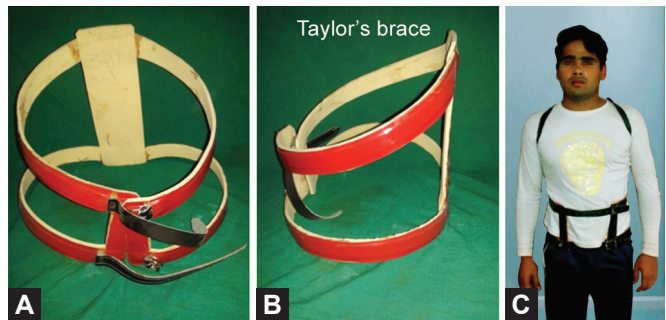
- thoracolumbosacral orthosis (TLSO), affects the thoracic, lumbar and sacral regions of the spine.
- Orthoses can be classified as per the different regions for which they are given:
- Spinal orthosis
 - Cervical orthoses (Figs. 13.8A to C): Cervical orthosis, previously known as cervical collar, post collars, cervicothoracic orthosis, halo devices
 - Thoracolumbar orthosis (Figs. 13.9A to C)
 - Lumbosacral orthosis
 - Upper limb orthoses: Wrist Hand Orthosis (WHO, previously known as cock-up splint)
 - Lower limb orthoses: Ankle Foot Orthosis (AFO, previously called as below knee caliper), Knee Ankle Foot orthosis (KAFO, prevoiusly known as above knee caliper), Hip Knee Ankle Foot Orthosis (HKAFO), Knee orthosis (KO, previously known as knee brace) etc.

Footwear Modifications

Footwear can also be modified to relieve or improve pain in many foot problems. The footwear modifications that are available for various orthosis are given in Table 13.2.



Figs. 13.8A to C: Cervical orthoses.



Figs. 13.9A to C: Thoracolumbar orthosis.

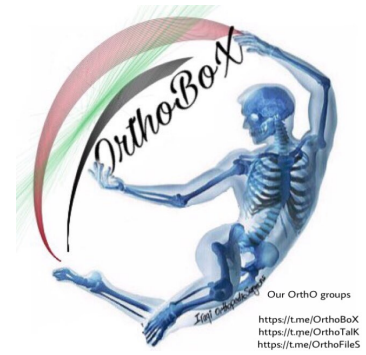
Table 13.2: Footwear modifications for various orthosis	
Footwear	Type of orthosis
Thomas heel (Crooked and Elongated heel)	Flat foot
CTEV shoes	Clubfoot
Silicone Heel pad	Planter fasciitis
Metatarsal Bar	Metatarsalgia
Inner/Medial border raise	Genu valgum
Outer/Lateral border raise	Genu varum and osteoarthritis
Metatarsal pad	Corn
Arch support	Flat foot

HIGH-YIELD POINTS

- The earliest recorded use of lower limb prosthesis was that of a Persian soldier, Hegesistratus, who cut off his own foot to escape from stocks in 484 BC. He apparently replaced his foot with a wooden foot, as reported by Herodotus.
- In India first artificial limb center was started in Armed Force Medical College, Pune.
- “Osseointegration” is a new method of attaching the artificial limb to the body. This method is also sometimes referred to as exoprosthesis (attaching an artificial limb to the bone), or endo-exoprosthesis.
- An ambulatory aid is a device that helps a patient maintain functional independence by increasing the area of support and maintaining the center of gravity within that area. The important ambulatory supports include: canes, crutches and walkers.
- A cane or crutch is always carried in hand opposite to the side of pathology.
- Weight transmission in single cane is 20–25% but in axillary crutch it is up to 80%.
- Jewett brace is a hyperextension thoracolumbar orthosis that prevents a patient from bending forwards. It may be used to facilitate healing of an anterior wedge fracture involving the T10 to L3 vertebrae.
- Floor reaction orthosis (also called Ground Reaction AFO): A floor reaction AFO is generally used with patients affected by neurological conditions such as spina bifida, cerebral palsy and post-polio paralysis. In these cases, the floor reaction AFO functions to maintain the affected joints in proper alignment, to accentuate knee extension at midstance and compensate for weak or absent gastro-soleus (calf) muscles.

CHAPTER 14

Recent Advances



TOURNIQUET IN ORTHOPEDICS

Introduction

Tourniquets are commonly used in orthopedic surgeries to achieve blood less clean surgical field. They are applied proximally on the limb to get blood less clean field distally.

History

- Joseph Lister was the first to use a tourniquet in 1864.
- Friedrich von Esmarch devised a flat rubber bandage for exsanguination (now known as “Esmarch”)
- Modern pneumatic tourniquet was first introduced by Harvey Cushing in 1904.

Types

- Pneumatic tourniquets.
- Non-pneumatic tourniquets—Petit (belt) tourniquet and Esmarch (elastic) tourniquet.

In modern orthopedic surgeries, pneumatic tourniquets have replaced non-pneumatic tourniquets.

How to Use (Figs. 14.1A to C)

Proximal part of the limb is wrapped with several layers of cast padding (usually of cotton) and then tourniquet is applied over the padding. Limb is first exsanguinated by elevation and applying Esmarch from distally to proximally. After exsanguination of limb tourniquet is inflated. Inflated tourniquet prevents blood flow distal to tourniquet and provides blood free clean surgical field.

Principles of Its Use

- Tourniquets are available in several sizes. Wide tourniquets are more effective at lower inflation pressures than narrow ones, so widest possible cuff size should be used.
- Solutions used in limb cleaning and painting (savlon, betadine, etc.) should not be allowed to seep underneath the tourniquet. It may cause chemical burn.
- Safe time and pressure—2 hours are usually considered as the safe upper limit for tourniquet application.

A general practice is to keep the pressure 100 mm Hg plus the systolic blood pressure for the upper arm and 100–150 mm Hg plus the systolic blood pressure for the thigh tourniquet. If more than 2 hours are required then tourniquet should be deflated for 10 minutes and then again inflated.

Limb occlusion pressure (LOP)—Ideally LOP should be used to calculate the tourniquet inflation pressure. LOP is the pressure at which the distal arterial blood flow as evidenced by the Doppler probe, stops. Tourniquet should be inflated to a pressure higher than the LOP to cover the intraoperative fluctuations in arterial pressure.

Contraindications

Peripheral vascular disease, deep vein thrombosis (DVT), severe infection of the limb and compromised cardiac status are relative contraindications to use of tourniquets.

Complications

- Nerve injury is the most common complication of tourniquet application. Nerve injuries are more common in upper limb tourniquets and radial nerve is the most common nerve to be involved. Excessive pressure and insufficient pressure (causing venous congestion) both may cause nerve palsy. Direct pressure by cuff on the nerves is the most common cause followed by ischemia, so nerve injury is related more to cuff pressure than duration.
- *Post-tourniquet syndrome*: It is mainly related to ischemia. It presents with postoperative edema, redness, pain dysesthesia and stiffness. It is caused by muscle injury due to high mechanical pressure.
- *Chemical burns*: It may occur due to seepage of antimicrobial solutions used for skin preparation underneath the tourniquet cuff.
- Compartment syndrome is infrequent but most devastating complication.

BONE CEMENT

Bone cement is one of big inventions that have revolutionized orthopedic surgeries.



Figs. 14.1A to C: (A) Modern pneumatic tourniquet; (B) Application of tourniquet; (C) Application of Esmarch before tourniquet inflation.

Constituents

Commercially available bone cement has one liquid (methyl methacrylate monomer) and one powder component (polymer, polymethylmethacrylate). Mixing of polymer to monomer produces dough that can be modulated. Bone cement actually acts as grout (space filler, no adhesive properties) by producing interlocking fit between surfaces.

How to Use

It is prepared during surgery by mixing the monomer liquid and polymer powder. After mixing in a bowl it is stirred well. It takes few minutes to become dough when it is ready to apply on the bone surfaces or to insert into the femoral canal. After application of bone cement on the bone surfaces (or putting bone cement into femoral canal) implantation is done.

Whole Process is Divided into Four Phases

1. *Mixing time:* Time taken by the powder and liquid to fully integrate.
2. *Dough time:* From the beginning of mixing to the point when the cement no longer sticks to surgical gloves.
3. *Working time:* Time during which the cement can be manipulated and the prosthesis can be inserted. Implant must be implanted before the end of working time.
4. *Setting time:* Time from the beginning of mixing until the time at which the exothermic reaction heats the cement (usually 10–12 minutes).

Mixing Techniques

Mixing techniques have been discussed in Table 14.1.

Table 14.1: Mixing techniques

First generation	Hand mixing of cement, it is put in canal by finger.
Second generation	Femoral canal is prepared by brush and made dry. Cement restrictor is inserted into the canal and then cement is put using cement gun.
Third generation	Vacuum-mixing of the cement to reduce cement porosity Pulsatile lavage of bone surfaces and femoral canal Cement pressurization for better bone penetration.
Fourth generation	Prosthesis is inserted using distal and proximal centralizers to ensure an even cement mantle.

HIGH-YIELD POINTS

- Barium sulphate is added to bone cement to make it radio-opaque.
- *Antibiotic bone cement*: Many antibiotics can be added to bone cement to be delivered at surgical sites. Gentamicin, tobramycin, cefuroxime, vancomycin are commonly added antibiotics.
- Factors increasing bone cement dough and setting time.
 - Decreased temperature of OT
 - Decreased humidity
 - Slow mixing
- *Bone cement implantation syndrome*—It occurs at the time of cementation, reaming, prosthesis insertion or at the time of tourniquet deflation in replacement surgeries and characterized by hypoxia, hypotension and/or loss of consciousness.

PLASTER OF PARIS AND MODERN SYNTHETIC CAST MATERIAL

Traditionally orthopedic casts are made up of plaster of Paris ($\text{CaSO}_4 \cdot \frac{1}{2} \text{H}_2\text{O}$). Cotton bandages impregnated with plaster of Paris when mixed with water, soluble form of calcium sulfate becomes insoluble ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) and hardens.

Modern fiberglass casts (Fig. 14.2) are available as ready to apply roll. They are composed of a fabric matrix impregnated with a thermal setting resin that will set-up at room temperature.

Plaster is more pliable and has a slower setting time than fiberglass. This gives sufficient time to apply and mold the cast before it sets, thus it is more reasonable option in displaced fractures which require adequate molding of the cast to keep the fracture reduced. Fiberglass is lighter than plaster, more radiolucent (X-rays of fractures with fiberglass have better visibility than plaster) have less setting time, but expensive. Fiberglass is commonly used for nondisplaced fractures and severe soft-tissue injuries.

**Fig. 14.2:** Fiber cast.

PRINCIPLE OF LIMB SALVAGE AND MEGAPROSTHESIS

Treatment of musculoskeletal malignant tumor has come long way from amputation as the sole treatment to limb salvage surgery. Osteosarcoma is the most common tumor for which the limb salvage surgery is needed.

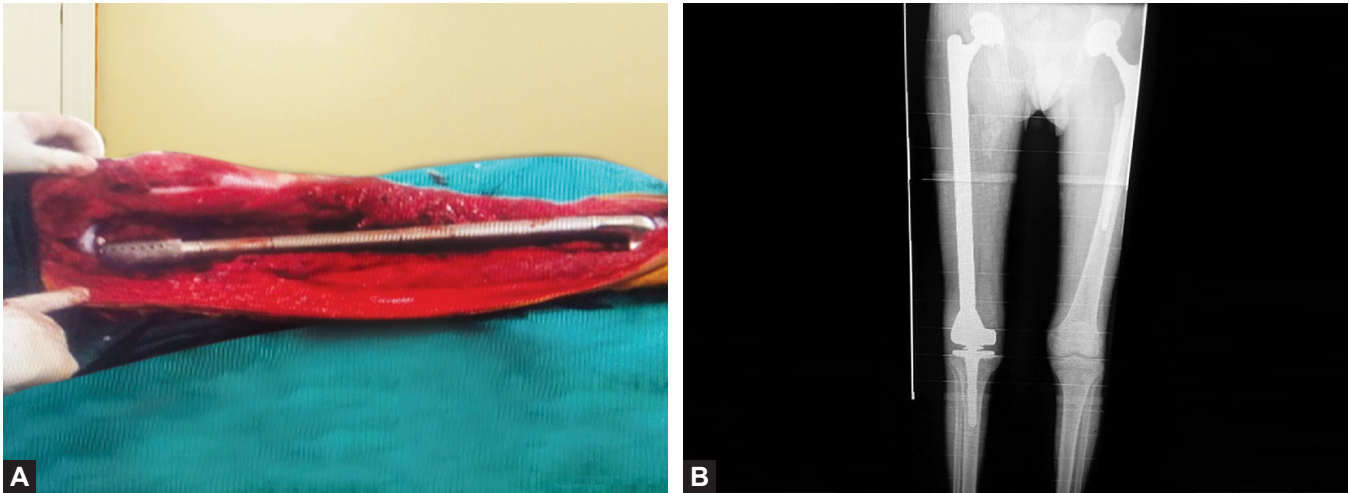
Work-up of patient: All patients should undergo an array of imaging modalities to know the extent of disease. MRI is the most important tool to see the local extension of the disease. Bone scan is used to screen for skip lesions and involvement of other bones. CT scan of chest is done to rule out pulmonary metastases as lung is the most common site for metastasis from musculoskeletal tumor. PET-CT has revolutionized the way of doing tumor staging. Histopathological diagnosis should be made by biopsy. It is important to plan the biopsy site so as entire biopsy track could be excised en block along with the tumor.

Indications and Contraindications for Limb Salvage

Any tumor that can be adequately removed with a safe margin and leaving behind a functional limb should be the candidate for limb salvage. Involvement of major nerves and/or vessels, pathological fracture and inadequate motors (muscles) after resection are relative contraindications for limb salvage surgery.

Megaprosthesis

Megaprosthesis is a large prosthesis that is designed to replace the large segment of bone and adjacent joint. A customized megaprosthesis is made according to patient's dimension. With modern endoprosthetics, it is possible to replace whole of the bone with adjacent joints (Figs. 14.3A and B).



Figs. 14.3A and B: (A) Replacement of whole femur with knee and hip joints with megaprosthesis. (B) AP view of thigh with hip joint and knee joint showing megaprosthesis (on right side) left side is showing total hip replacement.
Courtesy: Dr. RK Sharma, (Indraprastha Apollo hospital, New Delhi).

AO/ASIF (ASSOCIATION FOR THE STUDY OF INTERNAL FIXATION) AND LATEST CONCEPTS IN FRACTURE FIXATION

The AO foundation was started by a Swiss study group, Arbeitsgemeinschaft für Osteosynthesefragen (German for “Association for the Study of Internal Fixation”, or AO), in Switzerland in 1958. Eminent members in the founder group were Maurice Muller (main proponent of internal fixation concept, orthopedic surgeon of the century title conferred by international orthopedic society SICOT), Robert Danis and Ruedi Allgower. This foundation runs training courses on internal fixation of fractures for orthopedic surgeons in many countries.

The AO Principles of Fracture Care

- Anatomic reduction of fractures
- Stable fixation
- Preservation of the blood supply
- Early mobilization to allow full rehabilitation.

These early principles of fracture fixation have evolved over time. Now it is a fact of consensus that anatomical reconstruction and stable fixation are required only for fractures involving joint and articular surfaces. In diaphyseal fractures anatomical reduction is not necessary and utmost importance should be given to keep the damage to blood supply of fracture fragments minimum. Development of minimally invasive surgeries have carried the AO principles a step forward.

MINIMALLY INVASIVE PLATE OSTEOSYNTHESIS

Intramedullary nailing does not provide stable fixation of periarticular fractures and traditional open reduction

and internal fixation (ORIF) of periarticular fractures require large incisions with potential damage to periarticular blood supply and carries the increased risk of infection and delayed fracture healing/nonunion. To overcome these problems minimally invasive plate osteosynthesis (MIPO) was developed.

Principles of MIPO Technique

- It is particularly useful for comminuted metaphyseal fractures. Anatomically contoured periarticular plates [locked compression plates (LCPs)] are introduced through small incisions (Fig. 14.4) in epiperiosteal plane.
- Fracture site is not opened, and fracture reduction is done by indirect techniques using traction and reduction forceps.
- Locked compression plate does not compress the periosteal blood supply. Thus fracture’s biological environment is largely maintained and it improves the healing rates and reduces complications.

Advantages of MIPO Technique

Faster healing, less non-union rates, reduced complication rates, short operative time and smaller skin incisions are advantages of MIPO technique.

ARTHROSCOPIC SURGERY

Arthroscopic surgery is a minimally invasive surgical procedure which allows examination and management of many joint disorders using an arthroscope and arthroscopic instruments. An arthroscope is an endoscope that is inserted into the joint through a very small incision (called as the *viewing portal*) to visualize the interior of the joint. Arthroscope is attached to a camera and a light source to see inside the joint (Fig. 14.5). Arthroscopic instruments



Fig. 14.4: MIPO technique—Insertion of plate in epiperiosteal plane without opening the fracture site.

are specially designed instruments that are inserted into the joint through another small incision (the *working portal*) to perform the procedure. The working and the viewing portals, though are fixed for every joint, the can be switched as per the surgeons convenience. Arthroscopic surgery has various advantages over conventional surgery.

Advantages

- Small incisions and scars. Usually stab incisions are given for making portals which heal with minimal scarring.
- Less postoperative pain.
- *Faster rehabilitation and faster return to work:* Selected arthroscopic procedures can be performed under local anesthesia.
- Reduced hospital stay.
- *Making the diagnosis:* Arthroscopy is the gold standard in diagnosis of knee ligament injuries.
- Reduced complication rate.
- *Dynamic assessment of joint:* Though functional MRI has now been launched in many centers, to assess the status of the joint during various movements, arthroscopic evaluation of the joint in motion, has been done for long to assess the same.
- Perform procedures which cannot be performed through open surgery, e.g. partial meniscectomy, meniscus repair.

Indications

With the development of newer instruments and better understanding of the mechanism of injuries, the indications of arthroscopic surgery are on an increase. Knee is the most common joint to undergo arthroscopic procedures, followed by shoulder, though virtually every major joint in the body (viz. elbow, wrist, hip and ankle) are being “scoped’ for diagnostic and therapeutic purposes. The common indications for arthroscopic surgery of knee and shoulder are listed in Table 14.2.

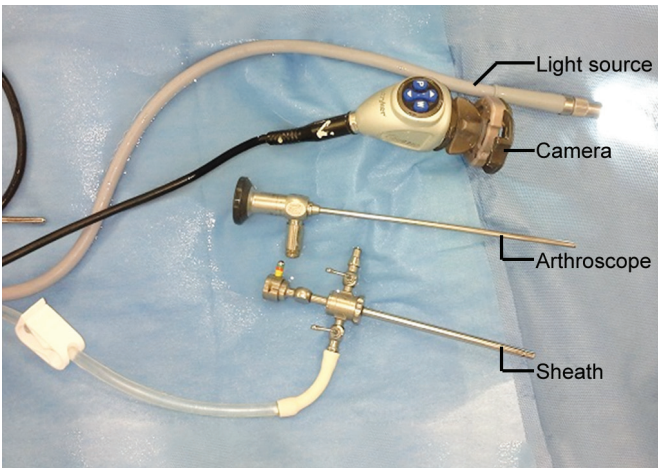


Fig. 14.5: Arthroscope—camera and light source.

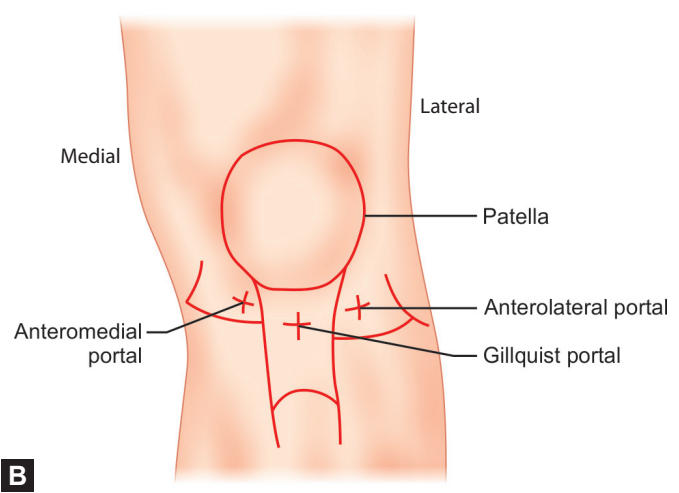
Table 14.2: Common indications for arthroscopic surgeries	
Knee joint	To confirm the diagnosis (diagnostic arthroscopy), partial or complete Meniscectomy, cruciate ligament reconstruction, microfracture/OATS/ACI for osteochondral lesions, synovectomy, synovial biopsy, arthrolysis for stiff knee, loose body removal.
Shoulder joint	Rotator cuff repair, Bankart’s repair, SLAP repair, arthroscopic release in frozen shoulder, AC joint reconstruction, loose body removal, subacromial decompression, debridement of joint, etc.
Ankle joint	Loose body removal, correction of anterior impingement, microfracture/OATS/ACI for osteochondral lesions (most common indication), debridement and synovial biopsy.
Elbow joint	Arthrolysis for stiff elbow, loose body removal (most common indication), synovial biopsy.
Wrist joint	Triangular fibrocartilage complex repair (TFCC), excision of wrist ganglion, synovial biopsy, radiocarpal fractures, etc.
Hip joint	Labral tears (most common indication), femoroacetabular impingement (FAI), snapping hips, loose bodies removal, synovial biopsy.

(OATS: Osteochondral autologus transfer system; ACI: Autologus chondrocyte implantation; SLAP: Superior labrum anterior and posterior).

ARTHROSCOPY OF INDIVIDUAL JOINTS

Knee Arthroscopy (Fig. 14.6A)

Knee arthroscopy is performed with the patient supine, and under tourniquet applied over proximal thigh. Firstly diagnostic arthroscopy is performed. With the use of a 4-mm-diameter, 30-degree oblique viewing arthroscope introduced through the anterolateral portal, almost all of the structures within the knee joint can be seen.



Figs. 14.6A and B: (A) Knee arthroscopy. (B) Knee arthroscopy portals label as shown.

Important Knee Arthroscopy Portals (Fig 14.6B)

Anterolateral: This is the main viewing portal (main diagnostic portal) and first portal to be made. It can view all structures except- anterior horn of lateral meniscus, periphery of posterior horn of medial meniscus and posterior cruciate ligament (PCL). It is made 1 cm above the lateral joint line and 1 cm lateral to patellar tendon.

Anteromedial: This is main working portal. It is made 1 cm above the medial joint line and 1 cm medial to patellar tendon. It is used for viewing lateral compartment and also for inserting arthroscopic instruments inside the knee.

Posteromedial: It is used for repair of posterior horn meniscal tears, PCL tears and loose body removal from posterior compartment.

Superolateral portal: It is used for viewing the patello-femoral articulation

Central transpatellar portal of Gillquist: It is located in midline 1 cm inferior to lower pole of patella. It is used in anterior cruciate ligament (ACL) reconstruction after graft has been harvested.

Shoulder Arthroscopy

Shoulder is the second most common joint to undergo arthroscopic procedures. Shoulder arthroscopy is performed in either beach chair position or lateral decubitus position.

- **Posterior portal:** The posterior portal is the primary entry portal for shoulder arthroscopy. It allows examination of most of the joint and assists in the placement of subsequent portals. This portal is located approximately 2 cm inferior and 1 cm medial to the posterolateral tip of the acromion.
- **Anterior portal:** It is established after the posterior portal. It passes through the anterior soft spot, which

is a triangle bounded by the biceps tendon superiorly, the subscapularis tendon inferiorly, and the anterior edge of the glenoid at the base.

Complications of Arthroscopic Surgeries

Damage to articular cartilage and hemarthrosis are the common complications of the arthroscopic surgeries.

HIGH-YIELD POINTS

- Professor Kenji Takagi (Japanese surgeon) performed the first arthroscopic examination of knee joint (tubercular knee), and is credited with the discovery of arthroscope.
- Masaki Watanabe (Japanese surgeon), developed the first commercial arthroscope, was the first to develop the concept of triangulation and perform arthroscopic surgery.

Femoroacetabular impingement (FAI): This is a recently described pathology coming up as an important cause of osteoarthritis of hip. In this condition the bones of the hip are abnormal in shape.

It is of two types: Cam and Pincer (Fig. 14.7)

Cam type (more common): In this type abnormal bony prominence is present at the head-neck junction, mostly anterosuperiorly. So head is not spherical and during hip flexion this abnormal protrusion grinds the cartilage inside the acetabulum.

Pincer type: In this type head is normal but acetabular is abnormally shaped or angled. Acetabulum is either retroverted or a bony growth from the anterolateral rim of acetabulum crushes the labrum during range of motion.

A third type, mixer of both Cam and pincer is actually the most common type.

Hip arthroscopy has a role in treatment of this condition and thereby prevention of development of osteoarthritis of hip.

ARTHROPLASTY

Arthroplasty or joint replacement surgery is a surgery whereby the natural articulating surfaces of the joint are replaced by artificial surfaces. If one of the articulating surfaces is replaced it is called hemiarthroplasty (partial joint replacement) and if both the articulating surfaces are replaced it is called *total joint arthroplasty* (total joint replacement). The most commonly done total joint replacement is knee followed by hip. The most common partial joint replacement is hip, followed by shoulder.

Hip

Hemiarthroplasty

In this procedure only the femoral head is replaced by artificial prosthesis and the natural acetabular surface is retained. The indication for hemiarthroplasty hip is a fracture neck of femur in an elderly patient, though it can also be done for intertrochanteric fracture where fixation is either not possible or anticipated to be weak. The prosthesis used for replacement of femoral head can be unipolar or bipolar. In unipolar prosthesis the motion occurs only at one interface, i.e. between the femoral head and acetabular surface; they can further be of two types uncemented (e.g. Austin more prosthesis) and cemented (e.g. Thompson prosthesis). The disadvantage of unipolar design is that it causes acetabular erosion due to continuous rubbing of the prosthetic femoral head with the acetabulum leading to anterior thigh pain and acetabular protrusion.

The bipolar prosthesis is a head within a cup design. It is called bipolar because theoretically, motion occurs at two interfaces, viz. head and cup, and cup and acetabulum.

Total Hip Replacement (THR)

In this procedure, both the femoral head and the acetabular surface are replaced (Figs. 14.8A and B). It can be

cemented where both acetabular and femoral components are fixed with cement, uncemented where both the components are uncemented (fixation initially is press fit and over time by bone ingrowth over a porous surface) or hybrid, where one of the components is cemented and the other is uncemented. Uncemented THR has longer life and is done for younger and active individuals and cemented THR are done for elderly low demand patients. The THR design has following components:

- Acetabular component, femoral head, an offset neck and femoral stem (page 405)

Indications

- Degenerative arthritis (primary osteoarthritis; secondary osteoarthritis as in SCFE, DDH, Perthes disease, Pagets disease, post traumatic)
- Osteonecrosis
- Inflammatory arthritis, (Rheumatoid arthritis, ankylosing spondylitis, Juvenile rheumatoid arthritis).
- Failed reconstruction [osteotomy, previous total hip replacement (THR), resurfacing arthroplasty].
- Bone tumor of proximal femur.
- Tuberculosis (healed).

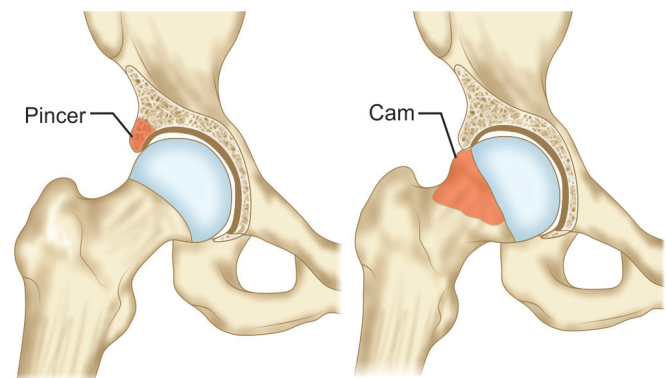
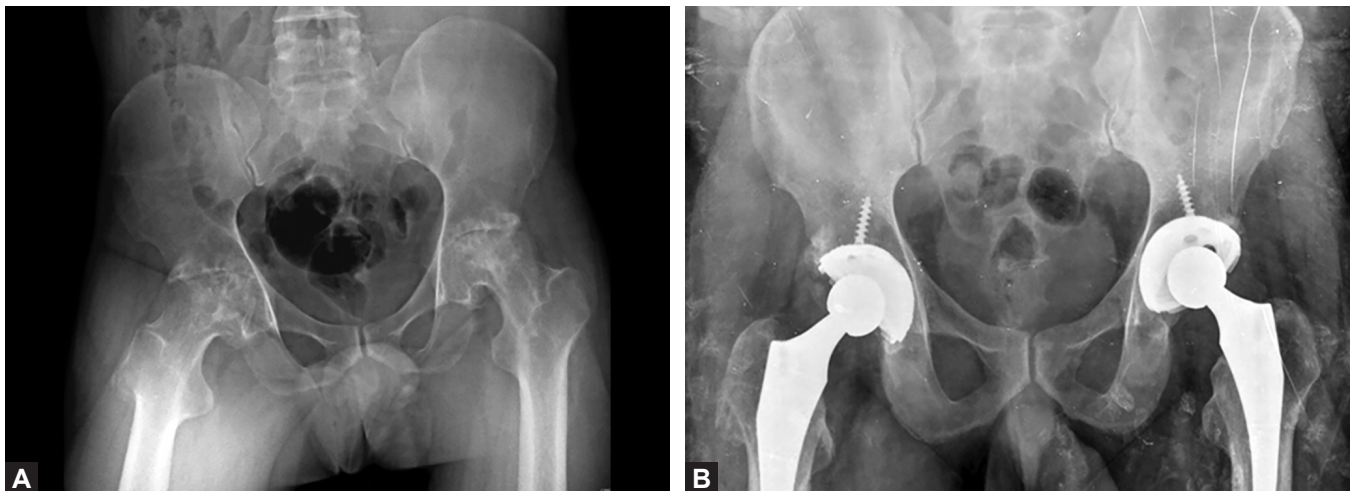


Fig. 14.7: Figure showing Cam and Pincer types of Femoro-acetabular impingements.



Figs. 14.8A and B: (A) X-ray pelvis with AP views showing bilateral AVN of head of femur and (B) bilateral total hip arthroplasty.

Contraindication

Absolute contraindications

- Active infection
- Medical ailment with poor tolerability for surgery

Relative contraindications

- Charcot arthropathy
- Abductor insufficiency
- Rapidly progressive neurological diseases.

Complications

- **Thromboembolism:** Venous thromboembolism is one of the most common serious complications arising from total hip arthroplasty. Preventive measure for thromboembolic complications include administration of low molecular weight heparin, DVT pumps, early mobilization and ankle pump exercises.
- **Nerve injuries:** The sciatic nerve is the most common nerve injured during posterior approach to hip but femoral, obturator and superior gluteal nerves can be injured, depending upon approach used. Important causes include direct surgical trauma, excessive retraction, injury during implant positioning.
- **Heterotopic ossification:** It occurs in the soft tissues around a hip. Risk factors include anterior or anterolateral approach, post-traumatic arthritis and male patients with hypertrophic osteoarthritis. Current areas of attention in prevention of heterotopic bone are low-dose radiation and nonsteroidal antiinflammatory drugs (NSAIDs).
- **Limb length discrepancy:** Shortening or lengthening of the limb is possible due to inaccurate resection of femoral neck, choosing inappropriate offset and improper implant position.
- **Subluxation or dislocation:** The incidence of dislocation post THR is 3%. Contributing factors include, posterior approach to hip, history of previous hip surgery, improper implant positioning, inadequate soft-tissue tension and malpositioning of the limb in early postoperative period.
- **Fracture:** Fractures of the femur or acetabulum can occur during and after the surgery. Femoral fractures are more common and require treatment, unlike their acetabular fractures which are usually not clinically apparent. Fracture may occur during dislocating the hip, during femoral canal reaming or during implant insertion. Late onset fractures may occur due to stress concentration.
- **Infection:** Infected joint replacement is a disaster. Meticulous sterility and proper infection control measures should be undertaken before the joint replacement surgery. If infection occurs then Interleukin-6 is the best marker to document it. ESR and CRP values may be used in monitoring also, however, one must know that ESR may not return to normal until 6 months (at times an year) after surgery while CRP values may also take upto 3 weeks to normalize.

- Femoral and acetabular loosening are the most serious long-term complications of total hip arthroplasty and the most common indications for revision.
- Most common cause of loosening is hypersensitivity response to polythene debris.

Bearing surfaces in total hip arthroplasty: It simply means surfaces of acetabular liner and femoral head. Bearing surfaces can be of different types:

- Metal on poly-metal head and polyethylene liner—polyethylene wear is a concern
- **Metal on metal:** Both head and liner are made up of metal—increased levels of cobalt and chromium in blood is a concern which is contraindicated in renal failure and women of child bearing age group. A hypersensitivity reaction may cause pseudotumor around prosthesis
- Ceramic on poly-ceramic head and polyethylene liner
- **Ceramic on ceramic:** Both head and liner are made up of ceramic—A complication unique to ceramic on ceramic bearing is squeaking (clicking sounds coming from the joint).

Knee

Unicondylar Knee Replacement

When only one compartment of the three compartments in the knee is affected, unicondylar knee replacement (UKR) is indicated. In this procedure, articulating bones of only one compartment (either medial or lateral tibio-femoral compartment) are resurfaced and polyethylene insert is placed. Both the cruciates are retained. Varus/valgus deformities greater than 10 degrees, torn ACL, inflammatory arthropathy and morbid obesity are contraindications to UKR.

Total Knee Replacement (Figs. 14.9A and B)

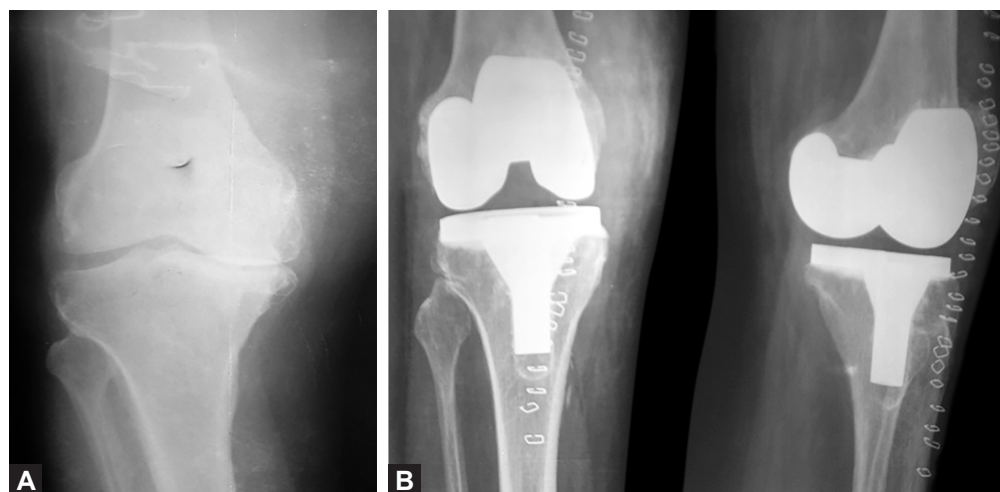
It is basically a resurfacing arthroplasty, where the articular surfaces of the femur and tibia are replaced by artificial components (Fig. 14.10). The surgery involves accurate bony cuts and soft tissue releases, so at the end of the surgery appropriate limb alignment is attained. In a standard TKR three components are used—metal tibial baseplate, metal femoral component and polyethylene insert (kept between the femoral and tibial components). The recent introduction of computer navigation total knee replacement system allows the bone cuts to be made more precisely. The patella may/may not be resurfaced.

Indications:

- Painful disabling arthritis of knee
- Osteonecrosis with subchondral collapse of femoral condyle
- Disabling deformity
- Chondrocalcinosis and pseudogout causing disabling pain.

Contraindications:

- Septic knee
- Remote or ongoing sepsis



Figs. 14.9A and B: (A) X-ray knee AP view showing advanced osteoarthritic changes and (B) X-ray knee AP and lateral views showing total knee arthroplasty.

- Knee extensor mechanism insufficiency
- Severe recurvatum secondary to muscular weakness.

Types of total knee replacement:

- On the basis of cementing:
 - Cemented
 - Uncemented
- On the basis of bearing surface:
 - *Mobile bearing*: The polyethylene insert rotates within the tibial base plate (rotating platform)
 - *Fixed bearing*: The polyethylene insert is fixed in the tibial base plate
- On the basis of (PCL retention) cruciate retention:
 - Cruciate retaining (PCL retaining)
 - Bicruciate retaining (both PCL and ACL retaining)
 - Cruciate sacrificing (both PCL and ACL sacrificed)
 - Posterior stabilized
 - Ultra congruent (deep dish design).

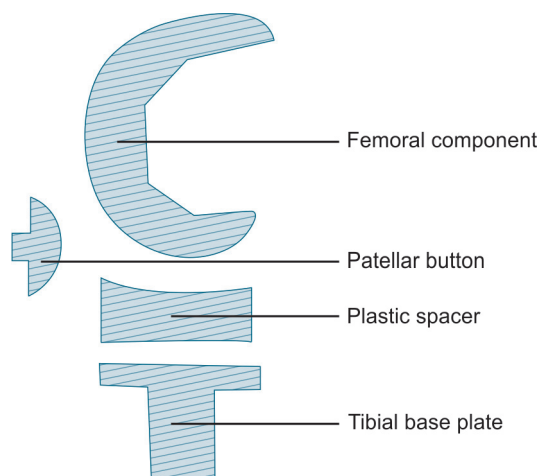


Fig. 14.10: Different components of total knee arthroplasty.

Shoulder

Three types of arthroplasties are done in shoulder joint commonly:

- *Hemiarthroplasty*: Only the humeral head is replaced. It is done in severely comminuted fractures of proximal humerus, especially in elderly patients
- *Total shoulder arthroplasty*: It is done in painful arthritic shoulder. A plastic “cup” is fitted into the shoulder socket (glenoid), and a metal “ball” is attached to proximal humerus. It relies on rotator cuff muscles to function properly
- *Reverse total shoulder arthroplasty*: In it, the cup is placed on the humeral head and ball on the glenoid surface. It is done in patients with chronic irreparable rotator cuff tears, and relies on deltoid to function properly.

HIGH-YIELD POINTS

- Insall is credited with developing the modern knee replacement prosthesis designs.

- The most common cause of death following THR is Myocardial infarction > Pulmonary embolism.
- There is an apprehension regarding arthroplasty procedure that when a joint is replaced the proprioceptive receptors are damaged and hence the final gait of the patient gets affected. However, most scientific studies have rather found that the left over receptors get up regulated and eventually there is no effect on the gait pattern after both hip or knee arthroplasty.
- The first THR was done by Dr John Charnley in 1960. He gave the principles of low friction arthroplasty
- Other forms of arthroplasty:
 - *Excision arthroplasty*: The femoral head is excised, creating a pseudo joint. It relieves pain but limp persists. E.g. Girdlestone arthroplasty. Other sites where excision arthroplasty is performed includes- elbow, great toe (Keller’s operation)
 - *Interposition arthroplasty*: Interposition of natural/synthetic material between articular surfaces. E.g. muscle, fascia, fat or synthetic membranes.

CHAPTER 15

Orthopedic Surgeries



COMMON INSTRUMENTS AND IMPLANTS USED IN ORTHOPEDIC SURGERIES

Periosteum Elevator (Fig. 15.1)

It is an instrument used to strip the periosteum off the bone to be worked with. By elevating the periosteum, we get a safe plane in the operating field, because all the important structures like blood vessels, nerves and tendons are outside the periosteum. Muscles attached to the bone are attached to the periosteum which has to be elevated to get a smooth surface of the bone for the purpose of internal fixation. Periosteal elevator has one blunt bevelled edge. It can be of different shapes and sizes depending upon the bone where they are used.

Osteotome (Figs. 15.2A and B)

It is the instrument used in osteotomy (the process of cutting the bone). It has a sharp end which is bevelled at

both sides and a broad end for hammering. It is also of various sizes and shapes.

Bone Chisel (Fig. 15.3)

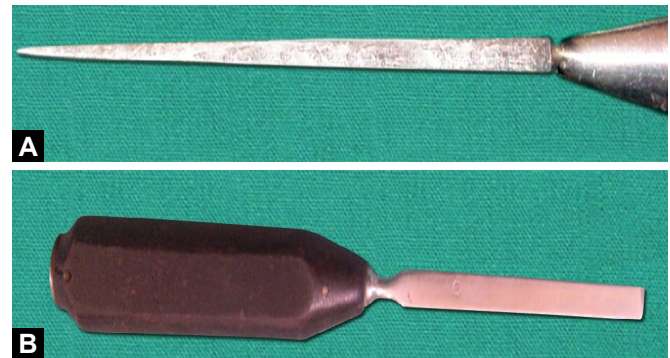
It looks very much similar to an osteotome except that its sharp end is bevelled on only one side. It is used to level an irregular bony surface as in removing excessive callus or in removing osteophytes in knee replacement surgery.

Bone Levers (Fig. 15.4)

They are used to lift or lever out the bone from the depth of the surgical wound or to keep the soft tissues away from the working field. Bone levers are of different sizes depending on the bone where they are used.



Fig. 15.1: Periosteal elevator.



Figs. 15.2A and B: Osteotomes.



Fig. 15.3: Bone chisel.

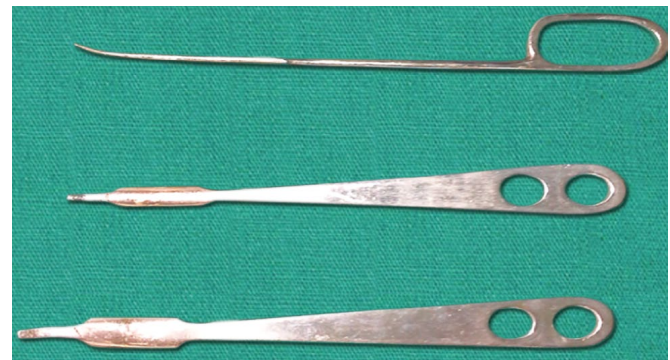


Fig. 15.4: Bone levers.

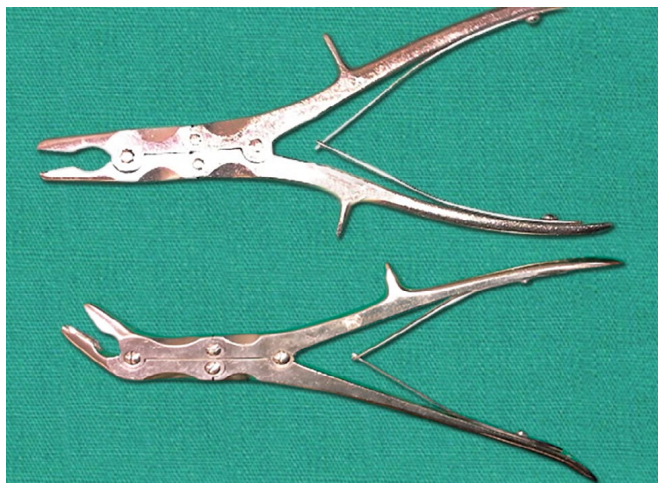


Fig. 15.5: Straight and curved bone nibblers.



Fig. 15.6: Bone cutter.



Fig. 15.7: Hammer/mallet.



Fig. 15.8: Bone curette.

Bone Nibblers (Fig. 15.5)

Bone nibblers are used to nibble bone or fibrous tissues. They are used in spinal surgeries and surgeries for non-union. They are of various shapes:

- *Straight nibbler*: For general use
- *Curved nibblers*: For spinal surgeries
- *Double action nibbler*: Straight and curved.

Bone Cutter (Fig. 15.6)

It is used to cut bones into smaller pieces as in preparing a bone graft or removing osteophytes in joint replacement surgeries. It is also available in various shapes and sizes.

Mallet/Hammer (Fig. 15.7)

It is used for hammering a chisel or an osteotome.

Bone Curette (Fig. 15.8)

It is a spoon-shaped instrument used to curette out a bony cavity as in a giant cell tumor or in preparing a fracture end for fixation.



Fig. 15.9: Bone gouge.

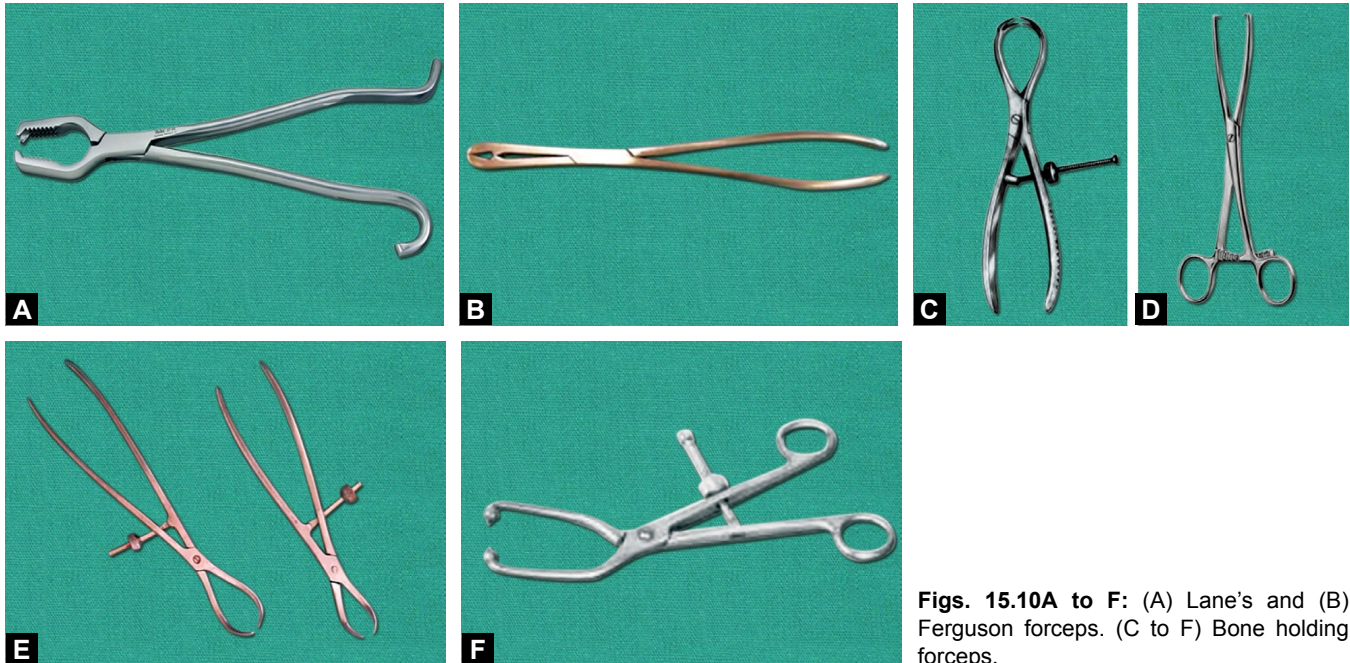
Bone Gouge (Fig. 15.9)

It is a concave-bladed chisel used mainly in the process of harvesting bone grafts (for cutting cortical bone or for scooping cancellous bone).

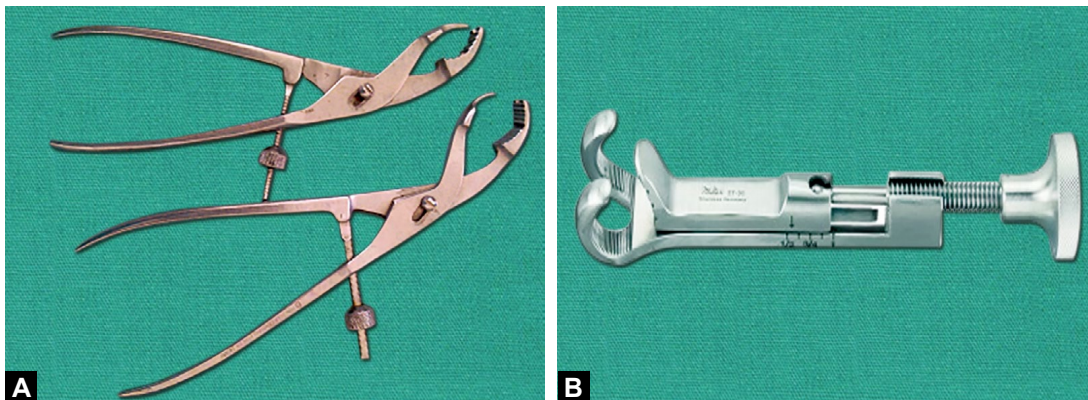
Bone Holding Forceps (Figs. 15.10A to F)

It is an instrument used to hold the bone for manipulation. It is of various types:

- Lane's forceps (Fig. 15.10A) for holding femur and tibia
- Ferguson forceps or lion jaw forceps (Fig. 15.10B) for holding fibula and forearm bones



Figs. 15.10A to F: (A) Lane's and (B) Ferguson forceps. (C to F) Bone holding forceps.



Figs. 15.11A and B: Plate holding forceps and Lowman's clamp.

- Self-retaining reduction forceps of AO type (Fig. 15.10E) which have an arrangement for locking and self-retaining
- Reduction forceps like patella reduction forceps (Fig. 15.10C), pelvic reduction forceps (Fig. 15.10F), malleolar reduction forceps (Fig. 15.10D): These are used to hold the reduction of fractured fragments during surgery.

Plate Holding Forceps (Figs. 15.11A and B)

Once the bone is reduced, plate is placed over it and held with a plate holding forceps before it is fixed with screws. It can be a self-retaining forceps (Fig. 15.11A) or a Lowman's clamp (Fig. 15.11B).

Right Angle Retractor (Fig. 15.12)

It is used to retract different tissue layers during surgery.



Fig. 15.12: Right angle retractors.

Drill Bit (Fig. 15.13A)

It is an instrument used to drill a hole in the bone so that screws can be inserted. Depending upon the sizes of the screws, drill bits of varying sizes are used.

Screw Tap (Fig. 15.13B)

Once a drill hole is made, screw tap is used to create threads inside the hole so that screw can be inserted.

Screw Driver (Fig. 15.13C)

It is an instrument used to drive a screw into the screw hole. It usually has a hexagonal tip for driving the screws with hexagonal head.

Tooth and Nontoothed Forceps (Fig. 15.14)

It is used for grasping and holding tissues during surgery and to pick up the tissue layers while suturing. Nontoothed forceps are used to hold delicate tissues and to dissect out nerves and vessels.

Sponge Holding Forceps (Fig. 15.15)

It is used to hold sponge or swab during surgery. In orthopedic surgery, it is mainly used to hold the sponge for cleaning and painting of the part to be operated before the surgery.

Kocher's Forceps and Allis Forceps (Figs. 15.16A and B)

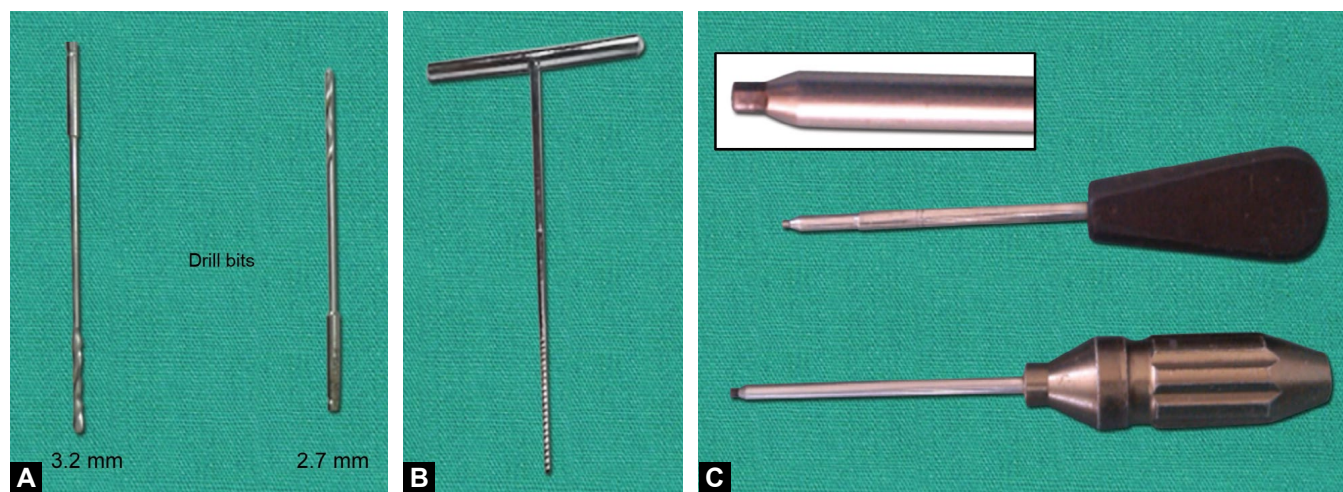
Kocher's forceps has serrated blades with interlocking teeth at the tips. It is used to hold tissues and for compression of bleeding tissues. Allis tissue forceps has inward curving toothed blades but no serrations. It is mainly used for grasping tough tissues like fascia, tendons, etc.

TRACTION INSTRUMENTS**Kirschner's Wires (K-Wire) (Fig. 15.17B)**

Kirschner's wires are straight stainless steel wires which are sharp at both ends. These are available in different diameters ranging from 1 mm to 3 mm. Both the ends are sharp. They are used in: (1) internal fixation of small bones of hands and feet; (2) internal fixation of bones in children; (3) for the purpose of traction in children; (4) for temporary fixation of fracture fragments (to hold the reduction) in adults during surgery; (5) in Ilizarov's fixation system.

Steinman's Pin (Fig. 15.17A)

It is a straight stout pin of varying diameter from 3 mm to 6 mm. One end is flat and the other end is sharp. It is used



Figs. 15.13A to C: Drill bits, bone tap and screw driver (See hexagonal tip of orthopedic screw driver).

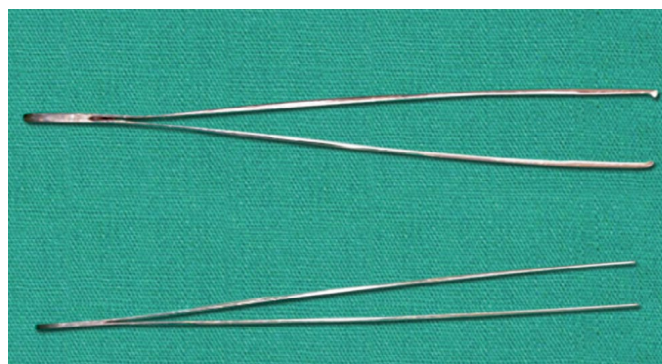


Fig. 15.14: Tooth and nontoothed forceps.

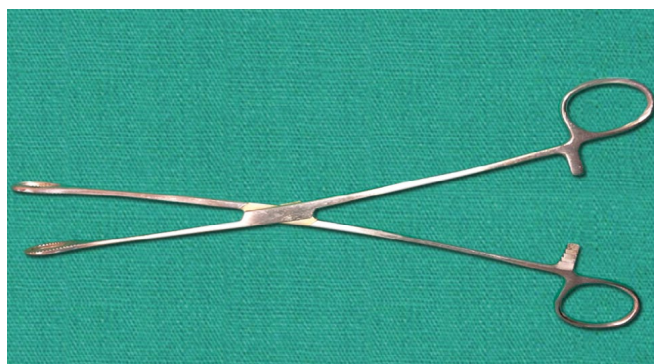
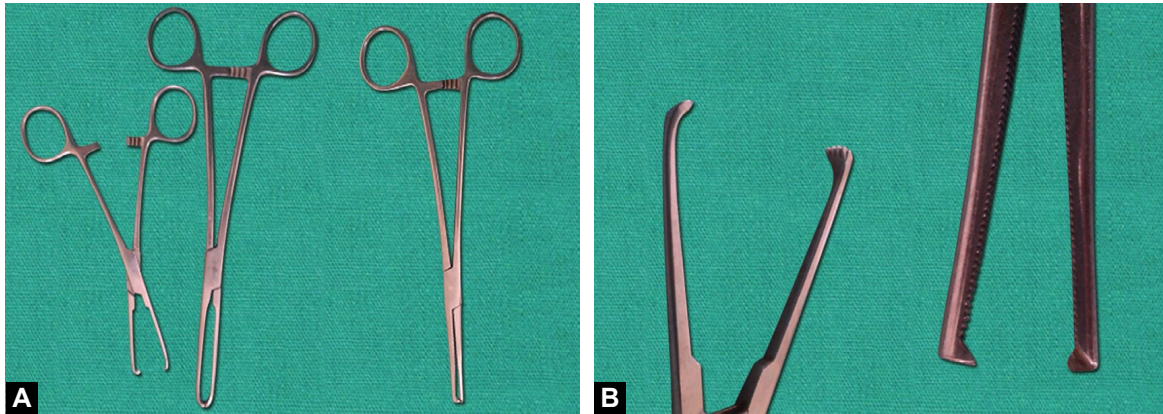
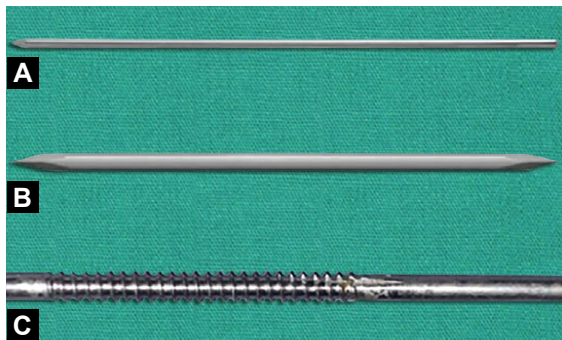


Fig. 15.15: Sponge holding forceps.



Figs. 15.16A and B: (A) Kocher's forceps (right in figure) and Allis forceps (left in figure); and (B) Blades of Allis (left in figure) and Kocher's forceps (right in figure)



Figs. 15.17A to C: (A) Steinman's pin; (B) Kirschner wire; and (C) Denham's pin.

to apply skeleton traction, i.e. distal femur and proximal tibial skeleton traction.

Denham's Pin (Fig. 15.17C)

It looks exactly similar to Steinman's pin except that it has threads in the middle. The purpose of these threads is to get a firm grip in the bone in which it is inserted. It is used to apply traction in osteoporotic bones and cancellous bones like calcaneum.

Bohler's Stirrup (Fig. 15.18)

It is an instrument used to hold the Steinman's pin for applying traction. It has two screws at both the ends which will hold the pin tightly. The direction of the traction can be altered without rotating the pin inside the bone by varying the direction of the Bohler's stirrup.

Crutchfield Tong (Figs. 15.19A and B)

It is a type of skull tong which is used to apply skeletal traction through the skull in cases of cervical spine instability. It has two sharp prongs used for insertion into the outer table of the skull and a slot in the middle for applying traction.

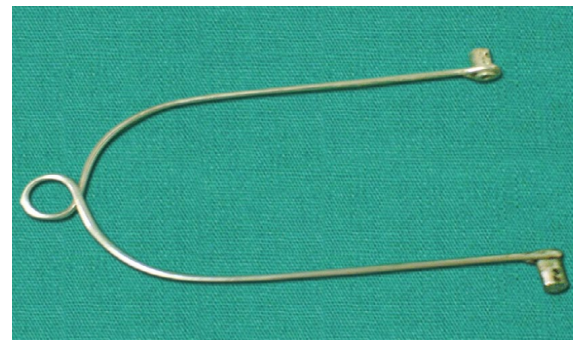


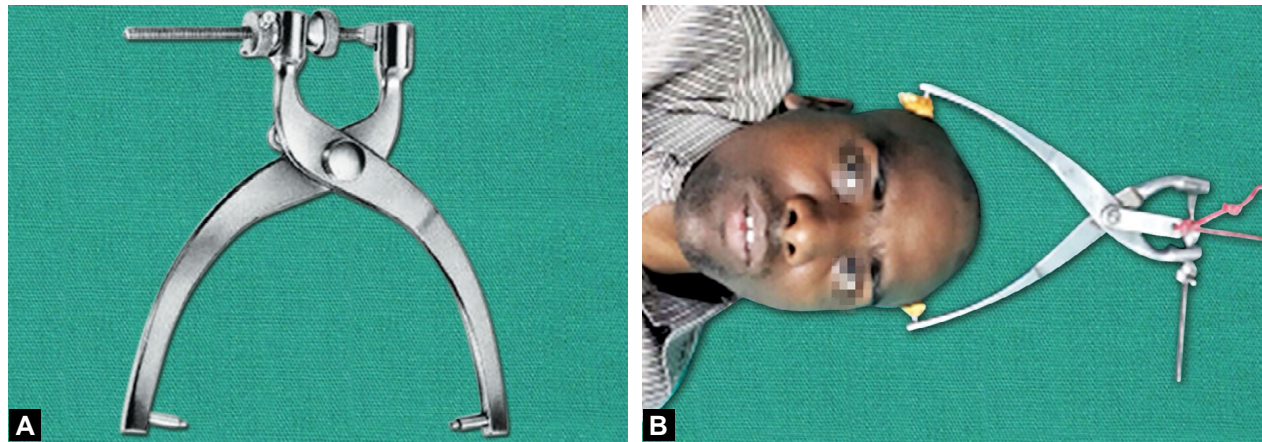
Fig. 15.18: Bohler's stirrup.

External Fixator Assembly (Fig. 15.20)

It is a set of implants used for external fixation of bones. It is used in case of open injuries, infected nonunion, deformity correction, etc. where we don't want to fix the bone internally. It consists of: (1) Schanz pins: Straight pins of varying sizes with threads at the tip. They are inserted to the bone percutaneously. (2) Tubular rods are used to span the Schanz pins and connected to it with the help of (3) universal clamps. Two tubular rods are connected to each other with a tube to tube clamp. With these parts, external fixators can be constructed to any length and shape as per requirement.

K Nail (Figs. 15.21A and B)

Kuntscher's nail first introduced by German scientist Kuntscher is an intramedullary nail used in fixation of femoral shaft fracture. It is a hollow nail with an open slot on one side. On cross-section, it is clover leaf-shaped. It has an eye at both the ends used for extraction of the nail. It comes in various lengths and diameter. It works under the principle of three point fixation—one at the isthmus and one at each ends. It is inserted either antegrade (from the pyriform fossa to the fracture and then to the distal part after inserting a guidewire) or retrograde (through the



Figs. 15.19A and B: (A) Crutchfield tong and (B) Application of Crutchfield tong.

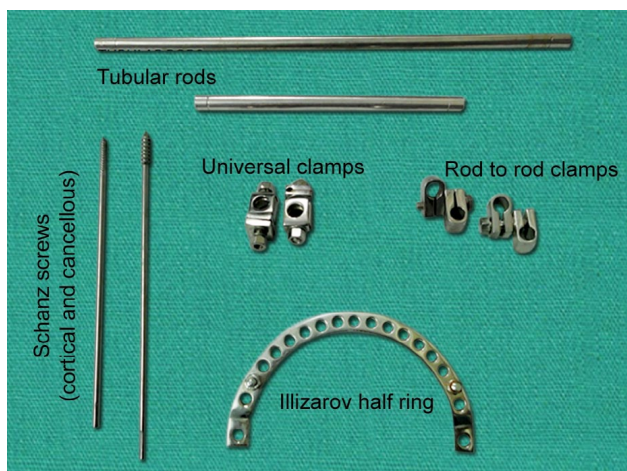
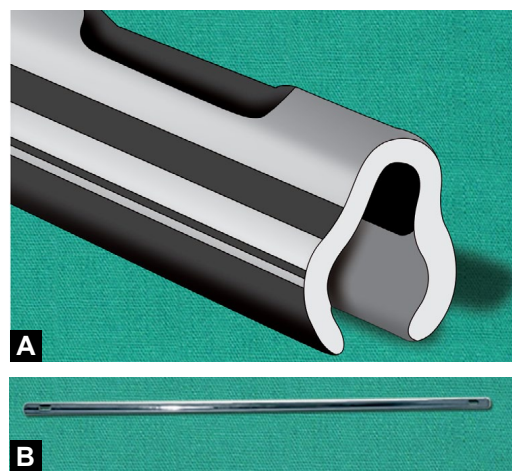


Fig. 15.20: External fixator assembly.



Figs. 15.21A and B: (A) Tip of K nail (observe the cloverleaf shape of nail with an eyelet) and (B) K nail.

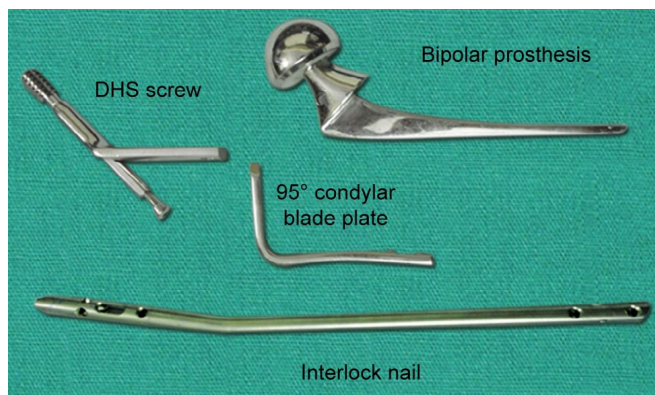


Fig. 15.22: Dynamic hip screw (DHS), bipolar hip prosthesis, condylar blade plate and interlocking nail.

fracture site to the piriform fossa and then distally back to the distal femur). It is inserted in such a way that the eye faces posteromedially and the slot faces anterolaterally.

Interlocking Nail (Fig. 15.22)

Though K nail is adequate for diaphyseal fractures, they don't provide rotational stability. To overcome this

problem, Modney designed the interlock nails. It is a hollow nail with a circular cross-section. It has two holes on each end which are used for locking the nail with the bone through locking screws. It is used for fixation of diaphyseal fractures of femur tibia and even humerus.

Hip Prosthesis (Figs. 15.22 and 15.23)

These are prostheses which are used to replace the hip joint as in case of fracture neck of femur, hip joint arthritis or avascular necrosis. It can be: (1) total hip arthroplasty where both the proximal femur and the acetabular surface are replaced; (2) hemiarthroplasty where only the proximal femur is replaced. There are various types of hip prostheses. They can be implanted with or without bone cement. Use of bone cement provides immediate stability in cemented THR. Whereas a noncemented prosthesis will not provide immediate stability, it becomes stable once there is ingrowth of bones into the grooves of the implant.

Prosthesis can also be classified as unipolar or bipolar: unipolar is where the head of the prosthesis is a single piece, whereas a bipolar prosthesis is one in which the head is made up of an inner component over which an

outer component revolves. Bipolar prosthesis experiences less wear and tear thereby increasing the longevity.

- *Austin Moore prosthesis (Fig. 15.23B)*: It is a unipolar, noncemented hip prosthesis. It is used in fracture neck of femur in an elderly patient with a large intramedullary canal. It has a head, a short neck, a shoulder and a stem. The stem has two holes in which ingrowth of bone occurs fixing the prosthesis.
- *Thompson's prosthesis (Fig. 15.23B)*: It is also a unipolar prosthesis without holes in stem and without a shoulder, can be used with or without cement in cases of fracture neck of femur in an elderly patient. It is particularly useful in cases where the neck has been resorbed completely.
- *Bipolar prosthesis (Fig. 15.22)*: Bipolar prostheses are two component prostheses in which the femoral head can move inside the acetabular component. It is also used for neck femur fractures (hemiarthroplasty).
- *Total hip prosthesis (see Fig. 15.23A)*: When the hip joint is arthritic, whole of the joint has to be replaced. Total hip prostheses are multicomponent prostheses. Components of typical total hip prosthesis are as follows:
 - Acetabular cup
 - Liner or insert made up of polyethylene or ceramic
 - Femoral head made up of metal or ceramic
 - Femoral stem.

Depending upon the material used, they can be metal on polythene, metal on ceramic or ceramic on ceramic (For details see Page x).

Dynamic Hip Screw (Fig. 15.22)

It is used for fixation of intertrochanteric fractures. It comprises of a sliding screw and an angled plate. The sliding screw has a threaded portion which gets engaged into the femoral head and a nonthreaded part. The plate is angled (usually in the range of 125–145, most commonly the angle being 135 degrees) and has a barrel which slides

over the nonthreaded portion of the sliding screw and a plate which is to be fixed to the femoral shaft with cortical screws. It works on the principle of controlled collapse of the cancellous bone in the intertrochanteric region, thereby aiding union.

Dynamic Condylar Screw (Fig. 15.24)

It is similar to dynamic hip screw except that the angle of the plate is 95° and is used in the treatment of subtrochanteric fractures in proximal femur or supracondylar fractures in distal femur.

Blade Plate (see Fig. 15.22)

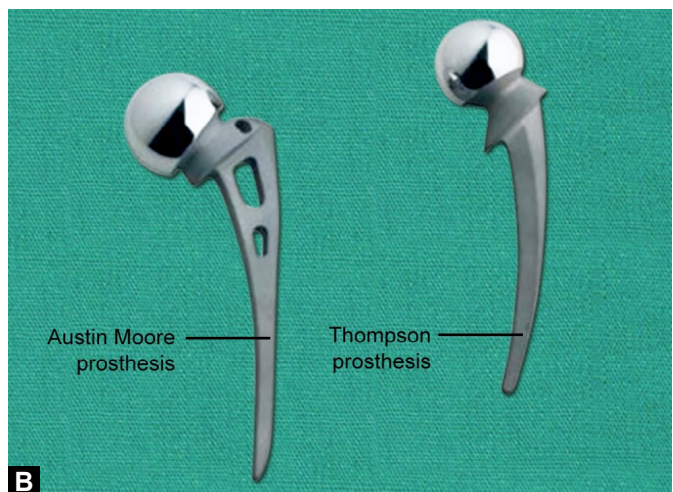
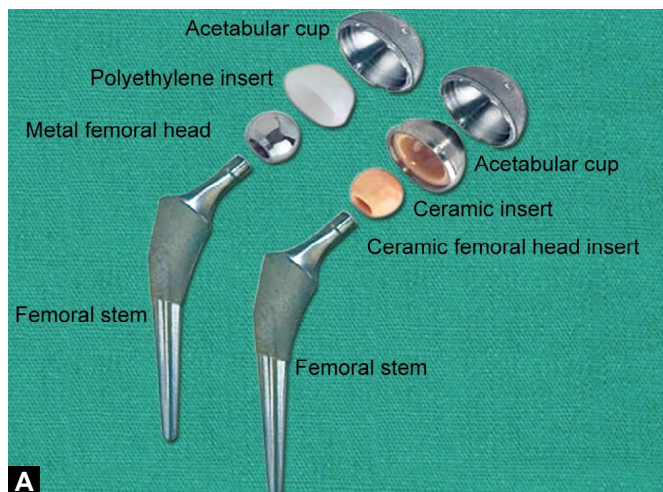
It is also an implant used for fixation of trochanteric fractures. It consists of a blade attached to a plate at an angle. It comes in variable angles. The blade is inserted into the femoral head and the plate is fixed to the femoral shaft. It also comes as a double-angled plate which is used in cases of valgus osteotomies.

Dynamic Compression Plate (Fig. 15.25)

It is an implant used for fixing diaphyseal fractures of long bones. These plates have special holes which are oval-shaped and the edges of the holes are inclined. Due to this feature when the screw is threaded into the hole eccentrically, it causes movement of the plate, thereby bringing compression at the fracture site.

Limited Contact Dynamic Compression Plate (Fig. 15.25)

It is similar to dynamic compression plate. In addition to this, it has multiple furrows on the undersurface, thereby limiting the contact surface of the bone. The idea behind development of this plate is by limiting the contact surface, more surface is allowed for the ingrowth of bone and periosteal blood vessels.



Figs. 15.23A and B: (A) Total hip prosthesis components and (B) Austin Moore and Thompson hip prostheses.



Fig. 15.24: Dynamic condylar screw.

Locking Compression Plate (Figs. 15.25 and 15.26)

Locking plate is specially designed for rigid fixation in cases of periarticular fractures and fractures of osteoporotic bones. The screws of this plate have threads with high pitch and also have threads in the screw heads that can be locked to the holes in the plates, thereby providing a very rigid fixation.

Screws (Fig. 15.25)

Screws are used to fix the plates to the bones or fixing the bone directly. Screws are of many types:

- **Cortical screws:** Used for fixing the plate to the cortical bone. It has a head with a hexagonal slot and a shaft with threads over it.
- **Cancellous screws:** Used for fixation in cancellous bones. It is similar to cortical screws except that its threads are deep so as to get a firm hold. Cancellous screws can be fully threaded or partially threaded. The use of partially threaded cancellous screws (lag screws)

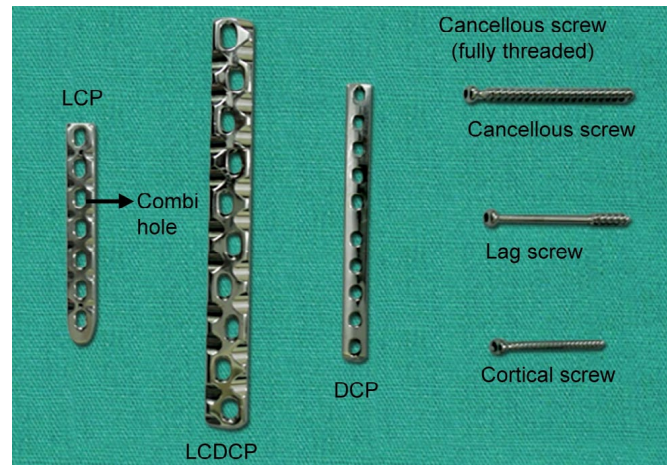


Fig. 15.25: Locking compression plate (LCP), limited contact dynamic compression plate (LCDCP), dynamic compression plate (DCP), cancellous and cortical screws.

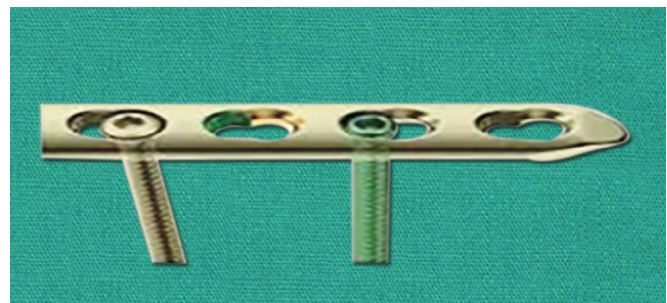


Fig. 15.26: Combi holes of LCP have slots for both locking screws and compression screws. Slots for locking screws have threads in which locking screws get locked.

is to bring about interfragmentary compression. The threaded portion of the screw engages to the distal fragment while the nonthreaded portion just slides through the hole while the head pulls the proximal fragment towards the distal part, thereby compressing the fracture.

ORTHOPEDIC IMPLANT MATERIALS AND IMPORTANT SURGICAL APPROACHES

ORTHOPEDIC IMPLANT MATERIAL

Three types of material mainly used for orthopedic implants are metal (stainless steel, titanium alloys and cobalt-chromium alloys), polymer [ultra-high-molecular-weight polyethylene (UHMWP)] and ceramics (aluminium oxide, calcium phosphate, etc.).

Stainless Steel

Internal fixation implants used for fractures are commonly made up of stainless steel. The form of stainless steel which is used in orthopedic implants is 316L (suffix L indicates low concentration of carbon). Carbon is

added for the strength and chromium is added to provide resistance to corrosion (it forms an oxide layer which prevents corrosion; this is known as *passivation*).

Titanium and Chromium-Cobalt Alloys

Titanium alloys are more biocompatible (causes less tissue reaction) than stainless steel and chromium alloy. They are more resistant to corrosion but also more sensitive to scratch (notch sensitivity). Titanium alloys are used for internal fixation implants and joint replacement prostheses. Chromium-cobalt alloys are mainly used for joint replacement prostheses.

HIGH-YIELD POINTS

- Ultra-high-molecular-weight polyethylene (UHMWP) is used in joint replacement implants (acetabular cup and tibial insert). Creep and wear are concern with UHMWP.
- Creep is slow deformation of material under load with time.
- *Biodegradable implants*: These implants provide sufficient strength to bone until fracture heals and then degrade, thus eliminating need for second surgery for their removal. These are mainly made up of polyglycolic acid, polydioxanone and polylevolactic acid.
- Ductility is the ability of the material to be stretched or shaped without breakage. This quality allows the surgeon for prefixation reshaping of the implant according to bone shape. Titanium alloys are more ductile than stainless steel implants.

IMPORTANT SURGICAL APPROACHES IN ORTHOPEDICS

Shoulder and Upper Arm

Generally opened from anterior aspect by Henry's approach. The plane is between deltoid and pectoralis major.

Forearm

- To open from anterior aspect, follow Henry's approach for forearm. Plane is between brachioradialis and flexor carpi radialis.
- To open from posterior aspect, follow Thompson's approach. It is generally used for operations on proximal forearm.

Pelvis and Acetabulum

- *Kocher-Langenbeck approach*: It is a nonextensile posterior approach to acetabulum which provides visualization of posterior wall and lateral aspect of posterior column of acetabulum. Posterior approach to hip joint (Moor's approach) uses the same incision and tissue plane.
- *Ilioinguinal approach*
- *Iliofemoral approach*.

Hip

This can be approached from all sides depending upon indication for surgery.

- *Anterior approach*: Smith Peterson
- *Posterior approach*: Moore's or Southern approach—incision is identical to Kocher-Langenbeck, except localized posterior to greater trochanter.

- *Lateral approach*: Watson Jones (anterolateral) and Hardinge's (direct lateral) approaches
- *Medial approach*: Hoppenfield and de Bore approach.
In case of developmental dysplasia of the hip (DDH), it is opened from anterior side by special approach called as Somerville approach. Common approaches for total hip replacement:
 - *Anterior approach (Smith Peterson approach)*: Surgical plane is present between the sartorius (femoral nerve) and tensor fascia latae.
 - *Anterolateral Approach (Watson-Jones)*: The approach utilizes the surgical plane between the tensor fascia latae and the gluteus medius.
 - *Direct Lateral or Transgluteal Approach (Hardinge)*: In this approach periosteum is elevated covering the greater trochanter and the anterior one-third of the gluteus medius and vastus lateralis insertions on the greater trochanter are split longitudinally and sharply separated from the greater trochanter.
 - *Posterior approach (Moore's approach)*: After incising TFL and gluteal fascia gluteus maximus is bluntly divided and then external rotators are cut.

Knee

Generally, knee is opened from anterior aspect by medial parapatellar approach.

Approaches for total knee replacement:

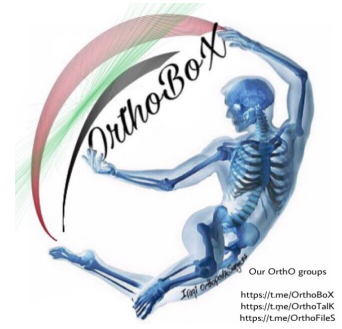
- *Medial parapatellar approach*: Most commonly used.
- *Subvastus approach*: It is a modification that's especially less damaging to vascularity of patella and the quadriceps muscle but has the disadvantages that exposure is not as good so can't be used in obese patients and in revision knee arthroplasties.
- *Midvastus approach*.

Ankle

- *Colona and Ralston (posteromedial approach)*: Incision is given behind medial malleolus. It is used particularly for fixing Pott's fractures (bimalleolar fractures).
- *Gatellier and Chastang (posterolateral approach to ankle)*: For fixing Cotton's fractures (trimalleolar fractures where the posterior malleolus also has to be fixed).
- *Ollier's approach*: It is a special approach where incision is on anterolateral aspect of ankle and foot in an area called sinus tarsi (a depression seen on anterolateral aspect of proximal foot). It can be used to expose three joints: subtalar, calcaneocuboid and talonavicular in single incision and hence would be the approach to perform triple arthrodesis in patients with CTEV who are older than 10 years.

CHAPTER 16

Synopsis of Orthopedics



FRACTURE EPONYMS

Upper Limb

Mallet finger: Avulsion or rupture of extensor tendon from the base of the distal phalanx.

Jersey finger: Avulsion of flexor tendon (FDP) from base of distal phalanx.

Gamekeeper's/Skier's thumb: Avulsion of the ulnar collateral ligament at MCP joint of thumb from base of proximal phalanx.

Bennett's fracture dislocation: Oblique, displaced intraarticular fracture of the base of the first metacarpal with subluxation of the trapeziometacarpal joint such that the shaft of the first metacarpal is displaced laterally by abductor pollicis longus.

Rolando fracture: Intra-articular Y shaped fracture of the base of the first metacarpal with same but relatively less of diaphyseal displacements as a Bennett's fracture.

Boxer's fracture: Fracture through the neck of the 5th metacarpal, usually occurs in boxers.

Kaplan's dislocation: Dislocation of the MCP joint (classically of index finger).

Colles fracture: A fracture at the corticocancellous junction of the distal end of the radius with dorsal tilt of distal fragment, commonly seen in postmenopausal osteoporotic females.

Smith's fracture: A fracture at the corticocancellous junction of the distal end of the radius with ventral tilt of distal fragment (also called as Reverse colles fracture).

Barton's fracture: Intra-articular fractures through the distal articular surface of the radius, taking a margin of radius with the carpals, displaced anteriorly or posteriorly.

Chauffeur fracture: A fracture of the styloid process of the radius.

Die punch fracture: A comminuted impacted fracture of distal radius.

Torus fracture: Special fracture pattern seen in children where a single cortex of bone is buckled inside. It is mostly seen in distal radius.

Green stick fracture: A special fracture pattern seen classically in children (due to elastic bones and a thick periosteum) where there is break in a single cortex of bone and on X-ray one finds only bending of bones.

Night stick fracture: A fracture of the shaft of ulna sustained while trying to protect from a stick blow.

Monteggia fracture: Fracture of the proximal third of the ulna with dislocation of the radial head.

Galeazzi fracture (Piedmont fracture): Fracture of the distal third of radius with subluxation of the distal radio ulnar joint.

Side-swipe injury (Baby car fracture): It is an elbow injury sustained when one's elbow is projecting out of a car and is side swept by another vehicle. The patient sustains fractures of the distal end of humerus with fractures of proximal ends of radius and ulna.

Nurse maid's elbow/Malgaigne's subluxation: Refers to Pulled elbow which is subluxation of radial head out of the annular ligament.

Hotchkiss terrible triad of elbow injury: Comminuted fracture of the radial head, fracture of the coronoid process of ulna and posterolateral dislocation of elbow.

Luxatio erecta: Refers to inferior dislocation of shoulder.

Pelvis and Lower Limb

Dashboard fracture: A fracture of posterior lip of the acetabulum, often associated with posterior dislocation of the hip (other concomitant injuries can involve femoral condyles, patella and Posterior cruciate ligament).

Straddle fracture: Bilateral superior and inferior pubic rami fractures.

Open book fracture: A pelvic fracture due to anteroposterior compression of pelvis where the pubic symphysis is disrupted and pelvis opens up like a book.

Malgaigne's fracture: A type of pelvis fracture due to side-to-side compression of pelvis where there is fracture of pubic rami anteriorly and sacroiliac joint or ilium posteriorly but on the same side.

Bucket handle fracture: A type of pelvis fracture due to side-to-side compression of pelvis where there is fracture of pubic rami anteriorly and sacroiliac joint or ilium posteriorly but on the opposite side.

Crescent fracture: Iliac wing fracture in pelvis that enters into SI joint.

Jumper's fracture: Transverse fracture of sacrum seen in patients who have a fall from height during a suicidal attempt. It is characterized by 'H' or 'U' shaped fracture line involving upper sacrum (S1 and S2).

Wind swept pelvis: It is a lateral compression injury of ipsilateral hemipelvis and open book or external rotation type injury of contralateral hemipelvis.

Duverney fracture: Isolated iliac wing fracture.

Unresolved fracture: Neck femur fracture.

Underwear fracture: Inter trochanteric fracture.

Hoffa fracture: Fracture of the condyles of femur in coronal plane.

Bumper fracture: A fracture of the tibial plateau.

Toddler's fracture: A spiral fracture of the tibial shaft seen in toddlers due to twisting injury.

Pott's fracture: Bimalleolar ankle fracture.

Cotton's fracture: Trimalleolar ankle fracture.

Bosworth fracture: A fracture dislocation at ankle where fibula is trapped behind tibia.

Massonai's fracture: In this an ankle fracture is associated with fracture of the neck of fibula.

Runner's fracture: Stress fracture of the distal fibula.

Pilon fracture: It is a comminuted intra articular fracture of the distal end of tibia.

Tillaux fracture: This is avulsion of anterior tibial margin by the anterior tibiofibular ligament (Salter Harris type III injury).

LeForte-Wagstaffe fracture: This is fibular avulsion fracture of the anterior tibiofibular ligament (counterpart of Tillaux fracture).

Aviator's fracture: Fracture of neck of talus.

Lover's fracture/Don Juan fracture: Calcaneum fracture when there is fall from height.

Chopart fracture – dislocation: A fracture – dislocation through inter tarsal joints.

Lisfranc fracture – dislocation: A fracture – dislocation through tarso-metatarsal joints.

Jone's fracture: Avulsion fracture of the base of the 5th metatarsal due to pull of peroneus brevis at the metaphyseal-diaphyseal junction.

Pseudo-Jones/Dancer's fracture: Avulsion fracture of the tip of 5th metatarsal.

March fracture: Stress fracture of the shafts of 2nd or 3rd metatarsal.

Spine

Jefferson's fracture: Burst fracture of the first cervical vertebra.

Whiplash injury: Cervical spine injury where sudden flexion followed by hyperextension (main damaging force) takes place.

Chance fracture: Also called seat belt fracture, the fracture line runs horizontally through the body of the vertebra, through and through, to the posterior elements.

Burst fracture: It is a comminuted fracture of the vertebral body where fragments “burst out” in different directions often entering the canal and injuring cord.

Clay-Shoveller fracture: It is an avulsion fracture of spinous process of one or more of the lower cervical or upper thoracic vertebra (usually C7 or T1).

Hangman's fracture: It is a fracture through the pedicle and lamina of C2 vertebra, with spondylolisthesis of C2 over C3, sustained in hanging (less commonly) or in road traffic accidents (more commonly).

Chalk stick fractures: In these fractures, the fracture line is transverse to the long axis of the bone, like a broken stick of chalk. They are seen mostly in long bones in Paget's disease, Osteopetrosis, Ankylosing Spondylitis.

Growing fractures: These are skull fractures seen mainly in infancy and early childhood characterized by progressive diastatic enlargement of the fracture line. A complication can be a cystic mass filled with CSF, called as a “leptomeningeal cyst”.

Motorcyclist's fracture: It is a fracture of the floor of the skull. The base of the skull is divided into two halves, anterior and posterior, each moving independent of each other as if connected via hinge, hence also called as “Hinge fracture”

IMPORTANT DEFORMITIES WITH PNEUMONICS

(Note—In fractures, describing deformity means defining the position of distal fragment in respect to proximal fragment)

Fracture supracondylar humerus: Cubitus varus (Gun stock deformity).

Fracture lateral condyle humerus: Cubitus valgus

Colles fracture: Dinner fork deformity

Smith's fracture: Garden spade deformity

Nonunion scaphoid: Hump back deformity

Ant dislocation shoulder (FABER): Flexion, Abduction and External rotation.

Postdislocation shoulder (FADIR): Flexion, Adduction and Internal rotation.

Inferior dislocation shoulder: Hyperabduction (Salute position).

Ant dislocation hip (FABER): Flexion, Abduction, External rotation.

Postdislocation hip (FADIR): Flexion, Adduction, Internal rotation.

Central fracture dislocation hip: Abduction/Adduction and I.R./E.R both are possible depending upon injury mechanism plus there is significant shortening.

Fracture NOF (intracapsular) (PDE): Proximal migration, Adduction, External rotation.

Fracture NOF (extracapsular) (PDE): But more exaggerated deformities as compared to intracapsular and also there is coxa vara i.e. reduced femoral neck shaft angle.

Fracture shaft of femur (PBF-E): Proximal fragment is abducted, flexed and externally rotated.

Pulled elbow: Arm by the side, forearm pronated.

O.A of hip (DEF): Adduction, Flexion, External rotation.

O.A of knee: Genu varum

TB Knee: Triple deformity i.e. flexion, external rotation and posterior subluxation of tibia on femur.

T.B hip

Synovitis: (FABER) with apparent lengthening

Early arthritis: (FADIR) with apparent shortening

Late arthritis: (FADIR) with true shortening

R.A Knee: Genu valgum, wind swept deformity.

R.A Hand: Swan neck deformity, Boutonniere's deformity, Z deformity of wrist.

R.A Foot: Hallux valgus, claw toes, hammer toes.

Rickets: Genu varum, valgum and wind swept deformity.

Blount's disease: Bilateral genu varum with genu recurvatum and internal tibial torsion.

IMPORTANT CLINICAL SIGNS AND TESTS

UPPER LIMB

- *Impingement at shoulder:*
 - Neer's test
 - Hawkin's Kennedy test
- *Supraspinatus testing (most common tendon rupture):* Jobe's empty can sign
- *Subscapularis testing:*

- Belly press test
- Left off test
- Bear hug test
- *Infraspinatus testing:* Drop arm sign
- *Axillary nerve testing (in shoulder dislocation or fracture neck humerus):* Regiment batch sign
- *Shoulder instability:*
 - *Anterior instability:* Apprehension sign

- *Posterior instability*: Posterior drawer/Jerk test
- *Inferior instability*: Sulcus sign
- *Anterior shoulder dislocation clinical tests*:
 - Dugas test
 - Callaway's test
 - Hamilton ruler
 - Bryant test
- *SLAP (superior labral tear from anterior to posterior) tear at shoulder*: O'Brien's test
- *Elbow dislocation*: Bowstring of triceps and disturbed three point relationship
- *Tennis Elbow*:
 - Cozen's test
 - Maudsley's test
 - Mill's maneuver
- *Biceps tendinitis*:
 - Speed test
 - Yergason test
- *VIC*: Volkmann's sign
- *Piano key sign*: Distal radio ulnar joint instability (e.g. Madelung deformity, Malunited colles fracture etc.)
- *De Quervain's synovitis*: Finkelstein test
- *Scaphoid fracture*: Watson's test
- *Flexor tenosynovitis*: Kanavel's signs
- *Finsterer sign*: Kienbock's disease
- *Opera glass deformity of hand*: Psoriasis

NEUROLOGY

- *Tinel's sign & motor march*: Signs of nerve regeneration
- *Serratus anterior/Rhomboides/trapezius palsy*: Winging of scapula
- *Erb's palsy*: porter tip hand
- *Claw hand*:
 - Klumpke's paralysis
 - Ulnar nerve palsy
 - Combined median & ulnar nerve palsy
- *Radial nerve palsy*: Finger drop (better) > wrist drop
- *Ulnar nerve palsy*:
 - Book test (Froment sign) for adductor pollicis
 - Card test for Palmar interossei
 - Egawa's test for Dorsal interossei
- *Median nerve palsy*:
 - Pointing sign/Clasping sign/Pope's sign
 - Pen test for abductor pollicis brevis
 - Ape thumb deformity due to paralysis of abductor pollicis brevis
 - Schaeffer's test for Palmaris Longus
- *Carpal tunnel syndrome*:
 - Phalen's test (conventional test)
 - Durkan's direct nerve compression test (most sensitive)
 - Hand diagram (most specific)
 - Semmes weinstein monofilament test
- *Sciatic/Common peroneal nerve palsy > Deep peroneal nerve palsy*: Foot drop
- *Mudler's click*: Morton's neuroma
- Tests for Thoracic outlet syndrome

- Adson's test
- Wright's test/hyperabduction test
- Military maneuver
- Roos test
- *Patency of radial & ulnar artery*: Allen's test
- *Signs of Nerve root compression*:
 - SLR (passive)
 - Well leg/cross leg SLR (large disk)
 - Lasegue's test
 - Bragard sign
 - Bowstring sign of Mcnab
- *Modified Schober's test*: For testing lumbar spine flexion (as in Ankylosing spondylitis)
- *Scoliosis*: Adam's test for determining fixity of a curve

LOWER LIMB

- *Signs of supratrochanteric shortening (Neck femur fracture, hip dislocation acute or chronic)*:
 - Nelaton's line (can detect shortening in bilateral conditions)
 - Chinese line
 - Shoemaker's line
 - Bryant's triangle
- *Fixed flexion deformity at the hip*: Thomas test
- *Iliotibial band contracture*: Ober's test
- *Posterior dislocation of hip*: Vascular sign of Narath
- *SCFE*: Axis deviation
- *AVN hip*: Sectoral sign
- *Siffert-Katz sign*: Blount's disease
- *CDH (leg length discrepancy)*: Allis's/Galeazzi test
- *Unstable hip (CDH, Non-union NOF fracture, Neglected dislocation of hip)*: Telescopy + gluteus medius weakness: Trendelenburg test
- *Iliopsoas tendonitis*: Ludloff sign
- *SI joint involvement (Ankylosing Spondylitis)*:
 - Gaenslen's test
 - Patric/FABER test
 - Pump handle test
- *Ankylosing Spondylitis with cervical spine involvement*: Fletche test
- *CDH screening*:
 - Ortolani's test
 - Barlow's test (better)
- *Osteochondritis Dissecans knee*: Wilson's test
- *Chondromalacia patellae*: Movie/ theatre/ cinema sign
- *Pes cavus*: Coleman block test
- *Tendo Achilles rupture (second most common tendon rupture)*: Simmonds Thompson test.

MISCELLANEOUS

- *Chvostek's sign*: Tetany
- *Beighton's criteria*: Generalized ligamentous laxity
- *Sausage digits and arthritis mutilans*: Psoriatic arthritis
- *Scurvy*: Pseudo-paralysis of parrot
- *Trident hand*: Achondroplasia
- *Blue sclera/Dentinogenesis imperfecta*: Osteogenesis imperfecta

RADIOLOGY EPONYMS

IMPORTANT X-RAY SIGNS

General Orthopedics

X-ray signs in Scurvy: Wimberger ring, White line of Frankel (also seen in healing rickets and lead poisoning, methotrexate therapy

and renal osteodystrophy), Trummerfeld zone, Pelkan spur, Pencil thin cortex, Corner sign

X-ray signs in Rickets: Widening/splaying of the physis and cupping of the metaphysis

X-ray signs in osteomalacia: Pseudofractures/looser's zones, triradiate and champagne glass pelvis, cod fish vertebrae

Conditions with Looser's zones: Osteomalacia (characteristic), Renal osteodystrophy, Fibrous dysplasia, Hyperthyroidism, Paget's disease of bone, X-linked hypophosphatemia, Osteogenesis imperfecta

X-ray signs in Perthes disease: Sagging rope sign, Gage sign and Crescent sign (also seen in Avascular necrosis of head of femur)

X-ray signs in SCFE: Trethowan sign, Metaphyseal blanch sign of steel

X-ray features in Achondroplasia: Short interpedicular distance, bullet shaped vertebra, champagne glass pelvis

X-ray features in Nail patella syndrome: Hypoplastic or absent patella, bilateral posterior iliac horns (Fong's prongs) and prominent anterior iliac spine

Dripping candle wax appearance/Flowing calcification: Melorheostosis (Leri's disease)

X-ray signs in Trochlear dysplasia: Crossing sign, Double contour sign

Rugger jersey spine: Hyperparathyroidism, osteopetrosis

X-ray signs in hyperparathyroidism: Papper pot skull, Salt and pepper appearance (skull), sclerosis at the base of skull, Brown's tumors, Rotting fence post appearance of femur, Sub-periosteal resorption of radial side of terminal and middle phalanges (For other causes of acroosteolysis see page 336)

X-ray signs in Ankylosing spondylitis: Romanus lesions of the spine (Shiny corner sign), Anderson's lesion (Spinal pseudarthrosis), Squaring of vertebrae, Bamboo spine appearance, Dagger spine appearance

Pencil in cup appearance: Psoriatic arthropathy

Ivory phalanx: Psoriatic arthropathy

Martel/ G sign: Gouty arthritis

Kissing spines: Baastrup's disease (A degenerative change, bony proliferation between the spinous processes of closely approximated adjacent vertebrae)

X-ray signs of Paget's disease: Osteoporosis circumscripta (cotton wool spots in skull), Tam O' Shanter sign (skull), Picture frame vertebra, Ivory vertebrae, Blade of grass or flame appearance (long bones), Brim sign

Bone within bone appearance (Endobones): Osteopetrosis, Sickle cell anemia, Thalassemia, Paget's disease, Acromegaly, Lead poisoning, Growth arrest lines (infancy), Gaucher's disease and congenital syphilis.

Erlen Meyer Flask deformity: Osteopetrosis, Achondroplasia, Metaphyseal dysplasia (Pyle's disease), Fibrous dysplasia, Rickets, Rheumatoid arthritis, Ollier's disease, Thalassemia, Gaucher's disease, Niemann-Pick disease

White bone (sclerotic bone) disorders: Osteopetrosis, osteopoikilosis, osteomyelitis, osteopathia striata, melorheostosis, Caffey's disease, pyknodysostosis

Fairbank's triangle: Congenital coxa vara (classical), Non-union neck femur in children

TB hip: Wandering acetabulum, Pestel and mortar appearance

TB spine: Aneurysmal sign (Anterior TB), Concertina collapse (Central TB)

Wormian bones: Osteogenesis imperfecta (see page 306 for list of all causes)

Vertebrae plana: See Bone tumor capsule

Risser's sign: Scoliosis

Trauma

Thurston Holland Fracture fragment: Type II and type IV physeal injuries

Light bulb sign: Posterior dislocation of shoulder

Hill Sachs lesion: Recurrent shoulder dislocation

Bankart's lesion: Recurrent shoulder dislocation

Sourcil sign: Massive retracted rotator cuff tear

Celery stalk appearance of distal femur: Chronic ACL tears (mucoid degenerations) and Congenital Rubella

Fat pad sign: Undisplaced supracondylar fracture humerus

Terry Thomas/David Letterman sign: Scapholunate dissociation due to ligamentous injury

Spilled tea pot sign: Lunate dislocation

Hawkins sign: Fracture talar neck for predicting avascular necrosis

Battered baby syndrome: Metaphyseal Corner fractures, Metaphyseal Bucket handle fractures,

Eggshell fractures, Subdural hemorrhages

Spur sign: Both column fracture acetabulum

Beheaded scottish dog sign (Oblique view) and Inverted Napoleon Hat sign (AP view): Spondylolisthesis

SOME IMPORTANT ANGLES, TRIANGLES, LINES AND INDICES

Southwick's angle: SCFE

Acetabular index: CDH

Alpha and Beta angles: CDH (on ultrasonography)

Kite's angle: CTEV

Singh's index: For grading osteoporosis by quantifying trabeculae in neck femur

Ward's triangle: Femoral neck (significant for osteoporosis grading)

Babcock's triangle: Neck of femur (could be starting point of TB hip)

Reimer's index: CDH

Center edge angle of Wiberg: CDH

Fairbank's triangle: Congenital coxa vara (classical), Perthes disease, Non union neck femur

Neck shaft angle: Normal is 127 degrees

Pauwel's angle: Neck of femur fracture

Hilgenreiner's epiphyseal angle: Congenital coxa vara

Shenton's line: Normally a continuous line. Broken in any pathology that affects supratrochanteric area

Bohler and Gissane's angles: Calcaneum fractures

Neutral triangle: Calcaneum

Meary's angle and calcaneal pitch: Pes planus and cavus

Bauman's angle and Anterior humeral line: Supracondylar humerus fracture

Distal radius indices: Radial length, Volar tilt, Ulnar variance

Gilula lines: Congruent arcs in normal wrist X-ray

Cobb's angle and Mehta's angle: Scoliosis

Matta's roof arc angle: Acetabular fractures

Metaphyseal-Diaphyseal angle of Drennan: Blount's disease.

SOME X-RAY VIEWS TO REMEMBER

Axillary view: Lateral view of shoulder joint

West point axillary view: For Bankart's lesion

Internal rotation view and Stryker notch view: for Hill Sachs lesion

Zanca view: Acromio-clavicular joint

Serendipity view: Sternoclavicular joint imaging to detect dislocation

Green span view: Fractures of radial head and capitellum

Jones (AP) view elbow: Evaluation of reduction in supracondylar humerus fractures

Oblique view wrist and PA view wrist in ulnar deviation: Scaphoid fractures

Brewerton view: Used to see metacarpal head fractures

Robert's view: Used for thumb CMC joint

Carpal tunnel view: For hook of hamate fractures

Ball catcher's view: For visualizing erosions in RA hand

Judet views (Obturator oblique and Iliac oblique views): Acetabular fractures

Frog leg view: A modified method of taking lateral view of hip joint intraoperatively

Von Rosen view: CDH

Axial view, Skyline view and Merchant's view: Patellar subluxation

Mortise view (ankle AP view in 15° internal rotation): Ankle injuries evaluation

Canale view: Talar neck fractures

Harris view of hind foot: Calcaneum fractures

Broden views: Intraoperative assessment in calcaneal fractures

Swimmer's view: Cervical spine lateral view (shoulder pull down) to assess lower cervical spine (C6, C7 and T1 can be visualized)

Ferguson view: This is 20° caudocephalic AP view of lumbar spine used to detect compression of L5 by a large transverse process of L5 vertebra against sacrum (called as Far out syndrome).

Extra Marks

Rule of two: In any injury X-rays should always include one joint above and one joint below the level of trauma

Ottawa ankle rule: used to avoid unneeded radiographs after ankle injury (i.e. which patient needs X-ray after ankle injury?). Ankle X-ray is required if there is pain in malleolar region plus bony tenderness along the distal posterior edge (or tip) of medial or lateral malleolus or inability to bear weight for four steps.

Ottawa foot rule: X-ray foot is required if there is any pain in the midfoot zone plus bony tenderness at the base of the fifth metatarsal or at the navicular bone or inability to bear weight for four steps.

BONE TUMOR CAPSULE

Father of Orthopaedic oncology: Enneking

Classification system of bone tumors: ENNEKING classification

As per Bone Part Involved

All bone tumors in metaphysis except

Epiphyseal: GCT (metaphyseal if occurs before physeal closure), Chondroblastoma

Diaphyseal: Ewings sarcoma, osteoblastoma/osteoid osteoma, Fibrous dysplasia sometimes

As per Age Group

All tumors occur in less than 20 years age group except

40-60 years: Hemangioma, Chondrosarcoma

20-40 years: GCT

Bimodal: Osteosarcoma (Primary in 10-20 years and Secondary in 40-60 years)

Also remember, Ewing's age group is 5-15 years with second decade being more common

Most Common Sites

Fibrous dysplasia: Neck of femur and craniofacial bones (equal frequency)

Simple bone cyst: Proximal humerus

ABC: Proximal femur

Enchondroma: Hand bones

Chondroblastoma: Distal femur

Chondromyxoid fibroma: Proximal tibial metaphysis

Osteochondroma: Distal femur > Proximal tibia

Osteoid osteoma: Femur > Tibia (diaphysis)

Osteoblastoma: Vertebra (posterior elements) > Femur diaphysis

Hemangioma: Spine (T4-L4 region) > Skull

Giant cell tumor: distal femur > proximal tibia > distal radius

Osteosarcoma: Distal femur

Chondrosarcoma: Proximal femur

Ewings sarcoma: Femur diaphysis > Flat bones

Chordoma (tumor of notochord remnants): Sacrum

Ameloblastoma (also referred as Adamantinoma): Mandible

Adamantinoma of long bones is separate entity and its most common site is Tibia

Eosinophilic granuloma: Skull

Solitary plasmacytoma: Spine

Multiple myeloma: Spine

Glomus tumor: Subungual area of fingers

Synovial cell sarcoma: Knee

Pigmented villonodular synovitis (PVNS): Knee

Some Important One Liners

Most common tumor of bone: Metastasis

Most common primary tumor of bone: Multiple myeloma > Osteosarcoma > Chondrosarcoma

Most common benign bone tumor: Osteochondroma

Most common true benign bone tumor: Osteoid osteoma

Most common lesion of bone: Fibrous cortical defect

Most common malignant tumor of bone found in first decade of life: Ewings sarcoma

Most common radiation induced tumor: Osteosarcoma > Fibrosarcoma > Malignant fibrous histiocytoma

Most radiosensitive and chemosensitive bone tumor: Ewing sarcoma

Most common tumour of jaw is squamous cell carcinoma of oral mucosa but most common bone tumour of mandible is Ameloblastoma

Commonest bone tumor of hand bones: Enchondroma (benign tumor)

Commonest malignant bone tumor of hand bones: Chondrosarcoma (otherwise, most common malignant tumor of hand-squamous cell carcinoma)

Commonest malignant bone tumour of chest wall: Chondrosarcoma

Tumor with history night pains: Osteoid osteoma

Tumor showing diagnostic response to Aspirin/NSAIDs: Osteoid osteoma

Codman's tumor is Chondroblastoma

Pulsatile bone tumors include ABC, Osteoclastoma (GCT), Telangiectatic osteosarcoma, Metastasis from follicular carcinoma thyroid and renal cell carcinoma (most pulsatile).

Egg shell calcification is a clinical sign in: GCT

Cell of origin of Ewings sarcoma is: Mesenchymal/mesodermal

Markers for Ewing sarcoma: MIC-2 gene, CD-99, trl (11;22)

Mode of inheritance in Hereditary multiple exostosis is—Autosomal dominant

Virus associated with osteosarcoma is FBJ murine virus

Most common extraskeletal manifestation of Fibrous Dysplasia is Caif-Au-Lait spots

The least recurrence rate in extended curettage is seen with the use of Liquid nitrogen

Important X-Ray Signs

Fibrous dysplasia: Ground glass appearance, Rind sign (sclerotic margin around tumor), Shephard crook deformity (collapse of medial part of femoral neck so that proximal femur becomes hook shaped, seen in Paget's disease and Osteogenesis imperfect also)

Simple bone cyst: Fallen leaf sign (can be seen in ABC but less often), Trap door sign

Hemangioma: Corduroy appearance (Jail house sign), Polka dot pattern

Osteoid osteoma: Nidus < 1.5 cm and Osteoblastoma > 1.5 cm

GCT: Soap bubble appearance

Osteosarcoma: Codman's triangle, Sunray appearance (due to calcification along Sharpey's fibers)

Chondrosarcoma: Pop corn like calcification

Ewing sarcoma: Onion peel appearance (intense periosteal reaction in layers), Codman's triangle

Eosinophilic granuloma: Punched out lytic lesions in skull with double contours

Multiple Myeloma: Punched out lesions without a reactive/sclerotic surrounding zone

Causes of Vertebrae Plana (Flat Vertebrae)

Langerhan cell histiocytosis (LCH): Most common cause is Eosinophilic granuloma, a subtype of LCH

Ewing sarcoma

Lymphoma/Leukemia

Gaucher's disease

Aneurysmal bone cyst

Infection: Spondylitis

Some Syndromes Associated with Bone Tumors

McCune Albright syndrome: Polyostotic fibrous dysplasia, Pre-cocious puberty, Caif-Au-Lait spots

Mazabraud syndrome: Polyostotic fibrous dysplasia with intramural myxomas

Diaphyseal achalasia: Multiple osteochondromatosis/Hereditary multiple exostosis

Masada syndrome: Multiple osteochondromatosis in forearm

Ollier's disease: Multiple enchondromatosis

Maffucci syndrome: Ollier's disease plus multiple cavernous hemangiomas

Important Biopsy Patterns

Fibrous dysplasia: Chinese letter pattern

Chondroblastoma: Chicken wire appearance

Malignant fibrous histiocytoma: Storiform pattern

Fibrosarcoma: Herringbone pattern

GCT VARIANTS (where giant cells are there on biopsy): Chondroblastoma, ABC (closest), SBC, Osteosarcoma with giant cells, fibrous dysplasia, non-ossifying fibroma

Ewings sarcoma: Small round cells (Also seen in Lymphomas, neuroblastoma, pineoblastoma, medulloblastoma, retinoblastoma—so called Primitive neuroectodermal tumors)

Biphasic pattern: Synovial cell sarcoma

Important Tumor Markers

Ewings sarcoma: trl 11;22 (present in 85% cases), CD-99 and MIC-2 gene positive

Synovial cell sarcoma: trl X;18

Eosinophilic granuloma (LCH): S-100, CD1-a, Neuron specific enolase (Birbeck granules may be seen on electron microscopy)

Bone Metastasis

After lung and liver, skeletal system is the third common site to receive secondary metastatic deposits from a primary site. Infact metastasis form the most common tumors of the bone.

Metastasis can be blastic/sclerotic or lytic. Blastic are seen in prostate carcinoma and seminoma while lytic are seen in Kidney, Thyroid and Lung malignancies. However, the most common metastasis to bone come from breast carcinoma and are mixed and most commonly affect the thoracic spine.

Most common primary sites for metastasis to bone

In males: Prostate > Lung

In females: Breast > Lung

In children: Neuroblastoma

Overall: Breast > Prostate > Lung

Most common area to be involved in metastasis to bone is spine (thoracic spine)

Bone to bone metastasis is seen with Ewing's sarcoma > Osteosarcoma Metastasis distal to the knee and elbow are very rare and generally tend to arise from lung (most common) and tibia is the most common affected bone in these cases.

Metastasis from bone to other organs most commonly involve lung.

The IOC for detecting occult osteoblastic metastasis is bone scan and osteolytic ones is PET-CT.

Femoral neck is the most common site for a pathological fracture in bone metastasis.

Markers of Bone Formation and Resorption

Bone Resorption:

Urine and serum cross-linked N telopeptides

Urine and serum cross-linked C telopeptides

Urine hydroxyproline

Urine deoxypyridinoline

Urine hydroxylysine glycosides

Serum TRAP (Tartarate resistant acid phosphatase)

Serum bone sialoprotein

Bone Formation:

Serum bone specific alkaline phosphatase

Serum osteocalcin

Serum carboxy terminal extension peptide of procollagen-1

Serum type I collagen extension peptide.

Soft Tissue Sarcomas

Most common soft tissue sarcoma in adults: Malignant fibrous histiocytoma followed by liposarcoma

Most common soft tissue sarcoma in young adults: Synovial cell sarcoma

Most common soft tissue sarcoma in children: Rhabdomyosarcoma

Most common site of Rhabdomyosarcoma: Genitourinary followed by extremities.

Most common soft tissue sarcoma of the hand/upper extremity: Epithelioid sarcoma

Most common soft tissue sarcoma in the foot: Synovial cell sarcoma

Most important prognostic factor in soft tissue sarcomas: Histological grade

Most common radiation-induced soft tissue sarcoma: Malignant fibrous histiocytoma (otherwise, most common radiation-induced sarcoma-osteosarcoma)

Extra Marks

(#) *Prognostic factors for Ewing's sarcoma:* The most unfavorable prognostic factor in Ewing's sarcoma is the presence of distant metastasis at diagnosis. Other unfavorable prognostic factors include an age older than 10 years, a size larger than 8 cm, more central lesions (as in the pelvis or spine) and poor response to chemotherapy. The histological grade is of no prognostic significance, as all Ewing's sarcomas are of high grade. Fever, anemia, and elevated white blood cell (WBC) count, ESR, and lactate dehydrogenase (LDH) values have been reported to indicate more extensive disease and a poorer prognosis. The presence of t(11; 22) (present in 90% cases of Ewing sarcoma) however, does not seem to affect the clinical course.

(#) Extraosseous osteosarcoma and Ewing sarcoma are also known to occur. These generally involve older adults and have relatively bad prognosis as compared to the osseous counterparts. Most common site for extraosseous Ewing's is paravertebral musculature and chest wall while it's high for extraosseous osteosarcoma.

(#) The commonest site for an extramedullary myeloma is skin and soft tissues > liver. Over 80% of these arise in the region of head and neck, especially the upper respiratory tract.

SPINAL CRASH COURSE

SPINAL INJURIES

Vertebrae with most constant number are cervical while the most variable region is coccygeal

Most common mode of injury: Fall from height in developing and RTA in developed world

Most common level of vertebral fracture: D12 > L1

App 20% of spinal injuries land up with neurological deficit

Special X-ray view to visualize lower cervical spine: Swimmer's view

Dislocations without fractures are commonest in cervical spine

Osteoporosis is the most common cause of compression fractures.

Mechanisms of Vertebral Injury

Most common mechanism of injury: Flexion (Flexion distraction)

Most dangerous: Shear/translation > Flexion rotation > Flexion distraction

Facet dislocations seen in: Flexion rotation > Flexion distraction

Burst fractures occur due to: Axial compression

Tear drop fractures and wedge compression fractures occur in: Flexion compression injuries

Fracture Eponyms

Jefferson fracture: It is most common type of atlas fracture. It is a burst fracture of C1 vertebrae. Despite being a burst fracture, the chances of neurological deficit are considerably low.

Chance fracture (Seat belt injury/Jack knife injury): Seen in head on collision of vehicles. It's a flexion followed by flexion distraction injury. Vertebral column is transected thru and thru from front to back causing complete cord injury. Generally T12-L2 vertebrae are involved.

Whiplash injury (Rail road spine): It occurs when a vehicle hits your car from back (rear end collision). There is sudden hyperflexion of spine followed by hyper extension (main damaging force). The X-rays are mostly normal but sometimes there can be injury to the cord.

Clay Shoveller's fracture: Avulsion fracture of spinous process of vertebrae (C7 > T1)

Jumper's fracture: It's a transverse fracture (U or H shaped fracture line in upper sacrum) of sacrum when there's fall from height.

Hangman's fracture: Technically spondylolisthesis of C2 over C3/ or a fracture of pars/isthmus of C2. It is classified by Levine and Edwards classification into three types out of which Type II is commonest and in type II, cervical traction is contraindicated for treatment. Just immobilize with collar, union almost always occurs. Mechanism involves hyperextension followed by distraction in hanging and extension with axial loading (RTAs, more common). It is second most common type of axis fracture (Odontoid being most common). Acute post admission mortality is low.

SCIWORA: It refers to "spinal cord injury without radiological abnormality". It's an injury pattern classically seen in children < 8 years (classically infants) due to their lax ligaments. During injury there is distraction injury to cord but no visible injury to vertebral column.

Treatment Protocol for Spinal Fractures

Stable fractures are treated with cervical traction with crutchfield tongs

Unstable fractures (with neurological deficit) initially are managed with traction and once patient is stable, operative decompression with instrument stabilization is performed.

If a polytrauma patient presents to emergency now, even before airway management the first recommendation is cervical collar application for stabilizing spine.

Spondylolisthesis

Fracture in pars interarticularis part of vertebra which causes upper vertebra to slip forward over the lower

Isthmic > Degenerative type is commonest

Commonest level is L5-S1

X-ray signs include: Inverted napoleon hat sign in AP view and Scottish dog sign in lateral view

Least useful view for spondylolisthesis is AP view.

SPINAL CORD INJURY

Immediately after injury patient lands up with spinal shock i.e. there is complete loss of power and sensation below the level of lesion. Spinal shock lasts for app. 24-72 hrs. and then recovery starts. During recovery patient demonstrates increased tone and exaggerated reflexes below the level of lesion.

First reflex to come after spinal shock is over: Bulbocavernosus reflex

Neurogenic shock: It's a complication of spinal cord injury when the injury is above T6 generally. It refers to fall in BP due to loss of sympathetic support from cord. One has to differentiate it from hypovolemic shock. In neurogenic shock despite low BP, pulse rate is low because of absent sympathetic support but in hypovolemic shock there is tachycardia.

Autonomic dysreflexia: It's another possible complication of spine injury (generally above T6 level). It's characterized by paroxysmal hypertension due to autonomic overstimulation that occurs as a result of misinterpretation of the afferent stimuli from areas below the level of the lesion.

To localize level of any spinal cord injury important things to remember:

DERMATOMES

Upper Limb	Lower Limb
C4—Shoulder	L1—Groin
C5—Lateral arm	L2—Anterior thigh
C6—Thumb and lateral fore arm	L3—Anterior knee
C7—Index to ring finger	L4—Medial leg and foot
C8—Little finger	L5—Lateral leg and foot
T1—Medial forearm	S1—Plantar surface of foot and calf
	S5—Perianal area

MYOTOMES

Upper Limb	Lower Limb
C-5—Deltoid	L-2—Hip flexor (Ilio-psoas)
C-6—Wrist extensors	L-3—Knee extensors (Quadriceps)
C-7—Wrist flexors/Elbow extensor	L-4—Ankle dorsiflexor (Tibialis anterior)
C-8—Finger flexors to the middle finger	L-5—Long toe extensors (EHL)
T-1—Small finger abductors	S-1—Ankle plantar flexors (Gastro-soleus)

REFLEXES

Upper Limb	Lower Limb
Biceps- C5	Knee- L3, L4
Triceps- C7	Ankle- S1, S2
Supinator- C6	Plantar- L5, S1

**Beevor's sign:* (T7-T12)- Patient is asked to sit up from supine position with hands on back of head and movement of umbilicus is noted.

Complete vs Incomplete Cord Injury

To know if some part of cord is spared look for SACRAL SPARING represented by intact perianal sensations, voluntary rectal motor function and great toe flexor activity. This signifies that at least some part of cord (sacral being innermost) is intact and hence its incomplete cord injury and one can expect some functional return.

Incomplete/Partial Spinal Cord Injury Syndromes

Brown Sequard Syndrome: Hemi-transection of cord. I/L loss of muscle power, I/L loss of proprioception, sense of vibration AND C/L loss of pain and temp sensation. Prognosis for recovery is best with 90% patients improving.

Central Cord Syndrome: Most common syndrome. Patients have quadriparesis involving UL (FLACCID PARALYSIS > LL (SPASTIC PARALYSIS). It results from hyperextension injury in older person with preexisting OA of spine. The SC is pinched between the vertebral body ant and buckling ligamentum flavum post affecting the centrally placed UL tracts Prognosis is second best with > 50% patients recovering BB function, ambulation.

Anterior Cord Syndrome: Typically after hyperflexion. Predominantly patient has motor loss and pain and temperature loss. Dorsal column (sensations) preserved. Recovery rate poorest!

Cauda Equina Syndrome (Orthopedic emergency): Refers to multiple hanging lumbar nerve root compression in spinal canal occurring in vertebral injury level below L1 (where spinal cord ends and nerve roots are there in canal. Clinical features include saddle anaesthesia, bilateral radicular pain, asymmetrical flaccid paralysis in both lower limbs with areflexia and loss of voluntary bladder and bowel function.

Conus Medullaris Syndrome: Seen in T12-L1 injuries. There is loss of bladder bowel control due to injury to sacral part of spinal cord with perianal anesthesia (cf saddle in cauda). Knee reflex is always preserved which can be lost in Cauda equina. The bulbo cavernous reflex may be permanently lost.

Most common incomplete spinal cord injury syndrome: Central cord syndrome

Incomplete spinal cord injury syndrome with worst prognosis: Anterior cord syndrome

Incomplete spinal cord injury syndrome with best prognosis: Brown-Sequard syndrome.

Disk Prolapse

Commonest level is L4-L5 > L5-S1. In cervical spine commonest level is C6-C7 > C7-C8.

In disk prolapse, for example in L5-S1 prolapse, always lower level nerve root is compressed, so here S1 will be compressed. Same formula applies to disk prolapse in cervical spine

RED and YELLOW FLAG SIGNS: Red flag include signs that are possible indicators of serious spinal pathology while yellow flags include psychosocial factors indicative of problem ending up in long term chronicity and disability.

Treatment: In disk prolapse generally those patients are advised operative decompression (laminectomy) who either present with progressively increasing neurological deficit or those who do not respond to conservative treatment for minimum of 6 weeks.

Spinal Canal Stenosis

Refers to condition where mostly due to facet joint degeneration there is narrowed diameter of spinal canal (< 10 mm), mostly affecting the lumbar spine. These patients present with Ape like posture (forward flexed position) and intermittent claudication pain on walking a fixed distance. The clinical sign positive is Shopping cart sign. The patients not responding to conservative treatment need operative decompression for which conventionally laminectomy was advised while a recent option (especially for cervical stenosis) coming up is Laminoplasty. It is a method of spinal decompression mainly used in canal stenosis in cervical spine (use of laminoplasty for disk removal is not advocated). Here the lamina is not removed. Rather bone is cut and swung open to decompress the cord and then repositioned.

Vertebroplasty and Kyphoplasty

VERTEBROPLASTY refers to injecting bone cement (PMMA) in vertebral body via transpedicular route to strengthen the collapsing vertebrae, a treatment for prevention of osteoporotic compression fractures. KYPHOPLASTY is a better form where an inflatable balloon is introduced prior to cement injection to restore the height of the collapsed vertebra in order to correct the deformity.

Vertebroplasty is also employed in treatment of a vertebral hemangioma. However, the procedure is contraindicated in spinal or generalized infections, uncontrolled bleeding disorders, asymptomatic patients and in spinal tumors with cord involvement.

LIGAMENTOUS INJURIES OF KNEE REVISITED

Introduction

Two cruciate ligaments (ACL, PCL): Intra-articular but extrasynovial

Two collateral ligaments (MCL, LCL): Extra-articular and extrasynovial

Two menisci (cartilaginous c shaped washers between condyles with medial meniscus being larger than lateral): Intra-articular and intra-synovial

Mechanisms of Injury

MCL: Valgus thrust to knee

LCL: Varus thrust to knee

ACL: Hyperextension of knee (*With tibia grounded, when knee is hyperextended, femur moves back on tibia. This ruptures ACL which prevents tibia moving forwards on femur or vice versa*)

PCL: Dashboard injury to a hyperflexed knee

Menisci (Medial injured more than lateral): Twisting injury (rotation of condyles)

(A question comes that injury to menisci is impossible until there is no- Flexion, Extension, Rotation etc? Answer is Flexion as in extension knee is locked and no rotation is possible and hence no meniscal injury (prefer flexion as answer more over rotation)).

****But please make note that in clinical practice isolated injuries are seldom seen as combination of forces act on knee, resulting in specific patterns of injuries.**

Most common combination pattern: O'DONOGHUE'S UNHAPPY TRIAD (ACL, MCL, Medial meniscus)

Other important pattern is SECOND FRACTURE: ACL tear plus avulsion of capsule from Lateral tibial plateau (*The question that comes refers to chip of avulsed bone on lateral side of tibia and candidate is asked regarding associated ligament injury, answer is ACL*)

Diagnostic Tests

For Collateral ligament injuries: Stress tests (Varus stress test for LCL and Valgus stress test for MCL tear): most specific for collaterals when done at 30° of knee flexion, Apley's distraction test

For ACL: Anterior drawer, Lachman test that is done at 15° of knee flexion (most sensitive). Most specific test is Pivot shift test.

For PCL: Posterior drawer, Godfrey's posterior sag, Quadriceps active test

For Meniscus: McMurray test, Bounce home test, Apley's grinding test, Thessaly's test (currently being proposed as best screening test), Duck waddle test (Childress sign), Joint line tenderness (*Best test for meniscal injury*)

**** In chronic cases of ligament injuries there is Instability at knee and tests for instability include:**

Anterolateral instability (more common) (main component is ACL tear): Pivot shift test

Posterolateral instability (main component is PCL tear): Dial test, Reverse Pivot shift test

[Dial test is performed at both 90° degree and 30° degree knee flexion. At 30° degree positive test indicates posterolateral corner (PLC) injury while at 90° degree it indicates PCL plus PLC injury]

Management

For Collateral ligament injury: Conservative treatment as they mostly heal by themselves

For Cruciate ligament injuries: Reconstruction (i.e replace with hamstring tendon graft)

For menisci: They are avascular (except in peripheral zone, so remove the torn part (meniscectomy))

Competetion Points

Most common ligament injury overall: Medial collateral ligament (but most heal conservatively)

Most common surgically managed knee ligament injury: ACL injury
Ligament best seen on MRI- PCL (but diagnosis and surgery decision is mainly clinical)

Investigation of choice is MRI but the gold standard is Arthroscopy
Medial meniscal injury is more common than lateral but degenerative changes post-meniscectomy are more in lateral meniscus

The most common meniscus tear associated with ACL tear at the time of initial injury is lateral meniscus, though in chronic cases medial meniscus is torn more often than the lateral meniscus due to abnormal loading in ACL deficient knee. Over all posterior horn of medial meniscus is the most common meniscal tear and most tears are of longitudinal type (bucket handle tear is a severe variety of longitudinal type)

Locking (pathological): Refers to inability to extend knee to full extent generally due to a chock of bucket handle tear of meniscus lying inside the joint. (*The term locking has entirely separate and unrelated meaning in anatomy*)

Also remember, if one has to walk downhill, knee will need to go into hyperextension so ACL patients will fear instability while if one has to go uphill, PCL patients will have problems as there is pressure on a flexed knee

Pelligrini Steida Lesion: Calcification at femoral attachment site of MCL

A Bucket handle tear of meniscus gives a Double PCL sign on MRI of knee (not a PCL tear)

Multiligament knee injuries are defined as disruption of at least 2 of the 4 (ACL, PCL, MCL, LCL) major knee ligaments as a result of trauma.

ACL tear is the commonest cause of hemarthrosis in the knee joint

Swelling after cruciate ligament tear is immediate as blood vessels rupture but not so in meniscus which is avascular. In the latter case the swelling generally appears after a day as it is more commonly due to a synovial reaction

The most pain sensitive structure in the joint is the capsule and least pain sensitive structure in the joint is the articular cartilage

Although more common to tear is the medial meniscus, a meniscal cyst and a discoid meniscus (that increase chances of meniscal tear) are more commonly seen in lateral meniscus.

Cyst in a meniscus is more common in lateral meniscus and occurs in the posterior horn. The clinically appear as swellings along the posterior joint line and disappear within joint on knee flexion (Pisani sign)

Celery stalk appearance is seen on MRI in cases of chronic ACL tears (due to mucoid degeneration) while a celery stalk metaphysis is seen on X-ray in cases of Congenital Rubella

Screw home mechanism: Tibia external rotates in extension while in flexed knee it internal rotates such that the tibial tuberosity comes to lie in line with the patella. This is called Screw home mechanism. It is due to specific bony anatomy of knee (condyles are unequal) and relative difference in lengths of the two cruciate ligaments.

Effusion in the knee joint can be tested by following tests:

Bulge sign (positive with 10-15 ml of fluid)

Patellar tap

Ballottement of patella

SURGERIES UNDER ONE ROOF

OPERATIONS WITH SPECIAL NAMES

Upper Limb

Bankart's operation: Anterior shoulder instability due to Bankart's lesion

Putti plat operation: Anterior shoulder instability due to Hill Sachs lesion

Bristow – Latarjet operation: Anterior shoulder instability due to Hill Sachs lesion

French osteotomy (modified): Cubitus varus deformity (Malunited supra condylar humerus)

Milch osteotomy: Cubitus valgus deformity (Non-union Lateral condyle humerus)

Maxpage operation: Volkmann's ischemic contracture

Steindler's release: Plantar fascia release for Pes Cavus

Fernandez osteotomy: Malunited Colles fracture.

Dwyer's osteotomy: Isolated heel varus (in CTEV)

Lambrinudi arthrodesis: Fixed equinus deformity at foot

Grice green procedure (subtalar arthrodesis): Congenital Vertical Talus

Steindler's flexorplasty (shifting flexor origin proximally for about 5 cm to strengthen elbow flexion): For loss of elbow flexion in paralytic disorders

Vulpus release: Equinus in Cerebral Palsy patients is generally due to selective contracture of soleus muscle and is treated by Vulpus release

Verebelyi-Ogston (V-O) procedure: A rigid clubfoot in meningomyelocele may need decancellation of talus and cuboid called as VO procedure

Keller's operation (excision arthroplasty): Hallux valgus

Mitchell's & Chevron osteotomy: Hallux valgus

Jone's operation: Claw toes

Lower Limb

Pelvic osteotomies in CDH

Salter's osteotomy: Conventional, most commonly done

Pemberton's osteotomy: Best correction

Chiari's osteotomy: Salvage procedure

Varus derotation osteotomy: Perthes disease

Girdle stone arthroplasty: TB hip

Core decompression: Nontraumatic AVN femoral head

Mcmurray's osteotomy: AVN Hip, osteoarthritis hip, non-union fracture neck femur

Pauwel's osteotomy: Non-union fracture neck femur

Meyer's/Bakshi's procedure: Non-union neck femur fracture, traumatic AVN femoral head (early stages)

Elmslie Trillat osteotomy: Recurrent dislocation patella

Yount's release: IT band contracture (Poliomyelitis)

Seek kebab treatment: Osteogenesis imperfecta

Tension band wiring: Transverse fracture patella, olecranon fracture & malleolar fractures

Turco's PMSTR: CTEV (1-5 years age)

Dillwyn evan's procedure: CTEV (5-10 years age)

Triple arthrodesis: CTEV (Age > 10 years)

Spine

Anterolateral decompression: TB SPINE

Hong Kong procedure (radical anterior decompression with bone grafting): TB cervical spine

Smith Peterson osteotomy: Ankylosing spondylitis

SOME IMPORTANT TENDON TRANSFERS

Omer's transfer: Ulnar nerve palsy

Jones transfer: Radial nerve palsy

Saha's transfer (trapezius to deltoid): Deltoid paralysis in polio or brachial plexus palsy

Camitz transfer (Palmaris longus to Abductor pollicis brevis): Carpal tunnel syndrome

Zancolli tenodesis: Claw hand

Sharad/mustard transfer (iliopsoas to greater trochanter): Gluteus medius paralysis (poliomyelitis)

Kaufer (tibialis posterior to peroneus brevis): Equinovarus deformity at foot

Hoffer (tibialis anterior to medial cuneiform): Equinovarus deformity at foot

Perry (peroneus brevis to tibialis posterior): Equinovarus deformity at foot

IMPLANTS AND THEIR USES

Charnley prosthesis: THR

Bipolar (Talwalkar) prosthesis: Hemiarthroplasty

Unipolar prosthesis: Hemiarthroplasty

Austin Moore prosthesis—young patients

Thompson prosthesis

SP (Smith-Peterson) nail: Neck femur fixation

Knowles and Moore's pins: Neck femur fracture fixation in children

Dynamic Hip Screw (DHS): Intertrochanteric fractures

Proximal Femoral Nail: Unstable intertrochanteric fractures

Reconstruction nail: Concomitant ipsilateral shaft and neck femur fracture

Condylar blade plate: Distal femoral fractures

K nail: Femur shaft diaphyseal fracture

Interlock nails: Femoral and Tibial diaphyseal fractures

Rush Nail: Long bone diaphyseal fractures

Enders Nail: Elastic nails for fixation of long bone diaphyseal fractures

Talwalkar nails: Diaphyseal fractures of forearm bones

Insall burstein prosthesis: TKR

Neer's prosthesis: Shoulder replacement

Bakshi's prosthesis: Elbow replacement

Swanson's prosthesis: Small joint arthroplasty in hand

K wires: Small bone fracture fixation

Steffi plate: Spine fixation

Implants for scoliosis correction: Hartshill rectangle, Harrington rods, Luque rods

Pedicle screws: Fixation of spinal fractures, Scoliosis correction

THE FIRST-THE LAST; THE SMALLEST-THE LARGEST; THE MOST-THE LEAST; THE BEST-THE WORST!

INFECTIONS

*Most common mode of spread of infection to bone—*Hematogenous

*Most common part of bone involved in osteomyelitis—*Metaphysis

Most common etiology in osteomyelitis:

Overall (in developed and developing countries, all age groups)—*Staph aureus*

In Sickle cell disease patients—*Salmonella*

In intra-venous drug abusers—*Pseudomonas*

In HIV/immune-compromised—*S. aureus*

In patients with prosthetic material—Coagulase negative staph
> *Propionibacterium*

After animal bite—*Pasteurella multocida*

After human bite—*Eikenella corrodens*

Diabetic foot ulcers/Fight bite—*Anaerobes*

In open fractures and posttraumatic cases—*Staph aureus*

In post-surgery cases—*Staph aureus*.

First X-ray sign of acute osteomyelitis: Soft tissue shadow > Periosteal reaction

Investigation for earliest diagnosis of Acute osteomyelitis: MRI (Magnetic Resonance Imaging) > Bone scan

Investigation of choice (IOC) for Acute osteomyelitis- MRI

Gold standard investigation for Acute Osteomyelitis: Aspiration of pus and culture sensitivity

Most common complication of acute osteomyelitis: Chronic osteomyelitis

Most common site for acute hematogenous osteomyelitis (seen predominantly in children) is distal femur

Most common site of osteomyelitis (acute or chronic) in adults is vertebrae

Most common complication of chronic osteomyelitis: Acute exacerbation > Pathological fracture

Most common site of Garre's osteomyelitis is jaw > Diaphysis of tibia

Most common site for Brodie's abscess is proximal tibia

Salmonella osteomyelitis most commonly involves: diaphysis of tibia and forearm bones

Most common organism causing septic arthritis: *S. aureus* in all age groups except in young sexually active adults where *Neisseria Gonorrhea* is the commonest cause

The most common joint affected in septic arthritis: knee > hip > shoulder

The most common joint affected in Brucellosis- Hip joint.

Most common organism causing hand infections- *S. aureus*

Most common site for felon—Thumb > Index finger

The most common type of actinomycosis—oro—cervico-facial

Overall, most common site of actinomycosis—mandible

The most common bone affected in congenital syphilis—Tibia

In Leprosy, ulnar nerve is the most common nerve involved, followed by common peroneal nerve. Most common cranial nerve involved is facial nerve.

Tuberculosis (TB)

Most common site of skeletal tuberculosis—spine > hip > knee

Least common site of skeletal tuberculosis—Bursal TB

Amongst bursal TB, most common bursa to be involved—Trochanteric bursa

Most common part of spine to be affected in TB spine—dorsal > lumbar > dorsolumbar (D12-L1)

Most common type of anatomical lesion in TB spine—Paradiscal

In posterior TB, least commonly involved facet joint > spinous process

Earliest and most common symptom of TB spine—back pain

Most common cause of paraplegia in TB spine—compression by tuberculous granulation tissue and pus

Paraplegia in TB most commonly results from disease of upper thoracic spine

The first clinical sign of TB spine- paraspinal muscle spasm

The order of neurological involvement in TB spine- Ankle clonus (first neurological sign) > Plantar extensor > Spastic motor weakness > Sensory loss > BBI

Paraplegia is commonest in TB involving dorsal spine

The first X-ray sign of TB spine—Disk space reduction

The IOC for TB spine—MRI

The best/gold standard investigation for TB spine—CT guided biopsy of involved vertebra

Earliest radiological sign of healing in tuberculosis—sharpening of fuzzy paradiscal margins

Tuberculosis is the most common cause of kyphosis in India

Painful limp is the earliest and most common symptom of tuberculosis of hip joint

The earliest X-ray feature of TB hip is juxta-articular osteopenia > joint space reduction

TRAUMA AND RELATED AREAS

General

Most mobile joint in the body—Shoulder

Most stable joint in the body—Hip

First clinical stage of union is woven bone while first radiological stage of union is callus (provisional callus that is seen earliest by 3 weeks)

Most common bone to fracture overall and at birth- clavicle > distal end of radius

Most common fractures in different age groups:

Birth: Clavicle

Children: Greenstick fracture of forearm bones > Torus fractures at distal end radius

Adults: Vertebral fractures > Distal end radius

Most common fractures when there is history of fall on outstretched hand:

Child (< 8-10 years old): Supracondylar humerus fracture

Adolescent: Scaphoid fracture

Adult: Distal end radius fracture

Some important facts about dislocations:

Most common dislocation in Adults—Shoulder > Elbow

Most common dislocation in Children—Elbow

Most common site for Recurrent dislocation—Shoulder > Patella

Most common site for Habitual dislocation—Shoulder > Patella

One of rarest site for recurrent dislocation—Ankle

Most dangerous and one of rarest dislocation—Knee

Most common site of open fractures—Tibia

Most common joint to be involved in open injuries—Knee

Most common site of non union—Distal Tibia

Most common cause of non union—Inadequate immobilization

The most common joint involved in myositis ossificans is elbow > hip. However, the most common muscle involved in myositis is quadriceps

In heterotopic ossification the earliest detection can be done by a bone scan. However, the screening investigation for the purpose is alkaline phosphatase levels

Most common site of physeal injury in a child—Phalanx > Distal end of radius

Most common type (Salter Harris) of physeal injury—Type II

Weakest zone of growth plate—Hypertrophic zone

Most common site of stress fracture—Lower tibia > Metatarsals > Fibula

Most common site of stress fracture in foot—Metatarsals (2nd > 3rd)

Most common tarsal bone to sustain stress fracture—Navicular

IOC for stress fractures—MRI

IOC for bilateral stress fractures—Bone scan

IOC for occult fractures—MRI

Most common cause for destructive bone lesion in adults—Metastatic carcinomas

The most common site of pathological fracture—Femoral neck

In Limb re-implantation the first structure to be re-implanted is bone while the greatest priority is given to vessels

In Crush injury hand the first to be repaired is bone while greatest priority is given to skin

Shoulder and Arm

Most common complication of fracture clavicle—malunion

Most common type of shoulder dislocation—Anterior > Posterior > Inferior (Luxatio Erecta)

Most common subtype of anterior shoulder dislocation—Sub coracoid > Sub glenoid

Most common subtype of posterior shoulder dislocation—Sub acromial

Most common acute complication of shoulder dislocation—Axillary nerve injury (circumflex branch)

Most common (overall) complication of shoulder dislocation—Recurrent dislocation

Most common lesion leading to recurrent shoulder dislocation—Bankart's repair

Most common complication of proximal humeral fractures—stiffness

The most common complication of fracture shaft humerus—radial nerve palsy

The most common cause of non-union in fracture shaft of humerus—distraction at the fracture site

Elbow and Forearm

The most common type of supracondylar humerus fracture- extension type

Most common complication of supracondylar humerus fracture- cubitus varus/gun stock

deformity (malunion)

The most common fracture associated with vascular injury in child- supracondylar humerus fracture.

Most common nerve involved in supracondylar humerus fractures:-

Overall and in extension type—Anterior interosseous nerve > Median nerve > Radial nerve

Flexion type—Ulnar nerve

Post-surgery—Ulnar nerve

Postero medial (more common than postero-lateral)—Radial

Posterolateral—Median

The most reliable and earliest sign of compartment syndrome is passive stretch test. The last clinical sign is paralysis and most unreliable is pulselessness

The most common cause of compartment syndrome is fracture. In children it is supracondylar humerus fracture while in adults it is proximal tibia fracture. Overall compartment syndrome is more common in leg and tibia fractures are the commonest cause.

The most common/ first muscle involved in supracondylar humerus fracture- FDP > FPL

The most common nerve involved in Volkmann's Ischemic contracture (VIC) is Anterior interosseous nerve

Ipsilateral radius fracture is most commonly associated fracture with supracondylar humerus fracture.

The most common deformity after lateral condyle humerus fracture is cubitus pseudo-varus (due to lateral spur formation) > cubitus valgus > cubitus varus

Lateral condyle fracture is the commonest cause of tardy ulnar nerve palsy.

Elbow dislocation is second commonest dislocation in adults and the commonest dislocation in children

Most common type of elbow dislocation is posterolateral

The most common nerve injured in simple elbow dislocation is the median nerve while in complex elbow dislocations (dislocation with fractures) it is the ulnar nerve that is generally injured

Most common associated fracture with elbow dislocation—Medial epicondyle

The most common complication of distal end radius fractures—stiffness > malunion

Most common cause of Sudeck's osteodystrophy—distal end radius

Most common type of Monteggia fracture—Bado Type II

The most common nerve injured in Monteggia fracture—Posterior interosseous nerve.

Wrist and Hand

The most sensitive and specific investigation to detect a fracture of scaphoid—MRI

Most common type of wrist dislocation—Perilunate

Nerve most commonly involved in perilunate dislocation and lunate fracture—Median nerve

Most common carpal bone to fracture is Scaphoid while least common is Trapezoid

Neck is the most common site of metacarpal fracture and fifth metacarpal is most commonly involved metacarpal (Boxer's fracture)

Phalangeal fractures and dislocations are most common hand injuries and fracture of distal phalanx is the most commonly fractured bone in hand

Thumb followed by fifth finger MCP joints are most commonly dislocated MCP joints. Proximal interphalangeal joint dislocations are more common than distal IP joint dislocation.

Mallet finger is the most common closed tendon injury in sportsmen
Ring finger is the most commonly involved finger in Jersey finger

The most common complication of hand injuries is stiffness

Extensor tendon injuries in hand are more common than flexor tendon injuries. The most common tendon injury in hand is extensor tendon of middle finger. Zone IV (disruption over the metacarpals) is most commonly injured area.

Worst outcome of flexor tendon repair is seen in zone II (dangerous area or no man's land) because both FDS and FDP run together in common sheath.

Pelvis, Hip and Femur

Most common type of pelvic fractures are rami fractures due to lateral impaction injury

Posterior wall fractures are the most common type of acetabular fractures

The most common complication of acetabular fractures is secondary osteoarthritis of the hip joint

Most common type of hip dislocation—posterior > anterior > central

Most common acute complication of dislocated hip—Sciatic nerve injury (mostly neuropraxia)

Most common complication of dislocated hip—osteoarthritis of hip joint

Most dangerous complication of dislocated hip is AVN of femoral head
Although fat embolism is most commonly seen after fracture of femur, it is a rare complication of femur fracture.

Fracture of middle third (transverse fracture pattern) is the most common location of femoral shaft fracture. However, in children the fractures most commonly involve the upper third while pathological fractures especially in elderly involve the relatively weak metaphysio-diaphyseal junction.

Knee ligament injuries are most common associated injury and fracture neck femur is the most commonly missed concomitant fracture with fracture shaft of femur

Lower limb fractures with maximum shortening are posterior dislocation of hip > femoral shaft fracture > subtrochanteric femur fracture > inter-trochanteric fracture > intracapsular neck femur fracture.

The Leg, Ankle and Foot

In compartment syndrome of tibia the anterior compartment is most commonly involved compartment

Ankle joint is the commonest site for a ligament injury in the body and ankle sprains are the commonest sports injuries

The most common ligament injured in ankle sprain is the Anterior Talo Fibular Ligament > Calcaneofibular ligament

Most common complication of talar fractures—Osteoarthritis of subtalar joint

The most common dislocation of the foot—Lisfranc fracture dislocation

The most common site of stress fracture in the foot—metatarsals

The most common bone of the foot to fracture—calcaneum > talus

Second metatarsal is the longest of all metatarsals and most common site for stress fracture. Fifth metatarsal is most commonly fractured metatarsal.

NEUROLOGY

Largest cord of brachial plexus—Posterior cord

Most common cause of neurological deficit in upper limb—Erb's palsy

Most common peripheral nerve injury (PNI)—Radial nerve

Most common nerve injuries in athletes—Burners/ Stingers

Most common cause for nerve injuries—Fracture-Dislocations

Most common nerves involved in some common fracture-dislocations

Clavicular fractures: Lower trunk of brachial plexus

Shoulder dislocation (all types): Axillary nerve (circumflex branch)

Surgical neck humerus fracture—Axillary nerve

Shaft humerus fracture (including Holstein Lewis fracture): Radial nerve

Fracture supracondylar humerus: Median nerve (anterior interosseous branch) > Radial in extension type and ulnar nerve in flexion type

Medial condyle humerus fractures—Ulnar nerve

Lateral condyle humerus fractures—Ulnar nerve (Tardy ulnar nerve palsy)

Elbow dislocations—Median nerve in simple dislocations and ulnar nerve in complex dislocations with associated fractures

Monteggia fracture dislocation—Posterior interosseous nerve

Lunate dislocation—Median nerve

Hip dislocation—Sciatic nerve

Knee dislocation—Common peroneal nerve

Fibular neck fractures—Common peroneal nerve

Most common infection causing PNI—Leprosy

Most common nerve injured in Total Hip Arthroplasty—Sciatic nerve

Most common nerve injured in intra muscular injections—Sciatic nerve followed by Radial nerve

Most common combined nerve injuries—Median plus Ulnar

Nerve injured during McRobert's procedure for delivery of a child—Lateral femoral cutaneous nerve

Nerve injury with best prognosis—Radial nerve

Nerve injury with worst prognosis—Ulnar nerve

Nerve injury with worst prognosis after repair—Sciatic nerve

Earliest indicator of nerve recovery—Electromyography

Most common sites of nerve compressions—

Ulnar nerve—Cubital tunnel (behind medial epicondyle)

Median nerve—Carpal tunnel

Radial nerve—Fracture shaft humerus

Posterior Interosseous Nerve—Arcade of Froscie

Nerve least commonly involved in entrapment neuropathies—Femoral nerve

Commonest compression neuropathy overall—Carpal tunnel syndrome > Cubital tunnel syndrome

Most common cause of Carpal tunnel syndrome—Idiopathic > Hypothyroidism

Most sensitive test for Carpal tunnel syndrome—Durkan's direct nerve compression test

Most specific test for Carpal tunnel syndrome—Hand diagram

Most common cause of Tarsal Tunnel syndrome—Rheumatoid arthritis

Most common site of nerve grafting—Sural nerve while commonest site of tendon grafting—Palmaris longus

Commonest cause of wrist drop—Radial nerve palsy

RECENT UPDATES

First person to perform arthroscopic procedure—Takaji

Most common joint to undergo arthroscopic procedures—Knee > Shoulder

First person to perform Total Hip Replacement (THR)—John Charnley

Most common cause of death after THR—Myocardial Infarction > Venous thromboembolism

MIXED BAG

Most common types of collagen

In bone—Type I

In articular cartilage—Type II

In meniscus—Type I

The thinnest zone of articular cartilage (with thinnest collagen fibrils) is Zone I (Superficial zone) while the largest is Zone III (Deep zone)

The zone of articular cartilage with synthetically most active chondrocytes—Zone III (Deep zone)

Least active chondrocytes are present in—Zone IV (Calcified zone) of articular cartilage

The highest content of proteoglycans and the largest collagen fibrils are present in Deep zone (Zone III) of the articular cartilage

The most abundant cells in bone—Osteocytes

Bone apposition is best seen in Howship's lacunae in normal adult bone while in fractured bone it is best seen in sub-periosteal cambium layer

Most metabolically active part of bone and part of bone with maximum remodelling—endosteal surface

In Gait cycle, phase with maximum kinetic energy is heel strike/loading response while the phase with maximum potential energy is mid-stance

A bone with no muscle attachment—Talus

The most common congenitally absent muscle—Pectoralis Major

Longest muscle in the body—Sartorius

Strongest muscle in the body—Gluteus Maximus

Strongest ligament in the body—Ilio femoral ligament (Ligament of Bigelow)

Strongest tendon in the body—Tendoachilles

Largest bursa in the body—Iliopsoas bursa

Largest internal organ in the body—Skeletal muscles

Largest avascular structure in the body—Inter-vertebral disk

The most common site of bursitis is shoulder (sub-acromial)

Most common site of tendon rupture—Supraspinatus > Tendoachilles

Most common cause of tendon ruptures is overuse

First person to use ligatures—Ambroise Pare (Father of Amputation surgery)

First to use tourniquet—Joseph Lister

Nerve injury is the most common complication of tourniquet application. Most of these nerve injuries are neuropraxias. And Radial nerve is the commonest involved nerve.

The most common amputation performed in orthopaedics—Trans tibial

The most common indication for amputation—Peripheral Vascular Disease

The best treatment of post amputation neuroma—surgical excision

METABOLIC DISORDERS

Most common metabolic bone disease—Osteoporosis

The earliest symptom of osteoporosis—back pain

In osteoporosis, distal radius is the most common site of fracture in patients less than 70-year-old while in those more than 70-year-age, it is the dorsolumbar spine that is the commonest site. However, overall vertebral fractures are more common.

Most common complication of osteoporosis—vertebral fractures

The investigation of choice as well as the gold standard for screening as well as diagnosing and grading osteoporosis is DEXA scan

The drug of choice for osteoporosis (senile/ post-menopausal)—bisphosphonates

The drug of choice for bisphosphonate resistant osteoporosis—Teriparatide

Most common symptom of osteomalacia—dull aching pain in lower back, pelvis and hips

Biopsy is the gold standard investigation to make the diagnosis of osteomalacia

Most common cause of (non-traumatic) protrusio acetabuli in India is osteomalacia and in world is rheumatoid arthritis

First clinical sign of rickets—craniotabes

Most common deformity in rickets—Genu varum

The most common subtype of rickets in developing countries—Nutritional rickets

The most common tumour producing oncogenic osteomalacia—hemangiopericytoma

The most common site for sub periosteal haemorrhages in scurvy—lower end of femur and tibia

The most common cause of primary hyperparathyroidism—solitary adenoma of the parathyroid glands

The most common bones affected in Paget's disease of bone—Pelvis > Tibia

The drug of choice for Paget's disease—Bisphosphonates

The pain in Paget's disease is best relieved by—Calcitonin.

The most common part of spine involved in DISH—thoracic spine.

PEDIATRIC ORTHOPEDICS

The most common congenital anomaly of foot—CTEV

The prime deformity in CTEV—Talonavicular joint subluxation

Most common type of CTEV—primary idiopathic variety

Most common deformity to recur in CTEV—Equinus > Varus

Most common complication of Triple arthrodesis—Talonavicular joint pseudarthrosis

Most common cause of failure of conservative treatment/relapse in CTEV—non compliance with bracing

Most common type of tarsal coalition—talocalcaneal > calcaneonavicular

Most common cause of congenital pseudoarthrosis—idiopathic > neurofibromatosis

Most common cause of acquired pseudoarthrosis—nonunion

Most common cause of Genu varum- Rickets > Idiopathic in a child and Osteoarthritis in an adult

Most common cause of Genu valgum- Idiopathic > Rickets in a child and Rheumatoid arthritis in an adult

Most common cause of Wind swept deformity- Rickets in a child and Rheumatoid arthritis in an adult (the term was originally given for rickets)

The prime pathology in CDH- Shallow acetabulum
 IOC for CDH in a child less than 6 months is Ultrasound (MRI is difficult to get in infants). Thereafter an X-ray can provide the diagnosis in most cases but best anatomical details are given by MRI.
 The screening investigation of choice for CDH- Ultrasound
 The movements first restricted in CDH abduction and internal rotation

Acetabular osteotomies for CDH:

Most commonly performed—Salter

Best correction—Pemberton

Salvage procedure—Chiari

The most common cause of limp in a child less than 10 years of age—
 Transient synovitis > Septic arthritis > Perthes disease

In Slipped Capital Femoral Epiphysis (SCFE), slip is best seen in a frog leg lateral X-ray view of the affected hip. The earliest X-ray sign is wide and irregular physis with rarefaction in its juxta-epiphyseal region (preslip stage)

Frequency of affection by hemimelia (congenital deficiencies of long bones)—Fibula > Radius > Femur > Tibia

GENETIC AND NEUROMUSCULAR DISORDERS

Most common permanent disability of childhood is Cerebral Palsy

Most common type of cerebral palsy—Diplegia (Geographically), Spastic (Physiologically), Prenatal (Etiologically)

Most common muscle involved in Poliomyelitis—Quadriceps Femoris (partially paralyzed)

Most common muscle showing complete paralysis in Polio—Tibialis Anterior

Most common muscle of upper limb involved in Polio—Deltoid

Most common hand muscle to be involved in Polio—Opponens pollicis

Most common bone fracture in Poliomyelitis—supracondylar femur fracture

Most common bone fractured in muscular dystrophies and arthrogryposis—Femur

Most common type of Spina bifida—Spina bifida occulta

Most common site of Spina bifida—S1 > L5

Most common skeletal dysplasia—Osteogenesis imperfect

Most common lethal skeletal dysplasia—Thanatophoric dysplasia

Most common form of dwarfism—Achondroplasia

ARTHRITIS AND RELATED CONDITIONS

Most pathognomonic feature of RA—Rheumatoid nodules

Most common site for rheumatoid nodules—Olecranon

Most common eye manifestation of rheumatoid arthritis (RA)—Keratoconjunctivitis sicca

The most common cardiac manifestation of RA—Pericarditis

The DMARD of choice and the most commonly used DMARD in RA—Methotrexate.

The most common cause of mononeuritis multiplex in India—Leprosy

The first radiological sign of RA—soft tissue swelling > juxta-articular osteopenia

The most common arthritis to involve wrist—RA

The most common subtype of Juvenile RA—Pauciarticular

The most common autoantibodies associated with Juvenile RA are Anti-Nuclear Antibodies

The first joint to be involved in Ankylosing Spondylitis (AS)—SI (Sacro-iliac) joint > Lumbar spine

The first X-ray sign of AS- Haziness and widening (pseudo-widening) around SI joints (more on the iliac side) due to sub-chondral erosions that is followed by sclerosis and ossification (first fibrous and then bony ankylosis)

Most acute spinal fractures in the AS population occur in the cervical spine, particularly at C5-C6 and C6-C7 levels

Most common extra-articular manifestation of AS- acute anterior uveitis (iridocyclitis) occurring in almost one-third of cases

Most common triggering organism for reactive arthritis—Chlamydia > Shigella

Most common joint involved in reactive arthritis—Knee

The drug of choice for psoriatic arthritis—Methotrexate

The most common site of Pseudogout—Knee

Psoriatic arthritis most commonly involves—DIP joints of hand

The joint most commonly involved in primary Osteoarthritis (OA)—knee > hip

The most common bone involved in OA knee—Patella

The most common muscle weakness seen in OA knee—Quadriceps

Earliest X ray sign of OA is reduction of joint space

The first line drug for osteoarthritis—Paracetamol (Acetaminophen)

The most common joint involved in neuropathic/Charcot joint disease-Foot (mid tarsal joints)

The most common joint involved in Tabes Dorsalis-Knee

The most common joint affected in Ochronosis-spine (inter-vertebral disk) > shoulder

Most common site for intra muscular bleeding in hemophilia-Quadriceps

In intra-articular bleeding in hemophilia the order of involvement is knee > elbow > shoulder

Most common region where haemophilic pseudotumours develop—thigh

(soft tissue pseudotumors develop in quadriceps while the osseous ones in femur)

Most common nerve compressed by hematoma in hemophilia-Femoral nerve

The most common cause of loose bodies in knee joint—Osteochondritis dissecans (OD) in young adults and osteoarthritis in the elderly (overall osteoarthritis)

Most common site of OD—Knee (lateral surface of medial femoral condyle is the commonest site)

The most common cause of multiple loose bodies in a joint—synovial chondromatosis

Most common joint affected in synovial chondromatosis—Knee

Most common cause of spontaneous Avascular Necrosis (AVN) of femoral head—idiopathic > steroids

The earliest diagnosis in AVN is provided by MRI (most sensitive investigation) and it is also the IOC

The most common cause of monoarthritis in children—TB

Most common cause of bony ankylosis—Septic arthritis

CHAPTER 17

Practice Session



MULTIPLE CHOICE QUESTIONS

GENERAL ORTHOPEDICS

- Adult bone trabeculae are differentiated from fetal bone trabeculae by presence of
 - Harversian system
 - Lamellar structure
 - Certain special staining characteristics
 - Different types of bone cells in each
- Most metabolically active part in bone is
 - Cortical bone
 - Cancellous bone
 - Periosteal surface
 - Endosteal surface
- Bone apposition is best seen in
 - Endochondral ossification
 - Osteoblastic activity in howship's lacunae
 - Subperiosteal cambium layer
 - Osteoblastic activity at the area of stress
- Regarding bone remodelling all are true except
 - Osteoclastic activity at the compression site
 - Osteoclastic activity at the tension site
 - Osteoclastic activity and osteoblastic activity are both needed for bone remodeling in cortical and cancellous bones
 - Osteoblasts transform into osteocytes
- Callus induction is not hampered in
 - Hypoxemia
 - Micromovements
 - Muscle interposition
 - Multiple bone fragments
- Fracture healing is affected by all except
 - Osteoporosis
 - Infection
 - Poor blood supply
 - Soft tissue interposition
- Provisional callus is seen on X-ray earliest by
 - 2 weeks
 - 3 weeks
 - 6 weeks
 - 8 weeks
- Initial stage of clinical union of bone is equivalent to
 - Callus formation
 - Woven bone
 - Hematoma formation
 - Calcification only
- The most common cause of non union is
 - Infection
 - Inadequate immobilization
 - Ischemia
 - Soft tissue interposition
- Commonest 1st order site for bone grafting
 - Iliac crest
 - Tibial metaphysis
 - Medial malleolus
 - Femoral condyle
 - Greater trochanter
- Direct impact on the bone will produce
 - Oblique fracture
 - Spiral fracture
 - Transverse fracture
 - Comminuted fracture
- Most consistent sign of a fresh fracture is
 - Bony tenderness
 - Crepitus
 - Deformity
 - Abnormal mobility
 - Shortening of bone
- An 8-year-old boy with a history of fall from 10 feet height complains of pain in the right ankle. X-ray taken at that time of injury were normal without any evident fracture line. But after 2 years, he developed a calcaneovalgus deformity in the foot. The missed diagnosis seem to be
 - Undiagnosed malunited fracture
 - Avascular necrosis talus
 - Distal Tibial epiphyseal injury
 - Ligamentous injury of ankle joint
- Commonest site of Epiphyseal injury in children
 - Lower end radius
 - Lateral condyle humerus
 - Upper end femur
 - Lower end femur
- What is the type of joint seen in the growth plate?
 - Plane synovial
 - Primary cartilaginous
 - Secondary cartilaginous
 - Fibrous
- Traumatic dislocation of the epiphyseal plate of distal femur occurs (PGI type)
 - Medially
 - Laterally
 - Posteriorly
 - Anteriorly
 - Rotationally
- In children, best remodelling is seen in fractures with
 - Angulation in diaphysis
 - Angulation in metaphysis
 - Rotation in diaphysis
 - Rotation in metaphysis
- Commonest fracture in children
 - Fracture clavicle
 - Green stick fracture of lower end of radius
 - Supracondylar fracture
 - All of the above
- Salter Harris Type VI (Rang's) injury includes
 - Thurston Holland's sign
 - Perichondrial ring injury
 - Open injury with loss of physis
 - Transverse fracture of metaphysis with longitudinal extension into the physis
- A 6-year-old child falls on to his right side and develops a crack in only the dorsal cortex of mid region of radius. The best treatment is
 - Antibiotics and sedative
 - Bone plating and external fixation
 - Slab with wait for bone imperfect
 - Break the cortex other side and immobilisation by POP
- Thomas splint was devised by Sir H.O Thomas
 - To splint fracture shaft of femur
 - To stabilize cervical spine after trauma
 - For transportation of polytrauma patients
 - For treating tuberculosis of knee
- Thomas splint is not used for
 - Injuries around knee joint
 - Knee dislocation
 - Infective arthritis of knee
 - Fracture femur
- Plaster of Paris was discovered by
 - Percival Potts
 - Abraham Colles
 - John Charnley
 - Anotonius Mathysen
- Which side of plaster is manipulated for wedging?
 - Anterior
 - Posterior
 - Concave
 - Convex
- Which of the following is included in the management of intra articular fracture? (PGI type)

- a. Arthroplasty b. K wire
- c. Arthrodesis d. Excision
- e. Plaster of Paris
26. Epiphyseal enlargement occurs in
 - a. Sheurmann's disease b. Paget's disease
 - c. Juvenile rheumatoid arthritis
 - d. Epiphyseal dysplasia
27. Epiphyseal dysgenesis is a feature of
 - a. Hypothyroidism b. Hyperparathyroidism
 - c. Hypoparathyroidism d. Hyperthyroidism
28. Marker for bone formation is
 - a. Serum nucleotidase b. Osteocalcin
 - c. Urinary calcium
 - d. Tartarate resistant acid phosphate
29. Mirel's criteria is developed for the evaluation of
 - a. Severity of osteoporosis b. Risk of fatigue fracture
 - c. Risk of pathological fracture after metastasis
 - d. Severity of neurological deficit
30. Treatment of choice in pathological fractures is
 - a. Skin traction b. Internal fixation
 - c. Plaster of Paris casts d. External skeletal fixation
31. Most common cause of pathological fracture is
 - a. Cyst b. Osteoporosis
 - c. Carcinoma d. All
32. Stress fracture is treated by
 - a. Rest b. Cast immobilisation
 - c. Closed reduction d. Internal fixation
33. Fatigue fractures (stress fractures) are most commonly seen in
 - a. Metatarsals b. Tibia
 - c. Fibula d. Neck of femur
34. Runner's fracture is a stress fracture of
 - a. 2nd metatarsal b. 3rd metatarsal
 - c. Lower tibia d. Lower fibula
35. Bilateral stress fractures are best diagnosed by
 - a. X-Ray b. MRI
 - c. CT d. Bone scan
36. To detect multiple bone metastasis the preferred investigation is
 - a. MRI b. CT
 - c. Bone scan d. PET CT: d > c
37. Most reliable method of detection bony metastasis is
 - a. MRI b. CT
 - c. SPECT d. Radiograph
38. Rate of mineralization of newly formed osteoid can be estimated by
 - a. Labelled tetracycline
 - b. Alzarin red stain
 - c. Von Kossa staining for calcium
 - d. Immunofluorescence
39. For pronation to occur, which two foot joints must have their axis of rotation in parallel?
 - a. Talocrural and subtalar
 - b. Lisfranc and talonavicular
 - c. Talonavicular and calcaneocuboid
 - d. Subtalar and calcaneocuboid
- a. Foramen ring fracture with lumbar spine injury
- b. Depressed skull fracture with lumbar spine injury
- c. Gutter fracture with cervical injury
- d. Pelvic fracture with cervical spine injury
3. Permissible ischemia time for a proximal limb amputation is
 - a. 4 hours b. 6 hours c. 8 hours d. 12 hours
4. Severely injured patient presents with spinal fracture and unconsciousness. First thing to be done is
 - a. GCS scoring
 - b. Spinal stabilization by cervical collar
 - c. Mannitol drip to decrease ICT
 - d. Airway maintenance
5. Which of the following is not a component of the crush syndrome?
 - a. Myo-hemoglobinuria b. Massive crushing of muscles
 - c. Acute tubular necrosis d. Bleeding diathesis
6. Open fracture is treated by
 - a. Tourniquet b. Internal fixation
 - c. Debridement d. External fixation
7. A compound fracture is initially treated by antibiotics, wound toilet and
 - a. Skin cover b. External splintage
 - c. Prosthesis d. Internal fixation
8. All of the following factors evaluate the chances of amputation in a limb, except
 - a. Age b. B. P
 - c. Velocity of trauma d. Presence of infection
9. Motorcyclist's fracture is
 - a. Ring fracture of base of skull
 - b. Comminuted fracture
 - c. A hinged fracture where the skull separates into anterior and posterior halves
 - d. Fracture base of skull
10. A female child with abuse has fracture pelvis, multiple injuries and is bleeding per vaginum. The immediate step on presenting to the hospital is
 - a. Inform the police b. Airway assessment
 - c. External fixator application for pelvic fracture
 - d. Blood transfusion
11. In cardiopulmonary resuscitation, the commonly fractured ribs are
 - a. 1st and 2nd b. 3rd and 4th
 - c. 5th and 6th d. 8th and 9th
12. Which of the following structures is fixed first during re-implantation of an amputated digit?
 - a. Bone b. Artery c. Vein d. Nerve
13. In crush injuries of hand the greatest priority is given to repair of
 - a. Tendons b. Skin c. Bone d. Arteries

POLYTRAUMA

1. A 30 years male suffers from road traffic accident and a car runs over his right leg. On examination, vitals are stable. The right leg is crushed with exposed muscles and bones. The debate about limb survival can be resolved to an extent by MESS score which includes all except
 - a. B.P b. Nerve injury
 - c. Velocity of trauma d. Distal circulation
2. A person falls from height of 35 feet according to an eye witness. He landed on his feet on the ground which does correlate with his statement if following fractures are present

UPPER LIMB TRAUMATOLOGY

1. Axis of upper limb passes through
 - a. Capitulum b. Olecranon
 - c. Trochlea d. Radial styloid
2. In shoulder X-Ray, highest bony landmark is
 - a. Head b. Greater tuberosity
 - c. Lesser tuberosity d. Acromion
3. Preferred treatment modality in a 70-year-old male with fracture neck humerus
 - a. U slab b. Arthroplasty
 - c. Analgesic with triangular sling
 - d. Open reduction and internal fixation
4. Velpeau bandage and sling and swathe splint are used in
 - a. Fracture scapula
 - b. Fracture clavicle
 - c. Acromioclavicular dislocation
 - d. Shoulder dislocation

5. Hanging cast is used in which fracture?
 - a. Femur b. Tibia c. Radius d. Humerus
6. Most common cause of non union in a fracture shaft of humerus is
 - a. Compound fracture
 - b. Comminution at fracture site
 - c. Distraction at fracture site
 - d. Inadequate operative reduction
7. Which of the following acts as the dynamic stabilizer of shoulder joint?
 - a. Musculotendinous cuff b. Glenoid labrum
 - c. Coracohumeral ligament d. Glenohumeral ligament
8. Weakest portion of shoulder joint capsule is
 - a. Superior b. Inferior c. Anterior d. Posterior
9. Most common sub-type of anterior shoulder dislocation is
 - a. Subglenoid b. Subcoracoid
 - c. Posterior d. Subclavicular
10. Which is the true statement regarding shoulder dislocation?
 - a. Pain is severe in anterior dislocation
 - b. Posterior dislocation is often over looked
 - c. Radiography may be misleading in posterior dislocation
 - d. All of the above
11. All are related to recurrent shoulder dislocation except
 - a. Lax capsule b. Hill sachs defect
 - c. Bankart lesion d. Rotator cuff injury
12. Test for posterior glenohumeral instability is
 - a. Fulcrum b. Jerk test
 - c. Sulcus test d. Crank test
13. Nerve injured in inferior dislocation of shoulder
 - a. Posterior cord of brachial plexus
 - b. Radial nerve
 - c. Axillary nerve
 - d. Ulnar nerve
14. Bankart's lesion involves the avulsion of labrum from
 - a. Anterior lip of glenoid
 - b. Superior lip of glenoid
 - c. Antero-superior lip of glenoid
 - d. Antero-inferior lip of glenoid
15. Traumatic glenohumeral instability in one direction with Bankart's lesion is treated by
 - a. Conservative methods
 - b. Surgery
 - c. Rehabilitation
 - d. Inferior capsular shift surgery
16. Deformity in posterior elbow dislocation
 - a. Extension b. Flexion
 - c. Both d. None
17. Nerve mostly involved in a simple dislocation of elbow is
 - a. Median b. Ulnar
 - c. Radial d. Posterior interosseous
18. A 4-year-boy complains of pain around elbow which is held in pronation and extension. X-ray reveals a normal picture. What is the probable diagnosis?
 - a. Pulled elbow b. Monteggia fracture
 - c. Elbow dislocation
 - d. Supra condylar humerus fracture
19. Most common elbow injury in adolescents is
 - a. Elbow dislocation
 - b. Supracondylar humerus fracture
 - c. Physeal injury
 - d. Olecranon fracture
20. Fracture supracondylar humerus is usually caused by
 - a. Hyperflexion injury b. Extension injury
 - c. Axial rotation d. Hyperextension injury
21. 10-years-old boy presents with cubitus varus deformity and a history of trauma 3 months back. On clinical examination he has preserved three bony point relationship of elbow, most probable diagnosis would be
 - a. Non union lateral condylar humerus
 - b. Old unreduced dislocation of elbow
 - c. Malunited intercondylar fracture of humerus
 - d. Malunited supracondylar fracture of humerus
22. In the more common extension type of supracondylar humerus fracture, usual displacement is
 - a. Posteromedial b. Anteromedial
 - c. Anterolateral d. Posterolateral
23. All are true regarding compartment syndrome except
 - a. Pain on passive stretching is an early sign
 - b. Pulse is a reliable indicator
 - c. Interstitial pressure > capillary pressure
 - d. Paraesthesias are seen late
24. Most common nerve involved in Volkmann's ischemic contracture
 - a. Radial nerve b. Median nerve
 - c. Ulnar nerve d. Posterior interosseous nerve
25. Treatment of acute myositis ossificans is
 - a. Excision of myositis b. Infra red therapy
 - c. Passive mobilization d. Immobilization
26. Commonest site of myositis ossificans is
 - a. Knee b. Shoulder c. Elbow d. Wrist
27. False about myositis ossificans progressive is
 - a. Life longevity is normal
 - b. Pneumonia is common in these cases
 - c. Most common site involved is the spine
 - d. Onset is usually before 6 years of age
28. Which of the following is true about supracondylar fracture humerus in children?
 - a. Anterior displacement of the distal fragment is more common than posterior
 - b. Cubitus valgus is more common than cubitus varus during mal-union
 - c. The neurological complications are transitory
 - d. Weakness of elbow flexion is a common complication
29. Traction not used in lower limb
 - a. Gallows traction b. Bryant's traction
 - c. Dunlop traction d. Perkin's traction
30. Child presents with a supracondylar humerus fracture with cold and pulseless limb since 3 hours. Next management step is
 - a. Immediate exploration b. Immediate angiography
 - c. ORIF d. Closed reduction
31. A 6-years-old child had an accident and developed fracture around elbow. After 4 years he presented with tingling and numbness in the ulnar side of fingers. Probable fracture he had was
 - a. Olecranon fracture b. Dislocation of elbow
 - c. Lateral condylar fracture humerus
 - d. Supracondylar fracture humerus
32. First sign of compartment syndrome is
 - a. Pain on passive stretch b. Loss of pulse
 - c. Tingling d. Loss of movements
33. Indication for surgical compartment release in compartment syndrome in any compartment is absolute compartment pressure greater than
 - a. 15 mm Hg b. 20 mm Hg
 - c. 30 mm Hg d. 40 mm Hg
34. Three point symmetry at elbow is not disturbed in
 - a. Fracture ulna only b. Fracture radius only
 - c. Fracture of both bones of forearm
 - d. Weak posterior capsule
35. Excision of head of radius in a child should not be done because it
 - a. Leads to secondary osteoarthritis of elbow
 - b. Causes subluxation of inferior radio ulnar joint
 - c. Causes myositis ossificans
 - d. Produces instability of elbow joint

36. If head of radius is removed, it will result in
 - a. Varus deformity at elbow
 - b. No deformity
 - c. Valgus deformity at elbow
 - d. Lengthening of the limb
37. In fracture of the olecranon, excision of the proximal fragment is indicated in all of the following situations except
 - a. Old un-united fractures
 - b. Non articular fractures
 - c. Fracture extending to coronoid process
 - d. Elderly patient
38. Essex loppresti lesion in upper limb involves
 - a. Radial head fracture
 - b. Radial shaft fracture
 - c. Injury to interosseous membrane
 - d. Radial shaft fracture with proximal radio-ulnar joint dislocation
39. Tension band wiring is done in all except
 - a. Fracture patella
 - b. Fracture olecranon
 - c. Fracture medial malleolus
 - d. Colles fracture
40. Surgical excision is contraindicated in
 - a. Patella
 - b. Head of radius
 - c. Lateral condyle humerus
 - d. Olecranon process
41. Terrible triad of elbow injury comprises all except
 - a. Elbow dislocation
 - b. Radial head fracture
 - c. Coronoid fracture
 - d. Olecranon fracture
42. All of the following deformities are seen in a Colles fracture except
 - a. Lateral tilt
 - b. Volar tilt
 - c. Dorsal tilt
 - d. Supination
43. Not a complication of Colles fracture
 - a. Ulna plus deformity
 - b. Madelung deformity
 - c. Shoulder hand syndrome
 - d. Ulna minus deformity
44. Most important deformity to be corrected in Colles fracture
 - a. Lateral deviation
 - b. Posterior tilt
 - c. Posterior deviation
 - d. Impaction
45. An elderly female sustained Colles' fracture in her right hand which was properly treated. She now complains of stiffness and severe pain in the wrist with cold sensation and cyanosis in the fingers. X-ray of the hand revealed complete decalcification. She is most likely suffering from
 - a. Causalgia
 - b. Tubercular arthritis of wrist joint
 - c. Traumatic tenosynovitis
 - d. Sudeck's atrophy
46. Barton's disease is
 - a. Intra-articular fracture of 1st M.C
 - b. Rickets in presence of scurvy
 - c. Fracture neck of 5th M.C
 - d. Fracture of distal end of radius
47. In children, fracture scaphoid is rare but if it occurs it mostly involves
 - a. Waist
 - b. Neck
 - c. Proximal pole
 - d. Distal pole
48. In treating non-union of scaphoid, vascularized muscle pedicle graft is usually taken from
 - a. Pronator teres
 - b. Pronator quadratus
 - c. Brachioradialis
 - d. Extensor pollicis longus
49. Most common nerve involved in dislocation of lunate is
 - a. Median nerve
 - b. Posterior interosseous nerve (PIN)
 - c. Anterior interosseous nerve (AIN)
 - d. Ulnar nerve
50. Boxer's fracture is
 - a. Radial styloid fracture
 - b. Reverse colic's fracture
 - c. 5th metacarpal fracture
 - d. 1st metacarpal fracture
51. A Bennett's fracture is difficult to maintain in a reduced position mainly because of the pull of
 - a. Flexor pollicis brevis
 - b. Extensor pollicis brevis
 - c. Abductor pollicis longus
 - d. Adductor pollicis
52. The term Bennett's fracture is used to describe
 - a. Fracture dislocation of MCP joint of thumb
 - b. IP fracture dislocation of thumb
 - c. Anterior marginal fracture of distal end of radius
 - d. Fracture dislocation of trapeziometacarpal joint
53. True about Mallet finger is
 - a. Avulsion of tendon at the base of middle phalanx
 - b. Avulsion of extensor tendon at the base of distal phalanx
 - c. Fracture of distal phalanx
 - d. Fracture of proximal phalanx
54. Terry Thomas sign is seen in
 - a. Ulnar deviation of wrist
 - b. Scapholunate dislocation
 - c. Scaphoid fracture
 - d. Colles fracture
55. In hand surgery, no man's land refers to
 - a. Area over the proximal phalanx
 - b. Area over the distal phalanx
 - c. Area between middle of middle phalanx and distal palmar crease
 - d. Area in front of the wrist

HIP EXAMINATION

1. A patient has been given POP cast for tibial fracture of left leg. He is to be mobilized with a single crutch. It should be advised on which side?
 - a. Left
 - b. Any
 - c. Right
 - d. Both
2. With the hip in 90 degrees flexion a line joining the anterior superior iliac spine (ASIS) and the ischial tuberosity passes through the greater trochanter tip. This line is called
 - a. Shoemaker's line
 - b. Nelaton's line
 - c. Cheines line
 - d. Morel's line
3. A 72-year-old female after hip replacement surgery developed Trendelenburg gait. The nerve likely injured is
 - a. Superior gluteal
 - b. Femoral
 - c. Sciatic
 - d. Inferior gluteal
4. Vascular sign of Narath is seen in
 - a. Anterior dislocation of hip
 - b. Central dislocation of hip
 - c. Posterior dislocation of hip
 - d. Subtrochanteric fracture of hip
5. Telescopic test is useful to diagnose
 - a. Perthes disease
 - b. Non united intracapsular fracture neck of femur
 - c. Ankylosis of hip joint
 - d. Malunited trochanteric fracture

PELVIS AND LOWER LIMB TRAUMA

1. Shenton's line is present in X-ray of
 - a. Knee
 - b. Shoulder
 - c. Elbow
 - d. Hip
2. Judet view X-ray are taken for
 - a. Pelvis
 - b. Calcaneum
 - c. Scaphoid
 - d. Spine
3. In pelvic fracture, the approximate amount of blood loss is
 - a. 1-2 units
 - b. 2-4 units
 - c. 2-6 units
 - d. 4-8 units
4. Maximum blood supply to the head of femur is contributed by
 - a. Lateral circumflex femoral artery
 - b. Medial circumflex femoral artery
 - c. Artery of ligamentum teres
 - d. Popliteal artery
5. An elderly woman was admitted with a fracture of the neck of right femur which failed to unite. On X-ray evaluation additionally an avascular necrosis of the head of femur was noted. The condition would have resulted most probably from the damage to
 - a. Superior gluteal artery
 - b. Inferior gluteal artery

- c. Acetabular branch of obturator artery
- d. Retinacular branches of circumflex femoral arteries
6. Jumper's fracture is seen in
 - a. Calcaneum
 - b. Tibia
 - c. Pelvis
 - d. Neck femur
7. True about crescent fracture is
 - a. Anteroposterior compression is the mechanism of injury
 - b. Diastasis of pubis with pubic rami fracture
 - c. Anteroposterior instability with rotational instability
 - d. Fracture of the iliac bone with sacroiliac disruption
8. In fracture neck femur, all the trabeculae of pelvis and femur are in alignment in which stage?
 - a. I
 - b. II
 - c. III
 - d. IV
9. Occult fracture of neck femur is best diagnosed by
 - a. X-Ray
 - b. CT
 - c. MRI
 - d. Bone Scan
10. 40-year-old female with a history of fall, complaints of pain in right hip and inability to walk. On examination there is tenderness in Scarpa's triangle. The X-ray is normal, next investigation to be ordered is
 - a. Aspiration
 - b. MRI
 - c. CT
 - d. Bonescan
11. A 60-year-old female lands up in emergency with history of fall, the attitude of limb is extension and external rotation, the probable diagnosis is
 - a. Acetabulum fracture
 - b. Posterior dislocation of hip
 - c. Intertrochanteric fracture
 - d. Intra capsular fracture neck femur
12. A 80-year-old man fell in the bathroom and was unable to stand on the right buttock region. He had ecchymosis with external rotation of the leg with the lateral border of the foot touching the couch. The most probable diagnosis is
 - a. Anterior dislocation of hip
 - b. Extra capsular fracture neck femur
 - c. Intracapsular fracture neck femur
 - d. Posterior dislocation of hip
13. A patient presents with lower limb in flexion, abduction and internal rotation with shortening. Diagnosis is
 - a. Anterior dislocation
 - b. Central dislocation
 - c. Posterior dislocation
 - d. Lateral dislocation
14. In per rectal examination, femoral head is palpable in
 - a. Anterior dislocation of hip
 - b. Posterior dislocation of hip
 - c. Central fracture dislocation of hip
 - d. Lateral dislocation of hip
15. A 32-year-old male presented to the casualty with pain in the left hip region following RTA. On examination there is shortening flexion and external rotation deformity. A mass is palpable in the left gluteal region which moves with movement of the femur. Most likely X-ray finding would be
 - a. Posterior dislocation of hip with neck in full profile
 - b. Dislocation of hip with lesser trochanter in full profile
 - c. Fracture roof of acetabulum with central dislocation
 - d. Acetabular fracture with posterior dislocation of hip
16. Following RTA a patient presents with flexion and external rotation deformity of the left hip. Shortening of affected limb by 7 cm was also seen. A mass was noted in the left gluteal region which was moving with the movements of the femur. Most likely X-ray finding would be
 - a. Pipkin's Type IV dislocation of hip
 - b. Dislocated hip with lesser trochanter in full profile
 - c. Posterior dislocation of the hip with neck in full profile
 - d. Acetabular roof fracture with central dislocation
17. Most common complication of intertrochanteric fracture femur is
 - a. Osteoarthritis
 - b. Malunion
 - c. Non union
 - d. Sciatic nerve injury
18. Non union is a very common complication of intracapsular fractures of the neck of femur. Which is not an important contributing factor?
 - a. Inadequate blood supply
 - b. Inadequate immobilization
 - c. Inhibitory effect of synovial fluid
 - d. Stress at fracture site due to muscle spasm
19. Femoral neck fracture 4 weeks old, in a young adult, should be treated by which one of the following methods?
 - a. Pauwel's osteotomy
 - b. Reduction of fracture & multiple screw fixation
 - c. Excision of hip
 - d. Prosthetic replacement of femoral head
20. Treatment of a 50-year-old male with fracture of neck of femur more than 3 weeks old is
 - a. Hemiarthroplasty
 - b. McMurray's osteotomy
 - c. THR
 - d. Girdlestone's arthroplasty
21. A 65-year-old man presented with fracture neck femur 3 days after injury. Treatment of choice would be
 - a. Multiple screw fixation
 - b. McMurray osteotomy
 - c. Hemi-arthroplasty
 - d. Total hip replacement
22. In a 65 year old male with history of fracture neck of femur six weeks old, treatment of choice is
 - a. SP nailing
 - b. McMurray's osteotomy
 - c. Hemiarthroplasty
 - d. None
23. Treatment of choice in fracture neck of femur in a 40-year-old male presenting after 2 days of injury is
 - a. Hemiarthroplasty
 - b. Closed reduction and internal fixation by cancellous screws
 - c. Closed reduction and Internal fixation by Austin Moore pins
 - d. Plaster and rest
24. The treatment of choice for a 4 weeks old femoral neck fracture in a 55-year-old man is
 - a. Open reduction and internal fixation
 - b. McMurray's osteotomy
 - c. Hemi replacement arthroplasty
 - d. Total hip replacement
25. Prosthetic replacement of femoral head is indicated in (PGI type)
 - a. A fresh intracapsular fracture of neck of femur in old patients
 - b. In reduced posterior dislocation of hip
 - c. Untreated femoral neck fracture over 65 years
 - d. Pathological fracture of NOF due to secondaries
26. In a 10-year-old male, a transcervical fracture neck femur is best treated by
 - a. Spica
 - b. Austin moore's prosthesis
 - c. K-wires
 - d. Cannulated cancellous screws
27. Avascular necrosis of head of the femur is most common in
 - a. Sub-capital neck femur fracture
 - b. Basal neck femur fracture
 - c. Intertrochanteric femur fracture
 - d. Trans cervical neck femur fracture
28. AVN is seen in which types of fracture of femur (PGI type)
 - a. Intertrochanteric fracture
 - b. Subcapital fracture
 - c. Trans cervical fracture
 - d. Basal fracture
29. Avascular necrosis of head of femur occurs commonly at
 - a. Transcervical region
 - b. Inter-trochanteric region
 - c. Subcapital region
 - d. Subchondral region
30. Fracture shaft femur is stabilized early in order to
 - a. To prevent blood loss
 - b. ARDS
 - c. Non union
 - d. Compartment syndrome
31. Blood loss in fracture shaft femur is
 - a. 1 units
 - b. 2 units
 - c. 3 units
 - d. 4 units
32. In upper one third femoral shaft fracture, the displacement of proximal segment is
 - a. Flexion, abduction & external rotation
 - b. Flexion, adduction & external rotation
 - c. Flexion, abduction & internal rotation
 - d. Flexion, adduction & internal rotation

33. Fracture shaft of femur in adult unites by
 - a. 3 to 4 weeks
 - b. 3 to 4 weeks
 - c. 3 to 4 months
 - d. 4 to 6 months
34. A person with multiple injuries develops fever, restlessness, tachycardia, tachypnoea and subconjunctival rash 72 hours after the injury. Probable diagnosis is
 - a. Pulmonary embolism
 - b. Air embolism
 - c. Fat embolism
 - d. Bacterial pneumonitis
35. Most common fracture associated with fat embolism is
 - a. Humerus
 - b. Tibia
 - c. Femur
 - d. Pelvis
36. In a road-traffic accident four people were injured. Now, person having which trauma should be treated first?
 - a. Posterior dislocation of hip
 - b. Fracture shaft of femur
 - c. Fracture neck of femur
 - d. Fracture shaft of humerus
37. Maximum shortening of lower limb is seen in
 - a. Fracture neck femur
 - b. Fracture shaft femur
 - c. Fracture intertrochanteric femur
 - d. Posterior dislocation of hip
38. Bulge sign in knee joint is seen after how much of fluid accumulation?
 - a. <30 ml
 - b. 100 ml
 - c. 200 ml
 - d. 400 ml
39. Cylinder cast is applied for
 - a. Neck humerus fracture
 - b. Neck femur fracture
 - c. Patellar fracture
 - d. Shaft humerus fracture
40. Transverse fracture of patella with separation of fragments is best treated by
 - a. Closed reduction with cylinder cast
 - b. Open reduction with screw fixation of the fragments
 - c. Blind fixation of the two fragments with k wire
 - d. Open reduction with k wire fixation of the fragment with tension band wiring
41. Patellar tendon bearing cast is preferred in which fracture
 - a. Patella
 - b. Femur
 - c. Tibia
 - d. Medial malleolus
42. Ankle Brachial Pressure index value suggestive of critical ischaemia is
 - a. 1
 - b. 0.9
 - c. 0.5
 - d. 0.3
43. The mechanism of injury in vertical fracture of medial malleolus is
 - a. Abduction injury
 - b. Adduction injury
 - c. Supination external rotation injury
 - d. Pronation dorsiflexion injury
44. In posterior compartment syndrome of leg, which passive movement causes pain?
 - a. Toe dorsiflexion
 - b. Dorsiflexion of foot
 - c. Foot inversion
 - d. Toe plantar flexion
45. Tillaux fracture is
 - a. Stress fracture of the distal fibula 3–8 cm above lateral malleolus
 - b. Avulsion fracture of medial femoral condyle at the origin of the medial collateral ligament
 - c. Lateral tibial plateau avulsion fracture with anterior cruciate ligament tear
 - d. Salter-Harris III fracture of tibia
46. Most common site for ligamentous injuries in the body
 - a. Shoulder
 - b. Knee
 - c. Elbow
 - d. Ankle
47. Ligament involved in ankle sprain is
 - a. Anterior talofibular ligament
 - b. Posterior talofibular ligament
 - c. Spring ligament
 - d. Calcaneofibular ligament
48. When the foot is suddenly inverted in plantar flexed position, which ligament is most likely injured?
 - a. Anterior talofibular
 - b. Calcaneocuboid
 - c. Posterior tibiofibular
 - d. Calcaneofibular
49. Commonest site of March fracture is
 - a. Shafts of 2nd & 3rd metatarsals
 - b. Avulsion of 5th metatarsal base
 - c. Neck of 2nd metatarsal
 - d. Neck of 3rd metatarsal
50. Jone's fracture is
 - a. Avulsion fracture of base of 5th metatarsal
 - b. Avulsion fracture of medial femoral condyle
 - c. Bimalleolar fracture of the ankle
 - d. Burst fracture of 1st cervical vertebra
51. Bohler's angle is reduced in fracture of
 - a. Calcaneum
 - b. Navicular
 - c. Talus
 - d. Cuboid
52. Bosworth's fracture is
 - a. Fracture distal end tibia
 - b. Fracture distal end femur
 - c. Fracture distal fibula with dislocation of distal fragment
 - d. Fracture distal fibula with posterior dislocation of proximal fragment
53. Cotton's fracture refers to a
 - a. Bimalleolar fracture
 - b. Trimalleolar fracture
 - c. Wrist subluxation
 - d. Knee subluxation
54. Most common complication of fracture neck talus is
 - a. Non union
 - b. AVN
 - c. Osteoarthritis of ankle joint
 - d. Osteoarthritis of subtalar joint
55. Neutral triangle is seen radiologically in
 - a. Neck femur
 - b. Calcaneum
 - c. Proximal humerus
 - d. Talus
56. Most commonly injured tarsal bone is
 - a. Talus
 - b. Cuneiform
 - c. Navicular
 - d. Calcaneum
57. Recurrent dislocations are least commonly seen in
 - a. Ankle
 - b. Shoulder
 - c. Hip
 - d. Patella

LIGAMENT INJURIES OF KNEE

1. Menisci are connected to tibia by
 - a. Arcuate ligament
 - b. Coronary ligament
 - c. Wrisberg ligament
 - d. Oblique ligaments
2. Pellegrini Stieda lesion is
 - a. Calcification at femoral attachment of MCL
 - b. Calcification at tibial attachment of MCL
 - c. Calcification at femoral attachment of LCL
 - d. Calcification at tibial attachment of LCL
3. Torsion of knee most commonly injures
 - a. ACL
 - b. Medial menisci
 - c. Tibial collateral ligament
 - d. Fibular collateral ligament
4. A 22-year-old young male, college student, suffered a left knee injury while playing hockey. After 2 months, there was anterior laxity in full extension and it was normal at 90° flexion. What is the most likely injured part?
 - a. Anteromedial bundle of anterior cruciate ligament
 - b. Posterolateral bundle of anterior cruciate ligament
 - c. Posterior cruciate ligament
 - d. Anterior part of medial meniscus
5. A dial test that is positive in 30° knee flexion suggests injury to
 - a. Posterior cruciate ligament
 - b. Posterolateral corner structures
 - c. Posterior cruciate ligament as well as PLC
 - d. Anterior-medial corner of knee
6. On lateral blow to knee with fracture in intercondylar area, structure damaged is
 - a. ACL
 - b. MCL
 - c. LCL
 - d. Menisci
7. In 'bounce home' test of knee 'end feels' are all except
 - a. Firm
 - b. Empty
 - c. Spongy block
 - d. Bony

8. Which activity will be difficult to perform in ACL deficient knee joint?
 - a. Sit cross leg
 - b. Walk uphill
 - c. Getting up from sitting
 - d. Walk downhill
9. Positive pivot shift test in knee is due to injury to
 - a. ACL
 - b. PCL
 - c. Medial menisci
 - d. Lateral menisci
10. Structural integrity of collateral ligaments is best tested by
 - a. Varus/Valgus stress test in full flexion
 - b. Varus/Valgus stress test in full extension
 - c. Varus/Valgus stress test in 30° flexion
 - d. Varus/Valgus stress test in 90° flexion
11. Locking of the knee can be due to
 - a. Loose body
 - b. Menisci
 - c. Both
 - d. None
12. Which of the following statements about menisci are not true?
 - a. Medial menisci is more commonly injured than lateral
 - b. Medial menisci is more mobile than lateral
 - c. It covers more tibial articular surface than lateral
 - d. It is predominantly made of type 1 collagen
13. 18-year-old boy, while playing football twisted his knee on the ankle & fell down. After 10 min, he got up and again started playing. Next day he developed swelling and could not move his knee. Probable diagnosis is
 - a. Medial meniscal tear
 - b. ACL tear
 - c. MCL tear
 - d. PCL injury
14. Investigation of choice for ligament injuries of the knee is
 - a. X-Ray
 - b. USG
 - c. MRI
 - d. Arthroscopy
15. Most common cause of hemarthrosis in knee joint is?
 - a. Medial collateral ligament tear
 - b. Anterior cruciate ligament tear
 - c. Fracture patella
 - d. Bumper fracture
16. Injury to the medial meniscus is rather impossible when the knee joint does not
 - a. Extend
 - b. Flex
 - c. Rotate
 - d. Abduct adduct
17. It is wise to keep and repair the meniscus rather than removing it when the injury is to
 - a. Medial part of meniscus
 - b. Mid part of meniscus
 - c. Lateral part of meniscus
 - d. Associated with collateral ligament injury
18. Injury to cartilage of knee is best diagnosed by
 - a. MRI
 - b. Arthrography
 - c. X-ray
 - d. Arthroscopy
19. Most common type of medial meniscal tear is
 - a. Radial tear
 - b. Longitudinal tear
 - c. Oblique tear
 - d. Horizontal tear
5. In a patient with head injury, unexplained hypotension warrants evaluation of
 - a. Upper cervical spine
 - b. Lower cervical spine
 - c. Thoracic spine
 - d. Lumbar spine
6. Dislocation without fracture is seen in
 - a. Sacral spine
 - b. Lumbar spine
 - c. Cervical spine
 - d. Thoracic
7. Compression fracture is commonest in
 - a. Cervical spine
 - b. Upper thoracic
 - c. Lower thoracic
 - d. Lumbosacral
8. Least helpful investigation for diagnosis of Spondylolisthesis
 - a. AP view of spine
 - b. Lateral X-ray of spine
 - c. MRI
 - d. CT Scan
9. The number of division in Holdsworth classification for determining stability in thoracolumbar injuries were
 - a. 1
 - b. 2
 - c. 3
 - d. 4
10. Spinal injuries without any radiological abnormalities are found in
 - a. Young adults
 - b. Old people
 - c. Teenagers
 - d. Infants
11. Regarding Hangman's fracture true statement is
 - a. High post admission mortality
 - b. Most common axis fracture
 - c. Surgical treatment is always necessary
 - d. Union almost always occurs
12. Most common mode of injury to spinal cord in head on collision of vehicles
 - a. flexion
 - b. flexion rotation
 - c. extension
 - d. circumduction
13. The first reflex to return once spinal shock is over is
 - a. Plantar reflex
 - b. Knee reflex
 - c. Biceps reflex
 - d. Bulbocavernous reflex
14. Which of the following is not included as a yellow flag sign for low back pain?
 - a. Radicular impingement
 - b. Systemic steroids
 - c. Social isolation
 - d. High functional limitation at 4 weeks/after 4 weeks
15. Distended bladder, incontinence of urine and priapism are
 - a. Signs of injury to the urethra
 - b. Signs of injury to cauda equina
 - c. Signs of injury to pelvis
 - d. Signs of spinal cord injury
16. For removal of vertebral disc all procedures are done except
 - a. Laminotomy
 - b. Laminectomy
 - c. Laminoplasty
 - d. Hemi-laminectomy
17. A 52-year-old woman presents to her GP with a longstanding history of lower back pain which has suddenly worsened in severity over the past few days. An urgent MRI scan of the lumbar spine shows a right paracentral disc protrusion at the L4/L5 level. The disc impinges on the lateral recess at this level. The most likely outcome would be
 - a. Cauda equine syndrome
 - b. Lumbar plexus compression
 - c. Loss of ankle dorsiflexion
 - d. Loss of function of EHL
18. Turn buckle cast is used for
 - a. Scoliosis
 - b. Fracture shaft femur
 - c. Hangman's fracture
 - d. Cervical spine injury
19. Progression of congenital scoliosis is least likely in which of the following vertebral anomaly?
 - a. Wedge vertebra
 - b. Fully segmented hemivertebra
 - c. Unilateral unsegmented bar with hemivertebra
 - d. Block vertebra
20. A patient has decreased sensation on the tip of the middle finger and decreased triceps reflex. It is due to disc prolapsed at
 - a. C5-C6
 - b. C6-C7
 - c. C8-T1
 - d. T1-T2
21. In spondylolisthesis, there is fracture of vertebra at
 - a. Spinous process
 - b. Pars interarticularis
 - c. Transverse process
 - d. Lamina

SPINE

1. Vertebra with most constant number
 - a. Cervical
 - b. Thoracic
 - c. Lumbar
 - d. Sacral
2. Complete transection of the spinal cord at the C7 level produces all of the following effects except
 - a. Hypotension
 - b. Limited respiratory effort
 - c. Anaesthesia below the level of the lesion
 - d. Areflexia below the level of the lesion
3. Wrist flexion and finger extension test the following nerve root
 - a. C6
 - b. C7
 - c. C8
 - d. T1
4. A 40-year-old male after RTA attains spinal injury. His lower limb power is greater than that of upper limb and sacral sensations are present. Type of spinal cord lesion is
 - a. Central cord syndrome
 - b. Anterior cord syndrome
 - c. Posterior cord syndrome
 - d. Complete spinal cord injury

22. Seat belt injury is
 - a. Tear drop fracture
 - b. Wedge fracture
 - c. Chance fracture
 - d. Whiplash injury
23. The most common site of disc prolapse is
 - a. L2 – L3
 - b. L3 – L4
 - c. L4 – L5
 - d. L5 – S1
24. A middle aged lady presents with complaints of neck pain. On examination there is weakness of extension of right wrist with no sensory impairment. If pathology is a disc prolapse, an MRI of the cervical spine would most probably reveal a prolapsed intervertebral disc at what level?
 - a. C3- C4
 - b. C5- C6
 - c. C4- C5
 - d. C1- C2
25. Which is not a deep heat therapy?
 - a. Short wave diathermy
 - b. Ultrasound therapy
 - c. Infrared therapy
 - d. Microwave therapy
26. Percutaneous vertebroplasty is indicated in all except
 - a. Tuberculosis
 - b. Metastasis
 - c. Osteoporosis
 - d. Hemangioma
27. A 6-year-old child, presents with scoliosis, hairy tuft in the skin of back and neurological deficit. X-ray reveals multiple vertebral anomalies and a vertical bony spur overlying lumbar spine on AP view. The most probable diagnosis is
 - a. Dorsal dermal sinus
 - b. Diastematomyelia
 - c. Tight filum terminale
 - d. Caudal regression syndrome
28. Most common type of spondylolisthesis
 - a. Congenital
 - b. Dysplastic
 - c. Degenerative
 - d. Isthmic
 - e. Traumatic
29. The commonest cause of spinal cord injuries in our country is
 - a. RTA
 - b. Fall into well
 - c. Fall from a height
 - d. House collapse
30. Most dangerous type of spinal cord injury is
 - a. Flexion
 - b. Compression
 - c. Extension
 - d. Flexion-rotation
31. All of the following about the fracture of atlas vertebra are true except
 - a. Quadriplegia is seen in 80% of the cases
 - b. CT should be done for the diagnosis
 - c. Jefferson fractures is the most common fracture of atlas
 - d. Atlanto-occipital fusion may sometimes be needed
32. Whiplash injury is caused due to
 - a. A fall from a height
 - b. Acute hyperextension of the spine
 - c. A blow to the top of head
 - d. Acute hyperflexion of the spine
33. True regarding Hangman's fracture is
 - a. Spondylolisthesis of C2 over C3
 - b. Odontoid process fracture of C2
 - c. Burst fracture of C1
 - d. Fracture of hyoid bone
34. Inverted radial reflex tests which level
 - a. C3
 - b. C5
 - c. L4
 - d. L5
35. absence of growth factor
36. absence of myelin formation inhibitors
3. The H-reflex is important for assessing which of the following?
 - a. S1 radiculopathy
 - b. L5 radiculopathy
 - c. L2 radiculopathy
 - d. L4 radiculopathy
4. Most common nerve used for nerve conduction study in H reflex is
 - a. Median nerve
 - b. Tibial nerve
 - c. Ulnar nerve
 - d. Peroneal nerve
5. A person was found lying in the right lateral position by the police. He had injuries on his right face, hand and on the right knee. Which of the following nerve injuries can explain the injuries caused in the patient?
 - a. Trigeminal nerve
 - b. Radial nerve
 - c. Femoral nerve
 - d. Common peroneal nerve
6. Foot drop due to injury to
 - a. Superficial peroneal nerve
 - b. Deep peroneal nerve
 - c. Common peroneal nerve
 - d. Tibial nerve
7. A child sustains supracondylar fracture humerus. On clinical examination there is extension at MCP joints and flexion at IP joints of hand. Also there is loss of sensations along medial aspect of hand and forearm. The likely cause is injury to
 - a. Upper brachial plexus
 - b. Lower brachial plexus
 - c. Musculocutaneous
 - d. Median nerve
8. Following anterior dislocation of the shoulder, a patient develops weakness of flexion at elbow and lack of sensation over the lateral aspect forearm. The nerve that could be injured is
 - a. Axillary nerve
 - b. Ulnar nerve
 - c. Radial nerve
 - d. Musculocutaneous nerve
9. Guyon's canal is entrapment neuropathy site for which nerve?
 - a. Ulnar nerve
 - b. Median nerve
 - c. Radial nerve
 - d. Axillary nerve
10. Clasp sign is seen in paralysis of
 - a. Ulnar nerve
 - b. Median nerve
 - c. Radial nerve
 - d. Axillary nerve
11. The best way to look for PIN palsy is
 - a. Loss of sensations over lateral two and a half fingers
 - b. Loss of sensations over the thumb web
 - c. Wrist drop
 - d. Drop at MCP joints of fingers
12. Cheiralgia paraesthetica is compression neuropathy of which nerve
 - a. Lateral cutaneous nerve of thigh
 - b. Superficial radial nerve
 - c. Sural nerve
 - d. Lateral cutaneous nerve of fore-arm
13. Motor march is seen in
 - a. Axonotmesis
 - b. Neuropraxia
 - c. Neurotmesis
 - d. All of the above
14. A pole vaulter had a fall during vaulting and had paralysis of the arm muscles. His recovery prognosis can be best assessed by
 - a. Strength duration curve
 - b. Electromyography
 - c. Muscle biopsy
 - d. CPK levels
15. All indicate good prognosis in a nerve injury except
 - a. Younger age
 - b. Neuropraxia
 - c. Pure motor nerve injury
 - d. Proximal injury
16. Muscles that are paralyzed in Erb's paralysis are all except
 - a. Biceps
 - b. Brachioradialis
 - c. Triceps
 - d. Brachialis
17. Klumpke's paralysis involves injury to
 - a. C1
 - b. C4
 - c. C8
 - d. T1
18. All are true regarding brachial plexus injury except
 - a. Erb's palsy causes paralysis of the abductors and external rotators of the shoulder
 - b. In Klumpke's Palsy, Horner's syndrome may be present on the ipsilateral side
 - c. Preganglionic lesions have a better prognosis than the post ganglionic lesion
 - d. Histamine test is useful to differentiate between the pre and post ganglionic lesions

PERIPHERAL NERVE INJURIES

1. Finding a slowed conduction time at a specified point along the course of nerve is often valuable in confirming a clinical diagnosis of
 - a. Malingering
 - b. Neurotmesis
 - c. Compression Neuropathy
 - d. Myopathy
2. A politician sustained injury at T8 level following a bullet that was fired at him during a rally. All mentioned below are causes of non-recovery except
 - a. absence of endoneurial tube
 - b. glial scar formation

19. Most common cause of neurological deficit in the upper limb is
 - a. Erb's palsy
 - b. Polio
 - c. C1-C2 dislocation
 - d. Fracture dislocation of the cervical spine
20. Compression of a nerve in the carpal tunnel produces inability to
 - a. Adduct the thumb
 - b. Abduct the thumb
 - c. Oppose the thumb
 - d. Flex the distal phalanx of the thumb
21. Ulnar paradox is due to
 - a. FDP
 - b. FPL
 - c. ECRB
 - d. A simultaneous radial nerve disease
22. Froment's sign tests
 - a. Abductor pollicis brevis
 - b. Abductor pollicis longus
 - c. Adductor pollicis
 - d. Extensor pollicis longus
23. Commonest cause of wrist drop is
 - a. Dislocation of elbow
 - b. Intramuscular injection
 - c. Fracture humerus
 - d. Dislocation of shoulder
24. Thoracic outlet syndrome is best diagnosed by
 - a. MRI
 - b. CT
 - c. Digital subtraction angiography
 - d. Clinical examination
25. Which of the following is not a clinical test for Thoracic outlet syndrome?
 - a. Allen's test
 - b. Adson's test
 - c. Roos test
 - d. Hyperabduction maneuver
26. Dislocation of which one of the following carpal bones can present with a median nerve palsy?
 - a. Scaphoid
 - b. Hamate
 - c. Lunate
 - d. Trapezium
27. Ape thumb deformity is observed in lesions of
 - a. Radial nerve injury
 - b. Ulnar nerve injury
 - c. Median nerve injury
 - d. Circumflex humeral nerve injury
28. The "Card test" tests the function of
 - a. Median nerve
 - b. Ulnar nerve
 - c. Axillary nerve
 - d. Radial nerve
29. Disability of hands is maximum with a lesion of
 - a. Median nerve at elbow
 - b. Median nerve at wrist
 - c. Ulnar nerve at elbow
 - d. Ulnar nerve at wrist
30. Ulnar nerve transection above elbow causes (PGI type)
 - a. Complete loss of sensation in 4th and 5th finger
 - b. Paralysis of all lumbricals
 - c. Paralysis of all interossei
 - d. Paralysis of flexor carpi ulnaris
 - e. Paralysis of flexor digitorum profundus
31. A patient presents with loss of sensation of ring and little finger with wasting of hypothenar muscles. Where is the likely site of lesion?
 - a. Deep branch of ulnar nerve is injured
 - b. Median nerve is involved
 - c. Ulnar nerve is transected prior to division into superficial and deep branches
 - d. Superficial branch of ulnar nerve is injured
32. In a patient with Claw hand due to leprosy, the deformity would be classified as
 - a. Grade 0
 - b. Grade I
 - c. Grade II
 - d. Grade III
33. Damage to the radial nerve in the spinal groove spares which muscle
 - a. Lateral head of triceps
 - b. Long head of triceps
 - c. ECRB
 - d. Anconeus
34. Which of the following factor does not predispose to carpal tunnel syndrome?
 - a. Hypertension
 - b. Hypothyroidism
 - c. Pregnancy
 - d. Acromegaly
35. Phalen's test is positive in
 - a. Carpal tunnel syndrome
 - b. De Quervain's disease
 - c. Tennis elbow
 - d. Ulnar bursitis
36. Meralgia paraesthetica involves
 - a. Axillary nerve
 - b. Sural nerve
 - c. Median nerve
 - d. Lateral cutaneous nerve of thigh
37. Which nerve has been reported to be injured during McRobert's procedure performed for delivering a child?
 - a. Axillary nerve
 - b. Sural nerve
 - c. Median nerve
 - d. Lateral cutaneous nerve of thigh
38. Most common cause of Tarsal tunnel syndrome
 - a. Osteoarthritis
 - b. Ankylosing spondylitis
 - c. Psoriatic arthritis
 - d. Rheumatoid arthritis
39. Which of the following does not involve nerve damage?
 - a. Guillain Barre syndrome
 - b. Volkmann's Ischemic Contracture
 - c. Neurotmesis
 - d. Erb's paralysis
40. Schaefer's test is for assesment of
 - a. Palmaris longus
 - b. Flexor hallucis longus
 - c. Brachioradialis
 - d. Coracobrachialis
41. Most common nerve injury in a typist involved in computer related work would be
 - a. Ulnar nerve
 - b. Radial nerve
 - c. Median nerve
 - d. Axillary nerve

INFECTIONS

1. Spina ventosa results from
 - a. Tuberculosis (TB)
 - b. Sarcoidosis
 - c. Both
 - d. None
2. Caries sicca is seen in
 - a. Hip
 - b. Knee
 - c. Shoulder
 - d. None
3. TB of spine commonly affects all of the following parts of vertebrae except
 - a. Body
 - b. Lamina
 - c. Spinous process
 - d. Pedicle
4. TB of spine starts in
 - a. Body
 - b. Nucleosus pulposus
 - c. Annulus fibrosus
 - d. Paravertebral fascia
5. Investigation for rapid diagnosis of osteomyelitis
 - a. X-ray
 - b. CT scan
 - c. MRI
 - d. Isotope scanning
6. Most common cause of osteomyelitis in sickle cell disease is
 - a. Salmonella
 - b. Staph aureus
 - c. Pseudomonas
 - d. Streptococcus pyogenes
7. Hong Kong procedure is useful for treating
 - a. Tuberculosis of cervical spine
 - b. Gout
 - c. AVN of hip
 - d. Caffey's disease patients
8. Wandering acetabulum is seen in
 - a. Fracture acetabulum
 - b. CDH
 - c. Dislocation of femur
 - d. TB hip
9. Triple deformity of knee is classically seen in
 - a. Fracture patella
 - b. TB knee
 - c. RA
 - d. Rickets
10. Kanavel's sign are seen in
 - a. Tenosynovitis
 - b. Trigger finger
 - c. Carpal tunnel syndrome
 - d. Dupuytren's contracture
11. Compound palmar ganglion is
 - a. Pyogenic affection of ulnar bursa
 - b. Tuberculosis affection of ulnar bursa
 - c. Non specific affection of ulnar bursa
 - d. Ulnar bursitis due to compound injury

12. Brodie's abscess is
 - a. Acute osteomyelitis
 - b. Subacute osteomyelitis
 - c. Chronic osteomyelitis
 - d. Septic arthritis
13. Most common organism causing infection after open fractures
 - a. Staphylococcus aureus
 - b. Pseudomonas
 - c. Klebsiella
 - d. Gonococcus
14. True about HIV osteomyelitis is all except?
 - a. Bilateral
 - b. Necrosis is absent
 - c. Periosteal new bone formation
 - d. Most common cause is Staph aureus
15. Earliest change of osteomyelitis on X-Ray
 - a. Lytic defects
 - b. Loss of soft tissue planes
 - c. Sequestrum
 - d. Periosteal reaction
16. Most common joint involved in septic arthritis
 - a. Knee
 - b. Shoulder
 - c. Hip
 - d. Elbow
17. A 7-year-old boy presented with abrupt onset of pain in right hip with the hip held in abduction. Hemogram and X-ray are normal but the ESR is raised. Appropriate line of management is from here would be
 - a. Hospitalise and observe
 - b. Intravenous antibiotics
 - c. Ambulatory observation
 - d. USG guided aspiration of hip
18. Tom smith arthritis manifests as
 - a. Hip stiffness
 - b. Ankylosis
 - c. Lengthening of limb
 - d. Increased hip mobility & instability
19. A 30-year-old male, HIV positive, on antiretroviral therapy, has pain in right hip region. There is flexion, abduction and external rotation deformity of right hip since 2 months. Most likely diagnosis is
 - a. TB Hip
 - b. Avascular necrosis
 - c. Septic arthritis
 - d. Transient synovitis
20. Most common site of actinomycosis amongst the following is
 - a. Femur
 - b. Mandible
 - c. Tibia
 - d. Rib
21. Most common finger infected by felon is
 - a. Thumb
 - b. Index finger
 - c. Middle finger
 - d. Ring finger
22. Ring sequestrum is seen in
 - a. Typhoid osteomyelitis
 - b. Chronic osteomyelitis
 - c. Amputation stump
 - d. Tuberculosis osteomyelitis
23. The common cause of limp in a child of seven years is
 - a. TB hip
 - b. CDH
 - c. Perthes disease
 - d. Slipped capital femoral epiphysis
24. Most common cause of monoarthritis in children in India is
 - a. Septic arthritis
 - b. Osteoarthritis
 - c. Tuberculous arthritis
 - d. RA
25. The first neurological sign in a patient with TB spine is
 - a. Sensory loss
 - b. Spastic weakness
 - c. Bladder involvement
 - d. Ankle clonus
26. Poncet's disease is
 - a. TB + monoarthritis
 - b. TB+ polyarthritis
 - c. RA with neutropenia
 - d. RA with leucopenia
27. Poor prognostic factor in Pott's paraplegia are (PGI type)
 - a. Acute onset paraplegia
 - b. Sudden progression of paraplegia
 - c. Long standing paraplegia
 - d. Motor paralysis alone
 - e. Paraplegia in children
28. Apparent lengthening of the limb is seen in which stage of TB hip?
 - a. Stage 1
 - b. Stage 2
 - c. Stage 3
 - d. Stage 4
29. The best diagnostic modality for tuberculosis of spine is
 - a. Clinical
 - b. X-Ray
 - c. MRI
 - d. CT guided biopsy
30. Bony ankylosis may result from (PGI type)
 - a. Pyogenic arthritis
 - b. Tubercular arthritis
 - c. Osteoarthritis
 - d. Rheumatoid arthritis

TUMORS

1. Classification system for bone tumors is named after
 - a. Galen
 - b. Enneking
 - c. Codman
 - d. Charnley
2. Which of the following is not true about osteoid osteoma?
 - a. Generally affect diaphysis of long bones
 - b. Commonest bone affected - tibia
 - c. Radiolucent nidus in centre
 - d. Pre - malignant
3. Sun-ray appearance in osteosarcoma is due to
 - a. Osteonecrosis
 - b. Periosteal reaction
 - c. Calcification along the muscle spindles
 - d. Calcification along the vessels
4. Most common malignancy that metastasizes to the spine is
 - a. Lung
 - b. Prostate
 - c. Breast
 - d. Thyroid
5. Bone to bone metastasis is most commonly seen in
 - a. Osteosarcoma
 - b. Ewings sarcoma
 - c. Chondrosarcoma
 - d. Reticulum cell carcinoma
6. Night pains are characteristically seen with
 - a. Osteoid osteoma
 - b. Osteosarcoma
 - c. Ewing sarcoma
 - d. Fibrous cortical defect
7. A 10-year-old child presents with a small lytic lesion surrounded by reactive sclerosis in the middle of shaft of tibia. The most likely diagnosis is
 - a. Fibrous cortical defect
 - b. Eosinophilic granuloma
 - c. Osteoid osteoma
 - d. Fibrous dysplasia
8. The commonest site for osteochondroma is fast growing ends of long bones. Next common site is
 - a. Crest of the ilium
 - b. Scapula
 - c. Ribs
 - d. Vertebra
9. Tumor with maximum bone matrix
 - a. Osteoid osteoma
 - b. Chondrosarcoma
 - c. Enchondroma
 - d. None
10. Hyperglycemia is associated with which of the following bone tumor
 - a. Multiple myeloma
 - b. Ewings Sarcoma
 - c. Osteosarcoma
 - d. Chondrosarcoma
11. The risk of malignancy in Multiple Osteochondromatosis is
 - a. 1%
 - b. 2%
 - c. 5%
 - d. 15%
12. Which of the following is a GCT variant?
 - a. Chondroblastoma
 - b. Aneurysmal bone cyst
 - c. Osteosarcoma with giant cells
 - d. Fibrous dysplasia
13. Increased LDH levels are a bad prognostic factor in which tumor?
 - a. Osteosarcoma
 - b. Osteoid osteoma
 - c. Giant cell tumor
 - d. Ewing's tumor
14. All of the following statements about synovial cell sarcoma are correct except
 - a. Occurs more often at extra articular sites
 - b. Originates from synovial lining
 - c. Usually seen in people under 50 years age
 - d. Knee is the most common site
15. Most common site of Admantinoma is
 - a. Mandible near symphysis menti
 - b. Mandible near the molar tooth
 - c. Diaphysis of tibia
 - d. Hard palate
16. A 30-year-lady presented with pain and tenderness in index finger just under the nail. She was unable to wash her hands with cold water. Patient did not reveal any history of trauma or injury. What could be probable finding noted in this case
 - a. Sausage digits
 - b. Ridging of nail, bluish discoloration and pin-head tenderness
 - c. Stiffness of whole hand
 - d. Hypersensitivity of finger

17. Generally radiotherapy should not be used for treating benign conditions, the only possible exception being
 - a. Chondromyxoid fibroma
 - b. Extensive pigmented villonodular synovitis
 - c. Benign fibrous histiocytoma
 - d. Desmoplastic fibroma so extensive that it cannot be surgically excised
18. Vertebra plana is seen in all except
 - a. Ewing's sarcoma
 - b. Paget's ds
 - c. Trauma ds
 - d. Malignancy
19. Most common malignant tumour of hand
 - a. Chondroblastoma
 - b. Enchondroma
 - c. Squamous cell carcinoma
 - d. Melanoma
20. Chondroblastoma is a tumor of
 - a. Epiphysis
 - b. Metaphysis
 - c. Diaphysis
 - d. Flat bone
21. Most common childhood tumor metastasizing to the bones is
 - a. Neuroblastoma
 - b. Wilm's tumor
 - c. Ewing's sarcoma
 - d. Ganglioneuroma
22. All of the following tumors are benign tumors except
 - a. Chondroma
 - b. Osteochondroma
 - c. Chordoma
 - d. Enchondroma
23. According to the newer hypothesis, Ewing's sarcoma arises from
 - a. Epiphysis
 - b. Medullary cavity
 - c. Diaphysis
 - d. Cortex
24. The cell of origin in Giant cell tumor is
 - a. Monocyte
 - b. Osteoclast
 - c. Osteoblast
 - d. Unknown
25. Which of the following is biphasic tumor?
 - a. Rhabdomyosarcoma
 - b. Osteosarcoma
 - c. Synovial sarcoma
 - d. Osteoblastoma
26. Fallen fragment sign is seen in
 - a. Giant cell tumor
 - b. Simple bone cyst
 - c. Aneurysmal bone cyst
 - d. Fibrous dysplasia
27. A classical expansile lytic lesion in the transverse process of the vertebra is seen in
 - a. Osteosarcoma
 - b. Osteoblastoma
 - c. Aneurysmal bone cyst
 - d. Metastasis
28. Differential diagnosis of a lesion, histologically resembling GCT in the small bones of the hands and feet includes all of the following except
 - a. Aneurysmal bone cyst
 - b. Osteosarcoma
 - c. Fibrosarcoma
 - d. Hyperparathyroidism
29. Most common radiation induced tumor is
 - a. Multiple myeloma
 - b. Malignant fibrous histiocytoma
 - c. Chondrosarcoma
 - d. Osteosarcoma
30. T-10 protocol for treatment of osteosarcoma includes all of the following except
 - a. Vincristine
 - b. Etoposide
 - c. High dose methotrexate
 - d. Bleomycin, cyclophosphamide, doxorubicin (BCD)
31. Maximum incidence of Ewing's occurs in
 - a. 1st decade
 - b. 2nd decade
 - c. 3rd decade
 - d. 4th decade
32. Most common bone tumor in the 1st decade is
 - a. Multiple myeloma
 - b. Ewing's sarcoma
 - c. Osteosarcoma
 - d. Metastasis
33. A poor prognostic sign for Ewing's sarcoma is
 - a. Females
 - b. Fever
 - c. Grade
 - d. Age <12years
34. Pigmented villo-nodular synovitis most commonly occurs at
 - a. Knee
 - b. Hip
 - c. Shoulder
 - d. Elbow
35. True about bone metastasis (PGI type)
 - a. 5% bone metastasis are symptomatic
 - b. MC secondary in females is breast
 - c. High serum levels of alkaline phosphatase
 - d. Prostate produces osteosclerotic lesion
 - e. Commonly involves hand & feet bones
36. Metastasis are least common in
 - a. Vertebra
 - b. Pelvis
 - c. Proximal parts of long bones of the upper limb
 - d. Small bones of the hand
37. Most common soft tissue tumor in a child
 - a. Rhabdomyosarcoma
 - b. Fibrosarcoma
 - c. Histiocytoma
 - d. Liposarcoma
38. Expansile lytic osseous metastases are characteristics of primary malignancy of
 - a. Breast
 - b. Prostate
 - c. Bronchus
 - d. Kidney
39. A 60-year-old male has bone pain, vertebral collapse and pathological fracture in pelvis. The most probable diagnosis is
 - a. Multiple myeloma
 - b. TB
 - c. Hamangioma of bone
 - d. Secondaries
40. A 4-year-old girl presents with history of fever and a palpable mass in thigh. X-ray shows periosteal reaction and destruction of bone. Next investigation to be done
 - a. Bone biopsy
 - b. Blood culture
 - c. Bone scan
 - d. CT scan
41. Osteosclerotic bone metastasis is seen most commonly in which carcinoma?
 - a. Kidney
 - b. Lung
 - c. Thyroid
 - d. Prostate
42. An elderly patient has back pain and urinary retention. Next investigation to be done should be
 - a. Alkaline phosphatase
 - b. Acid phosphatase
 - c. Serum calcium
 - d. Serum VMA levels
43. Most common site of osteosarcoma is
 - a. Upper end of femur
 - b. Lower end of femur
 - c. Lower end of humerus
 - d. Lower end of tibia
44. Maffucci syndrome is
 - a. Enchondromas with hemangioma
 - b. Haemangiomas and limb hyperplasia
 - c. Haemangiomas and precocious puberty
 - d. Haemangiomas and capillary malformation
45. When size of osteoclastoma exceeds the size of metaphysis (PGI type)
 - a. Tumor will be covered by cortex
 - b. Tumor will be covered by fibrous capsule
 - c. Tumor will be covered by a thin layer of bone
 - d. It is limited to metaphysis
 - e. It is covered by periosteum
46. The following bone tumor may cause dural deposits without causing bony changes
 - a. Hodgkin's lymphoma
 - b. Multiple myeloma
 - c. Secondaries
 - d. Fibrous dysplasia
47. Which is not a feature of malignant transformation in an Osteochondroma?
 - a. Wait loss
 - b. Pain
 - c. Rapid increase in size
 - d. Calcification on CT more than 2 cm
48. Shepherd crook deformity is seen in
 - a. Fibrous dysplasia
 - b. Paget's disease
 - c. Osteogenesis imperfecta
 - d. All the above
49. The treatment of choice for Ewing's sarcoma is
 - a. Radiotherapy
 - b. Chemotherapy
 - c. Wide surgical excision
 - d. Amputation

PEDIATRIC ORTHOPEDICS

1. A child is born with CTEV (Congenital Talipes Equinus Varus). All of the following can be the causes except
 - a. Poliomyelitis
 - b. Spina bifida
 - c. Idiopathic
 - d. Arthrogyposis multiplex congenita

2. Earliest changes in Perthes disease are detected by
 - a. X-ray
 - b. CT
 - c. MRI
 - d. Nuclear scan
3. Which of the following is not true about development dysplasia of hip (DDH)?
 - a. The hourglass appearance of the joint capsule may prevent a successful closed reduction
 - b. It is more common in females
 - c. Oligohydramnios is associated with higher risk of DDH
 - d. When the ossification centre is in the lower medial quadrant, the hip is dislocated
4. A 12-year-old obese boy was referred to emergency from endocrinology department for painful limp since 1 month. Which amongst the following will be the least helping investigation?
 - a. USG hip
 - b. CT B/L hip
 - c. X-ray pelvis with hip
 - d. MRI B/L hip
5. In a young male after injury to knee you observed a small piece of avulsed bone from the lateral tibial condyle. What test would you like to do?
 - a. Ortolani sign
 - b. Telescoping sign
 - c. McMurray's test
 - d. Lachman's test
6. Congenital pseudoarthrosis of tibia is best treated by
 - a. Above knee POP cast
 - b. Below knee POP cast
 - c. Internal fixation
 - d. Internal fixation and bone grafting
7. Pollicization is
 - a. Thumb reconstruction
 - b. Thumb amputation
 - c. Inflammation at the base of thumb in gouty arthritis
 - d. A treatment method for trigger thumb
8. The characteristic triad of Klippel Fiel Syndrome includes all of the following except
 - a. Limited neck movements
 - b. Low hair line
 - c. Short neck
 - d. Elevated scapula
9. All are true for congenital torticollis except
 - a. It can disappear spontaneously
 - b. Also called as Sternomastoid tumor
 - c. Seen only in cases of breech vaginal delivery
 - d. Untreated, neglected cases can result in plagiocephaly
10. Fair banks triangle is seen in
 - a. SCFE (Slipped Capital Femoral Epiphysis)
 - b. CTEV
 - c. DDH
 - d. Congenital coxa vara
11. An 8-year-old male presents with painless limp on examination and restricted abduction and internal rotation left hip. Most probable diagnosis is
 - a. CDH
 - b. Tuberculous arthritis of hip
 - c. Septic arthritis of hip
 - d. Perthes disease
12. Trethowan's sign is seen in
 - a. Perthes disease
 - b. CDH
 - c. SCFE
 - d. Fracture neck femur
13. Bachelor's cast is used in
 - a. Fracture radius
 - b. CTEV
 - c. DDH
 - d. Fracture calcaneum
14. Most common associated anomaly in DDH is
 - a. Femoral anteversion
 - b. Pelvic obliquity
 - c. Femoral retroversion
 - d. Shallow acetabulum
15. All of the following statements are true about DDH, except
 - a. More common in females
 - b. Twin pregnancy is a known risk factor
 - c. Oligohydramnios is associated with a higher risk
 - d. The hourglass appearance of the capsule may prevent a successful closed reduction
16. Charlie Chaplin gait is seen in
 - a. Genu valgum
 - b. External tibial torsion
 - c. Congenital coxa vara
 - d. CDH
17. Critical age of osteotomy for genu varum is
 - a. 4 years
 - b. 6 years
 - c. 8 years
 - d. 10 years
18. Rocker bottom foot is due to
 - a. Malunited fracture calcaneum
 - b. Neural tube defect
 - c. Horizontal talus
 - d. Over treatment of CTEV
19. Most common congenital anomaly of foot in India is
 - a. CTEV
 - b. Vertical talus
 - c. Metatarsus adductus
 - d. Hallux valgus
20. The ideal treatment of bilateral idiopathic clubfoot in a newborn is
 - a. Manipulation by mother
 - b. Manipulation and casts
 - c. Manipulations and dens brown splint
 - d. Surgical release
21. Triple arthrodesis involves fusion of which of the following joints?
 - a. Tibiotalar, calcaneocuboid and talonavicular
 - b. Calcaneocuboid, talonavicular and talocalcaneal
 - c. Ankle joint, calcaneocuboid and talonavicular
 - d. None of the above
22. The club foot characteristically involves
 - a. Foot, ankle and leg
 - b. Foot only
 - c. Foot and ankle
 - d. Foot, ankle, leg and knee joint
23. Most important pathology in club foot is
 - a. Calcaneal fracture
 - b. Tightening of tendoachilles
 - c. Congenital talonavicular dislocation
 - d. Lateral derangement
24. Not true about osteogenesis imperfecta
 - a. Deafness
 - b. Laxity of joints
 - c. Fragile fracture
 - d. Impaired healing of fracture
25. In which of the following conditions, bilateral symmetrical fractures occur?
 - a. Rickets
 - b. Osteogenesis imperfecta
 - c. Fluorosis
 - d. Osteopetrosis
26. Wormian bones are seen in
 - a. Pagets disease
 - b. Osteoclastoma
 - c. Scheurmann's disease
 - d. Osteogenesis imperfecta
27. Hallux valgus is associated with all except?
 - a. A bunion
 - b. An exostosis on the medial side of the head of the first metatarsal
 - c. Osteoarthritis of the first metatarsophalangeal joint
 - d. Over riding or under riding of the second toe by the third
28. Ligament stretched in flat foot is
 - a. Anterior talofibular ligament
 - b. Posterior talofibular ligament
 - c. Calcaneonavicular ligament
 - d. Calcaneofibular ligament
29. For Screening of neonatal hip instability, modality most commonly used is
 - a. USG
 - b. X-ray
 - c. MRI
 - d. CT
30. A 6-year-old boy presents to emergency department with painful limp. Clinical examination reveals tenderness in the femoral triangle and some limitation of hip movements. The X-ray is normal. What should be the next course of action?
 - a. Wait and watch (Observation)
 - b. USG
 - c. MRI
 - d. Aspiration
31. A one year old child presented with multiple fractures seen in various stages of healing. The most probable diagnosis in the case is
 - a. Scurvy
 - b. Rickets
 - c. Battered baby syndrome
 - d. Fall from height

32. Not true about B/L DDH
 - a. Exaggerated lordosis
 - b. B/L genu valgum
 - c. Waddling gait
 - d. Shenton's line broken
 - e. Short stature
33. Commonest presentation of congenital dislocation of knee is
 - a. Varus
 - b. Valgus
 - c. Flexion
 - d. Hyperextension
34. Most common cause of genu valgum in a child is
 - a. Osteoarthritis
 - b. Rickets
 - c. Paget's disease
 - d. Rheumatoid arthritis
35. Blount's disease is associated with all of the following except
 - a. Genu varum
 - b. Genu Recurvatum
 - c. Internal Tibial Torsion
 - d. External Tibial Torsion
36. Rocker bottom foot is seen in (PGI type)
 - a. Congenital vertical talus
 - b. Excessive correction of Grice procedure
 - c. Arthrogryposis
 - d. Holding club foot in too long corrected position
 - e. Force dorsiflexion against equinus
37. In correction of clubfoot by manipulation, which deformity should be corrected first?
 - a. Forefoot adduction
 - b. Varus
 - c. Tibia torsion
 - d. Equinus
38. Child 3¼ years is treated for CTEV by
 - a. Triple arthrodesis
 - b. Postero medial soft tissue release
 - c. Lateral wedge resection
 - d. Tendo Achilles lengthening
39. Pseudoarthrosis after Triple arthrodesis is seen at the joint of
 - a. Calcaneocuboid
 - b. Calcaneonavicular
 - c. Naviculocuboid
 - d. Talonavicular
40. Sprengel's deformity is
 - a. Absence of clavicle
 - b. Acromioclavicular dislocation
 - c. Congenital elevation of scapula
 - d. Recurrent dislocation of shoulder
41. Not true about Osteogenesis imperfecta
 - a. Autosomal dominant disease
 - b. Blue sclera
 - c. Associated with Otosclerosis
 - d. Defect in collagen type I
42. Jaw tumor is seen in
 - a. Osteoporosis
 - b. Osteomalacia
 - c. Osteopetrosis
 - d. Caffey's disease
43. Treatment of choice for Caffey's disease is
 - a. Multiple drilling
 - b. Penicillin
 - c. Tetracycline
 - d. Curettage
44. Jones operation is done for
 - a. CTEV
 - b. Hallus valgus correction
 - c. Cavus deformity of foot
 - d. Claw hallux
45. Excision arthroplasty is indicated in all of the following except
 - a. Hallux valgus
 - b. TB hip
 - c. Lateral condyle humerus fracture
 - d. Caries elbow
46. Siffert Katz sign is seen in
 - a. Perthes disease
 - b. Blount's disease
 - c. Osteogenesis imperfecta
 - d. Pulled elbow
47. Flexion deformity in hammer toe is at
 - a. PIP
 - b. DIP
 - c. Metatarsophalangeal
 - d. Calcaneonavicular
- c. Flexion at the hip and the knee
- d. Extension at the knee
2. Test for tight iliotibial band is
 - a. Ober's test
 - b. Simmond's test
 - c. Osner's test
 - d. Charnley's test
3. In a 3-year-old child with polio paralysis, tendon transfer operation is done at?
 - a. 2 months after the disease
 - b. 2 years after the disease
 - c. 6-12 months after the disease
 - d. After skeletal maturation
4. Tendon transfers in polio should be done after the age of
 - a. 6 months
 - b. 5 months - 1 year
 - c. 2 years
 - d. 5 years
5. Post Poliomyelitis, a patient has grade II power in Gastrocnemius, grade III in Peroneus, grade IV in Tibialis Anterior. The resultant deformity would be
 - a. Calcaneovalgus
 - b. EquinoVarus
 - c. Calcaneovarus
 - d. Genu valgus
6. Muscle most commonly affected in polio is
 - a. Tensor fascia lata
 - b. Tibialis posterior
 - c. Tibialis anterior
 - d. Quadriceps
7. Polio most commonly involves which one of the following upper limb muscles
 - a. Pectoralis major
 - b. Trapezium
 - c. Deltoid
 - d. Triceps

GENETIC AND DEVELOPMENTAL DISORDERS

1. Bone dysplasia is due to
 - a. Faulty nutrition
 - b. Faulty development
 - c. Trauma
 - d. Parathyroid tumor
2. Not seen in Osteopetrosis
 - a. Compression of cranial nerves
 - b. Osteomyelitis of mandible
 - c. Pancytopenia
 - d. Delayed healing of bone
3. Musculoskeletal abnormalities seen in neurofibromatosis
 - a. Pseudoarthrosis
 - b. Hypertrophy of limb
 - c. Scoliosis
 - d. All the above
4. Commonest cause of congenital pseudoarthrosis is
 - a. Fibrous dysplasia
 - b. Neurofibromatosis
 - c. Intrauterine fracture
 - d. Unknown
5. A 3-year-old male presented with progressive anemia, hepatosplenomegaly and osteomyelitis of jaw with pathological fracture. X-Ray shows chalky white deposits in bone. Probable diagnosis is
 - a. Alkaptonuria
 - b. Osteopetrosis
 - c. Myositis ossificans progressiva
 - d. Osteopoikilosis
6. Dripping candle wax appearance on X-ray of spine is seen in
 - a. Osteopetrosis
 - b. Metastasis
 - c. TB spine
 - d. Melorheostosis
7. The following is false about achondroplasia
 - a. Due to gene mutation
 - b. Mental retardation
 - c. AD
 - d. Shortening of limbs present
8. A 9-year-old child has high arched palate with shoulders meeting in front of his chest. Diagnosis is?
 - a. Cleidocranial dysostosis
 - b. Erb's palsy
 - c. Chondro-osteodystrophy
 - d. Cortical hyperostosis
9. Phocomelia is characterized by
 - a. Absence of short bones
 - b. Complete absence of extremities
 - c. Defects of long bones of limb
 - d. Partial absence of extremities

NEUROMUSCULAR DISORDERS

1. In a post polio case, iliotibial tract contracture is likely to result in
 - a. Extension at the hip and knee
 - b. Extension at the hip

10. Pseudoarthrosis is seen in all of the following except
 - a. Idiopathic
 - b. Fracture
 - c. Osteomyelitis
 - d. Neurofibromatosis
11. Nail patella syndrome is characterized by
 - a. Iliac horn
 - b. Sacral horn
 - c. Knee deformity
 - d. Dislocation of patella
12. "Trident hand" is seen in
 - a. Achondroplasia
 - b. Mucopolysaccharoidosis
 - c. Diphyseal achalasia
 - d. Cleido-cranial dystosis
13. The features of Achondroplasia include all except
 - a. Defective head
 - b. No mental retardation
 - c. Autosomal recessive
 - d. Familial
14. The characteristics of Morquio's disease include all except
 - a. Spinal kyphosis
 - b. Subnormal intelligence
 - c. Excessive excretion of keratin-sulphate in urine
 - d. Dwarfism
10. A 6-year-old child is on calcium supplementation for rickets and has Genu valgum. When can the child be referred to the surgeon for a corrective surgery?
 - a. When Vitamin D levels return to normal
 - b. When growth plate healing is seen radio-graphically
 - c. When serum alkaline phosphatase levels are normal
 - d. When serum calcium levels become normal
11. Which of the following is not a treatment option for osteoporosis?
 - a. Denosumab
 - b. Alendronate
 - c. Vertebroplasty
 - d. Corticosteroids
12. Denosumab – a monoclonal antibody against RANKL receptor is used in the treatment of?
 - a. Osteoarthritis
 - b. RA
 - c. SLE
 - d. Osteoporosis
13. Which is the drug of choice in Paget's disease?
 - a. Alendronate
 - b. Steroids
 - c. Allopurinol
 - d. Calcitonin
14. Pain in Paget's disease is best relieved by?
 - a. Radiation
 - b. Calcitonin
 - c. Simple analgesics
 - d. Narcotic analgesics
15. True about osteoclasts are all except
 - a. Derived from monocyte
 - b. Stimulated by PTH
 - c. Phagocytosis of foreign bodies
 - d. Resorption of bone
16. Rickets in infancy is characterised by all of the following except
 - a. Wide open fontanella
 - b. Bow legs
 - c. Rachitic rosary
 - d. Craniotabes
17. Oncogenic rickets not seen in
 - a. Osteosarcoma
 - b. Non ossifying fibroma
 - c. Chondroblastoma
 - d. Angiosarcoma
18. Salt and pepper skull is a feature of
 - a. Eosinophilic granuloma
 - b. Paget's syndrome
 - c. Primary hyperparathyroidism
 - d. Multiple myeloma
19. Absence of lamina dura in the alveolus occurs in
 - a. Rickets
 - b. Deficiency of vitamin
 - c. Osteomalacia
 - d. Hyperparathyroidism
20. Looser's zones are seen in
 - a. Osteomalacia
 - b. Renal osteodystrophy
 - c. Paget's ds
 - d. All of the above
21. Short 4th metacarpal is a feature of?
 - a. Hypoparathyroidism
 - b. Hyperparathyroidism
 - c. Pseudohypoparathyroidism
 - d. Scleroderma
22. Milkman's fracture is?
 - a. Fracture humerus
 - b. Fracture 1st metacarpal
 - c. Fracture of clavicle in children
 - d. Pseudo-fracture in adults
23. Barton's disease is
 - a. Rickets and fracture
 - b. Scurvy and fracture
 - c. Scurvy and rickets
 - d. Scurvy and syphilis
24. Osteoporosis is caused by all except
 - a. Fluorosis
 - b. Hyperthyroidism
 - c. Hypogonadism
 - d. Hyperparathyroidism
25. Most common manifestation of osteoporosis is
 - a. Loss of weight
 - b. Bowing of legs
 - c. Compression fracture of the spine
 - d. Backache
26. Diagnostic radiological finding in skeletal fluorosis
 - a. Interosseous membrane ossification
 - b. Osteosclerosis of vertebral body
 - c. Ossification of ligaments of knee joint
 - d. Sclerosis of sacroiliac joint
27. Increased density in skull vault is seen in?
 - a. Fluorosis
 - b. Renal osteodystrophy
 - c. Multiple myeloma
 - d. Hyperparathyroidism

METABOLIC BONE DISEASES

1. Which of the following statement is incorrect regarding Osteoporosis?
 - a. i/v Parathormone is useful in severe osteoporosis
 - b. T-score is less than 2.5
 - c. Bisphosphonates are the mainstay of treatment
 - d. Calcitonin is useful in acute pain
2. The maximum change in bone mineral density in hemiplegic patients after 1 year is seen in
 - a. Lumbar spine
 - b. Proximal femur of the paretic side
 - c. Distal radius of the paretic side
 - d. Humerus of the paretic side
3. Blade of grass lesion is seen in
 - a. Thalassemia
 - b. Osteoporosis
 - c. Carcinoma Prostate
 - d. Paget's disease
4. An elderly female is on treatment for osteoporosis with alendronate for 7 years. She now presents with complaints of hip pain. The next investigation for her should be
 - a. X-ray
 - b. DEXA scan
 - c. Vitamin D levels
 - d. ALP levels
5. Hypervitaminosis of which of the following vitamins can cause bony abnormalities? (PGI type)
 - a. Vitamin A
 - b. Vitamin C
 - c. Vitamin D
 - d. Vitamin K
 - e. Vitamin E
6. As per current recommendations which vitamin is required with Vitamin D for treatment of osteoporosis?
 - a. Vitamin A
 - b. Vitamin B
 - c. Vitamin C
 - d. Vitamin K
7. What is the biochemical analysis in osteoporosis?
 - a. Decreased Ca and P and Alkaline phosphatase
 - b. Increased Ca, P and Alkaline phosphatase
 - c. Decreased Ca and P but increased Alkaline phosphatase
 - d. Normal Ca, P and Alkaline phosphatase
8. All of the following statements regarding Paget's disease are correct except
 - a. Females are affected more than males
 - b. It can lead to Osteogenic sarcoma
 - c. Serum alkaline phosphate level is increased
 - d. Also called as Osteitis deformans
9. Which of the following is not a recognized risk factor for osteoporosis?
 - a. Early menarche
 - b. Sedentary life style
 - c. Smoking
 - d. Low dietary calcium intake

28. A 67-year-old man on biochemical analysis was found to have three fold rise in level of serum Alkaline Phosphatase (ALP) above that of upper limit of normal value during a routine check up. However, serum calcium and phosphorous concentration and LFTs were normal. He is asymptomatic. Probable cause could be
 - a. Paget's disease of bone
 - b. Multiple myeloma
 - c. Primary hyperparathyroidism
 - d. Osteomalacia
29. Rotting fence post appearance of femur is seen in
 - a. Fibrous dysplasia
 - b. Hyperparathyroidism
 - c. Paget's disease
 - d. Fracture neck of femur
30. Drug induced Osteomalacia is known to be associated with the use of
 - a. Steroids
 - b. Heparin
 - c. Phenytoin
 - d. Gentamycin
31. Alkaline phosphatase is elevated in all except
 - a. Rickets
 - b. Osteomalacia
 - c. Hypoparathyroidism
 - d. Hypophosphatemia
32. The characteristic finding in osteomalacia is
 - a. $\downarrow P$
 - b. $\downarrow Ca$
 - c. $\downarrow Ca$ & $\uparrow P$
 - d. $\downarrow Ca$ & $\downarrow P$
33. Most common cause of primary hyperparathyroidism is
 - a. Solitary adenoma
 - b. Chief cell hyperplasia
 - c. Multiple adenoma
 - d. Werner's syndrome
34. In hyperparathyroidism bone resorption is seen in all these sites except
 - a. Jaws
 - b. Metacarpals
 - c. Ribs
 - d. End of long bones
35. A 50-year-old man presented with multiple pathological fractures. His serum calcium was 11.5 mg/dl and phosphate was 2.5 mg/dl while Alkaline phosphatase was 940 I.U/dl. The most probable diagnosis is
 - a. Osteoporosis
 - b. Osteomalacia
 - c. Multiple Myeloma
 - d. Hyperparathyroidism
36. Paget's disease of bone most commonly affects
 - a. Skull
 - b. Vertebra
 - c. Pelvis
 - d. Femur
37. Deafness in cases of Paget's disease is due to
 - a. Thickened cranium
 - b. Narrowing of foramina of skull
 - c. Brain compression
 - d. Otosclerosis
38. Osteoporosis is seen in all the following except
 - a. Thyrotoxicosis
 - b. Rheumatoid arthritis
 - c. Hypoparathyroidism
 - d. Steroid therapy
39. The most common site of fracture of bone in senile osteoporosis is
 - a. Vertebra
 - b. Neck of femur
 - c. Radius
 - d. Shaft of femur
40. Risk factors for osteoporosis (PGI type)
 - a. Late menopause
 - b. COPD
 - c. Obesity
 - d. Smoking
 - e. OCPs
41. Drug of choice for senile osteoporosis is
 - a. Estrogens
 - b. DEXA scan
 - c. Calcitonin
 - d. Etidronate
42. Treatment of choice for postmenopausal osteoporosis
 - a. Calcitonin
 - b. Alendronate
 - c. Progesterone
 - d. Tamoxifene
43. Least useful anti-rachitic
 - a. 1,25-hydroxy cholecalciferol
 - b. Cholecalciferol
 - c. 25-hydroxy cholecalciferol
 - d. Calcium
44. Vitamin D deficiency rickets is confirmed by demonstration of
 - a. Epiphyseal changes in X-ray
 - b. Hypocalcaemia and hypophosphatemia

- c. Raised serum alkaline phosphatase
- d. Healing with physiologic doses of vitamin d3
45. Drug of choice for bisphosphonate resistant osteoporosis
 - a. Teriparatide
 - b. Denosumab
 - c. Anakinra
 - d. Calcitonin

ARTHRITIS AND RELATED DISORDERS

1. In articular cartilage, greatest density of active chondrocytes is seen in
 - a. Zone 1
 - b. Zone 2
 - c. Zone 3
 - d. Zone 4
2. Synovial fluid of low viscosity is seen in all except
 - a. Gout
 - b. Osteoarthritis
 - c. Septic arthritis
 - d. Rheumatoid Arthritis (RA)
3. What is the polymorph percentage in tubercular arthritis knee?
 - a. 20%
 - b. 40%
 - c. 60%
 - d. 90%
4. All of the following are **properties of synovial fluid except**
 - a. It is a pale yellow, clear and sufficiently viscous fluid that droplets expelled from a needle tip fall in a long string
 - b. Normally it doesn't contain any crystals
 - c. It doesn't clot since it lacks in fibrinogen
 - d. Normal WBC count in synovial fluid is 350 – 3500/mm³
5. Bouchard's nodes are present over
 - a. DIP
 - b. PIP
 - c. MCP
 - d. Wrist
6. Scheuermann's disease affects which age group?
 - a. Adolescents
 - b. Adults
 - c. Elderly
 - d. Infants
7. A female presents with swelling over the base of thumb and tenderness and 1st CMC joint. What is the probable diagnosis?
 - a. DeQuervain's disease
 - b. Osteoarthritis
 - c. Rheumatoid Arthritis
 - d. Ankylosing Spondylitis
8. Earliest radiological sign in Ankylosing Spondylitis (AS)
 - a. Squaring of lumbar vertebrae
 - b. Widening and haziness around SI joints
 - c. Bamboo spine
 - d. Narrowing and sclerosis around the SI joints
9. Plantar calcaneal spur is not seen in (PGI type)
 - a. Reiter's syndrome
 - b. Scleroderma
 - c. RA
 - d. Psoriatic arthropathy (PsA)
 - e. AS
10. Most common cause of AVN hip is
 - a. Steroids
 - b. Alcohol
 - c. Idiopathic
 - d. Sick cell disease
11. All of the following are done in osteoarthritis of knee except
 - a. Arthroscopy
 - b. Osteoclasts
 - c. Arthroplasty
 - d. Osteotomy
12. Osteochondritis dissecans involves
 - a. Medial part of lateral femoral condyle
 - b. Lateral part of medial femoral condyle
 - c. Inferior pole of patella
 - d. Tibial tuberosity
13. A 40-year-old man presents with acute onset pain left great toe. On investigation, punched out lesions with overhanging margins are seen on phalanx and adjacent soft tissue. Most likely diagnosis is
 - a. Rheumatoid Arthritis (RA)
 - b. Gout
 - c. Reiter's ds
 - d. Psoriatic arthropathy (PsA)
14. Chondrocalcinosis is seen in
 - a. Rickets
 - b. Ochronosis (Alkaptonuria)
 - c. Hypoparathyroidism
 - d. Hypervitaminosis
15. Most common joint involved joint in Pseudogout
 - a. Knee
 - b. Hip
 - c. Elbow
 - d. Great toe
16. Multiple loose bodies are seen most commonly in
 - a. Synovial chondromatosis
 - b. Osteochondritis dissecans
 - c. Osteoarthritis
 - d. Osteochondral fracture
 - e. RA

17. Commonest cause of loose bodies in the knee joint
 - a. Osteochondral fracture
 - b. Osteoarthritis
 - c. Synovial chondromatosis
 - d. Osteochondritis dissecans
18. Joint not involved in osteoarthritis
 - a. PIP
 - b. DIP
 - c. MCP
 - d. Knee
19. PIP, DIP and 1st carpometacarpal joint involvement and sparing of wrist and MCP joints is a characteristic feature of
 - a. Psoriatic arthropathy
 - b. RA
 - c. Pseudogout
 - d. Osteoarthritis
20. A 35-year-old male develops involvement of PIP, DIP & MCP with sparing of wrist and carpometacarpal joints. Probable diagnosis is
 - a. RA
 - b. Psoriatic arthropathy
 - c. Osteoarthritis
 - d. Pseudogout
21. A middle aged female of RA on treatment develops upper motor neuron signs in her limbs. The investigation required to evaluate her further is
 - a. Open mouth view
 - b. Swimmers view
 - c. Brodens view
 - d. Cervical spine flexion and extension lateral views
22. Earliest radiological sign in RA
 - a. Decreased joint space
 - b. Periarticular osteopenia
 - c. Articular erosion
 - d. Subchondral cyst
23. Joint mostly spared in RA is
 - a. Wrist
 - b. MCP
 - c. PIP
 - d. DIP
24. Which is the most pathognomic feature of RA?
 - a. Rheumatoid factor
 - b. Morning stiffness
 - c. Ulnar drift of fingers
 - d. Rheumatoid nodules
25. Swan neck deformity refers to
 - a. Flexion at PIP and extension at DIP
 - b. Flexion at MCP and extension at interphalangeal joint
 - c. Extension at PIP and flexion at DIP
 - d. Extension at MCP and flexion at interphalangeal joint
26. Wind swept deformity is seen in
 - a. Scurvy
 - b. RA
 - c. Rickets
 - d. Ankylosing spondylitis
27. Most common cause of Reactive arthritis
 - a. *S. aureus*
 - b. *S. flexneri*
 - c. *N. gonorrhoeae*
 - d. *E. coli*
28. A 65-year-old man has h/o back pain since 3 months. His ESR is raised. He also has dorsolumbar tenderness on examination and mild restriction of chest movements. On X-ray, syndesmophytes are present in vertebrae. Diagnosis is
 - a. Degenerative osteoarthritis of spine
 - b. Ankylosing spondylitis
 - c. Ankylosing hyperostosis
 - d. Lumbar canal stenosis
29. Pencil in cup deformity is seen in
 - a. AVN
 - b. RA
 - c. Ankylosing spondylitis
 - d. Psoriatic arthritis
30. Most common muscle for pseudotumor like growth in hemophilic arthropathy
 - a. Quadriceps femoris
 - b. Gastrocnemius
 - c. Hamstring muscle
 - d. Iliopsoas
31. Most common cause for neuropathic joints
 - a. Leprosy
 - b. Diabetes
 - c. Tabes dorsalis
 - d. Nerve injury
32. Clutton joints are feature of
 - a. Congenital syphilis
 - b. Primary syphilis
 - c. Secondary syphilis
 - d. Tertiary syphilis
33. Sausage digits are seen in
 - a. Psoriatic arthritis
 - b. Osteoarthritis
 - c. Lyme arthritis
 - d. None
34. A 60-year-old man with diabetes mellitus presents with painless, swollen right ankle joint. Radiographs of the ankle show destroyed joint with large number of loose bodies. Most probable diagnosis is?
 - a. Osteoarthritis
 - b. Charcot's joint
 - c. Clutton's joint
 - d. RA
35. In a patient suffering from tabes dorsalis, charcot's joints most commonly occurs at
 - a. Knee
 - b. Elbow
 - c. Wrist
 - d. Tarsometatarsal
36. Which of the following joint is least affected by neuropathy
 - a. Hip
 - b. Shoulder
 - c. Wrist
 - d. Elbow
37. Tophi in gout do not involve
 - a. Muscle
 - b. Cartilage
 - c. Bursa
 - d. Skin
38. In a patient of gouty arthritis, best investigation is
 - a. Uric acid in urine
 - b. Serum uric acid
 - c. Detection of urate crystal in synovial fluid
 - d. Serum calcium level
39. Calcification of menisci is seen in
 - a. Renal osteodystrophy
 - b. Hyperparathyroidism
 - c. Pseudogout
 - d. Acromegaly
40. A lady presents with right knee swelling, aspiration was done in which calcium pyrophosphate crystals were obtained. Next best investigation would be
 - a. RF
 - b. CPK
 - c. ANA
 - d. TSH
41. X-ray of a young man shows heterotopic calcification around bilateral knee joints. Next investigation is
 - a. Serum phosphate
 - b. Serum PTH
 - c. Serum calcium
 - d. Serum alkaline phosphatase
42. Deforming polyarthritis is associated with all of the following except
 - a. Psoriatic arthritis
 - b. RA
 - c. Behcet's syndrome
 - d. Ankylosing spondylitis
43. Erosion of the bone is seen in all except
 - a. Gout
 - b. Psoriasis
 - c. SLE
 - d. RA
44. A 85-year-old woman presented with bilateral osteoarthritis of knees with no h/o any previous GI disease. The first line treatment drug for her should be
 - a. Paracetamol
 - b. Naproxen
 - c. Celecoxib
 - d. Dihydro codeine
45. A 68-year-old man came with pain and swelling of right knee. Ahlback grade 2 osteoarthritic changes were noted on X-ray. What should be the further management?
 - a. Conservative
 - b. Arthroscopic washout
 - c. High tibial osteotomy
 - d. Total knee replacement
46. A patient of nephrotic syndrome taking steroids for 6 years presented with a limp. He had limitation of abduction and internal rotation. He most probably had
 - a. Renal osteodystrophy
 - b. Avascular necrosis of hip
 - c. Septic arthritis
 - d. Osteomyelitis of hip joint
47. Which of the following is not a variety of Osteochondritis
 - a. Pellegrini Stieda
 - b. Panner's
 - c. Calve's
 - d. Kohler's
48. Iseline's disease is osteochondritis of
 - a. 2nd Metacarpal
 - b. 5th Metacarpal
 - c. 2nd Metatarsal
 - d. 5th Metatarsal
49. Least common site to be involved in Osteoarthritis amongst the following is
 - a. Hip joint
 - b. Knee joint
 - c. Carpometacarpal joint of thumb
 - d. Metacarpophalangeal joint
50. The most common site of primary osteoarthritis is
 - a. Hip joint
 - b. Knee joint
 - c. Ankle joint
 - d. Shoulder joint
51. Earliest radiological sign of the Osteoarthritis is
 - a. Narrowing of joint space
 - b. Osteophyte formation
 - c. Cystic lesion in cancellous bone
 - d. Sclerosis in subchondral bone
52. The most common arthritis that affects the wrist is
 - a. Osteoarthritis
 - b. Tuberculous arthritis
 - c. Rheumatoid arthritis
 - d. Gout

53. Boutonniere's deformity occurs due to
 - a. Flexion at proximal interphalangeal joint
 - b. Flexion at distal interphalangeal joint
 - c. Extension at distal interphalangeal joint
 - d. Extension at metacarpophalangeal joint
54. The type of anemia seen in Rheumatoid arthritis is
 - a. Microcytic hypochromic anemia
 - b. Macrocytic hypochromic anemia
 - c. Normocytic hypochromic anemia
 - d. Normocytic normochromic anemia
55. Which of the following is an indication for systemic steroids in Rheumatoid arthritis
 - a. Mononeuritis multiplex
 - b. Carpal tunnel syndrome
 - c. Presence of deformities
 - d. Articular cartilage involvement
56. Disease where distal interphalangeal joint is characteristically involved
 - a. Psoriatic arthritis
 - b. Rheumatoid
 - c. SLE
 - d. Gout
57. Which of the following joint is least involved in Ankylosing spondylitis
 - a. Knee & Ankle
 - b. Sacroiliac joint
 - c. Wrist & elbow
 - d. Spine
58. The earliest diagnosis of Ankylosing spondylitis can be made on
 - a. MRI STIR sequence
 - b. Bone scan
 - c. CT scan
 - d. X-ray
59. All are features of haemophilic knee joint, EXCEPT:
 - a. Juxta-articular osteosclerosis
 - b. Sub chondral cyst formation
 - c. Widening of intercondylar notch
 - d. Squaring of patella
60. Arthroscopy is contraindicated in
 - a. Chronic joint disease
 - b. Loose bodies
 - c. Hemophila
 - d. Meniscal tear
61. Painless effusions in joints in congenital syphilis are called as
 - a. Clutton's joint
 - b. Higoumenakisign
 - c. Barton's joint
 - d. Chronic osteomyelitis
62. Most common joint involved in Gout
 - a. Knee
 - b. Hip
 - c. MTP joint of the big toe
 - d. MP joint of thumb
63. The most commonly involved joint in pseudo gout
 - a. Knee
 - b. Great toe
 - c. Hip
 - d. Elbow
64. Heterotopic calcification is seen in (PGI type)
 - a. Ankylosing spondylitis
 - b. Gouty arthritis
 - c. Forestier's disease
 - d. Traumatic paraplegia
65. Snowstorm appearance of knee joint on arthroscopy is seen in
 - a. Ewing's sarcoma of knee joint
 - b. Synovial chondromatosis
 - c. Fracture involving articular surface
 - d. Chondromalacia patellae
66. Osgood Schlatters disease involves
 - a. Medial malleolus
 - b. Lateral malleolus
 - c. Femoral condyle
 - d. Tibial tuberosity
67. Arthritis mutilans is seen in
 - a. SLE
 - b. Psoriatic Arthropathy
 - c. Osteoarthritis
 - d. Gout
68. Which arthritis causes no periosteal reaction?
 - a. Psoriatic arthritis
 - b. Reactive arthritis
 - c. Neuropathic arthritis
 - d. Rheumatoid arthritis
69. Investigation of choice for avascular necrosis of bone is
 - a. BONE scan
 - b. CT scan
 - c. MRI
 - d. USG
70. Avascular necrosis affects which part of femoral head?
 - a. Anteromedial
 - b. Anterolateral
 - c. Posteromedial
 - d. Posterolateral
71. Micro-fracture technique is carried out for
 - a. Avascular necrosis
 - b. Osteopetrosis
 - c. Osteochondral defects
 - d. Non-union
72. A 30-year-old HIV positive male who is on antiretroviral therapy (protease inhibitor) has pain in the right hip joint since 2 months. He has difficulty in abduction and internal rotation. Most likely diagnosis is
 - a. Septic arthritis
 - b. Tubercular arthritis
 - c. AVN
 - d. Osteoarthritis
73. Rheumatoid factor is
 - a. Ig G against IgM
 - b. Ig M against IgG
 - c. Ig A against IgE
 - d. Anti-Ig E auto-antibody
74. HLAs that are specific for RA (PGI type)
 - a. HLA DR-1
 - b. HLA-DR-2
 - c. HLA-DR-3
 - d. HLA-DR-4
75. All true about RA except (PGI type)
 - a. Associated with HLA DR4
 - b. Limited to articular cartilage
 - c. More common in females
 - d. Extra-articular manifestations are there in 20% patients
 - e. Hand, elbow & knee joints are commonly involved
76. A 45-year-old coal mine worker presents with cutaneous nodules, joint pains & occasional cough with dyspnoea. His chest radiographs show multiple, small nodules in bilateral lung fields. Some of the nodules show cavitation and specks of calcification. Most likely diagnosis is
 - a. Caplan's syndrome
 - b. Sjögren's syndrome
 - c. Silicosis
 - d. Wegener's granulomatosis
77. True regarding Felty's syndrome are all except
 - a. Splenomegaly
 - b. Neutropenia
 - c. RA
 - d. Nephropathy
78. All of the following are DMARDS except
 - a. Chloroquine
 - b. Penicillamine
 - c. Gold
 - d. BAL
79. Most common cause of Mononeuritis multiplex in india is
 - a. Hansen's ds
 - b. Tuberculosis
 - c. RA
 - d. PAN
80. All of the following are observed in gout except
 - a. Uric acid nephrolithiasis
 - b. Deficiency of xanthine oxidase
 - c. Increase in serum urate concentration
 - d. Renal tissue involving interstitial tissue
81. NSAID of choice in seronegative spondyloarthritis is
 - a. Phenylbutazone
 - b. Indomethacin
 - c. Aspirin
 - d. Corticosteroid
82. A young man back from leisure trip has swollen knee joints & foreign body sensations in eyes. Likely cause is
 - a. Behcet's disease
 - b. Reiter's disease
 - c. Sarcoidosis
 - d. SLE
83. Most common pattern of cardiac involvement in RA is
 - a. Pancarditis
 - b. Myocarditis
 - c. Pericarditis
 - d. Endocarditis
84. Etanercept used in RA acts by blocking
 - a. TNF alpha
 - b. TGF beta
 - c. IL-2
 - d. IL -6
85. Which of the following is least likely to occur in late extra-articular seropositive rheumatoid arthritis?
 - a. Neutropenia
 - b. Leg ulcers
 - c. Dry eyes
 - d. Hepatitis
86. Which of the following is not a presentation of calcium pyrophosphate deposition disease (CPPD)?
 - a. Pseudogout
 - b. Pseudoankylosing spondylitis
 - c. Apical Plate Excresences (APE)
 - d. Chondrocalcinosis

SOFT TISSUE DISORDERS

1. A positive Yergason's test indicates
 - a. Bicipital tendinitis

- b. Acromioclavicular subluxation
 - c. Dislocation of the shoulder
 - d. Radial head fracture.
2. What would be the appropriate most treatment for an irreparable tear of rotator cup in a 30-year-old patient?
 - a. Tendon Transfers
 - b. Total Shoulder replacement
 - c. Acromioplasty
 - d. Reverse shoulder arthroplasty
3. Jersey finger refers to rupture of
 - a. Flexor digitorum profundus.
 - b. Extensor digiti minimi.
 - c. Flexor digitorum superficialis
 - d. Extensor indicis
4. Forgotten muscle of rotator cuff is
 - a. Supraspinatus
 - b. Infraspinatus
 - c. Subscapularis
 - d. Teres minor
5. Most commonly damaged muscle in rotator cuff is?
 - a. Supraspinatus
 - b. Infraspinatus
 - c. Subscapularis
 - d. Teres minor
6. Lift off test is done for?
 - a. Supraspinatus
 - b. Infraspinatus
 - c. Subscapularis
 - d. Teres minor
7. Rotator interval is bounded by
 - a. Teres major and minor
 - b. Supraspinatus & subscapularis
 - c. Subscapularis & infraspinatus
 - d. Supraspinatus & teres minor
8. Infrapatellar bursitis is also called as
 - a. Housemaid's knee
 - b. Clergyman's knee
 - c. Tailor's knee
 - d. Tuberculous knee
9. Clergyman's knee is inflammation of
 - a. Superficial later of infra patellar bursa
 - b. Deep layer of infra patellar bursa
 - c. Superficial layer of pre patellar bursa
 - d. Deep layer of pre patellar bursa
10. A 60-year-old diabetic has restricted motion at right shoulder in all directions in both active and passive range. An X-ray was done but did not reveal anything. What is the best management at this stage?
 - a. Physiotherapy
 - b. MRI for evaluation
 - c. Arthroscopy for evaluation
 - d. Mantoux test
11. Movie sign/Cinema sign is seen in
 - a. Chondromalacia patella
 - b. Osteochondritis dissecans
 - c. Arthrogryposis multiplex congenita
 - d. Infantile tibia vara
12. Simmonds test helps in diagnosis in rupture of which tendon?
 - a. Extensor pollicis longus
 - b. Gastro soleus
 - c. Biceps
 - d. Ilio-psoas
13. Commonest cause for neuralgic pain in foot is
 - a. Injury to deltoid ligament
 - b. Compression of communication between medial and lateral plantar nerves
 - c. Exaggeration of longitudinal arches
 - d. Shortening of plantar aponeurosis
14. Bunion is commonly seen at
 - a. Great toe MTP joint
 - b. Medial malleolus
 - c. Lateral malleolus
 - d. Shin of tibia
15. A 40-year-old man was repairing his wooden shed in the morning. By afternoon, he felt that the hammer was becoming heavier and heavier. He felt pain on the lateral side of the elbow and also found that squeezing water out of sponge hurt his elbow. Which muscles are most likely involved?
 - a. Flexor digitorum superficialis
 - b. Extensor carpi radialis brevis
 - c. Biceps brachii & supinator
 - d. Triceps brachii & Anconeus
16. Which of the following is a risk factor for developing Dupuytren's Contracture?
 - a. Eptoin
 - b. Diabetes
 - c. Alcohol
 - d. All of the above
17. A 50 years old diabetic patient, presented with 15° flexion deformity of the little finger. Most appropriate management at this stage is?
 - a. Wait and watch
 - b. Subtotal fasciectomy
 - c. Total fasciectomy
 - d. Percutaneous fasciotomy
18. Trigger finger occurs in?
 - a. RA
 - b. Trauma
 - c. Osteosarcoma
 - d. Osteoarthritis
19. In trigger finger, constriction in the tendon sheath is most commonly present at the level of
 - a. Middle phalanx
 - b. PIP joint
 - c. Proximal phalanx
 - d. MCP joint
20. Constriction in trigger finger is present around which pulley?
 - a. A1
 - b. A2
 - c. A3
 - d. A4
21. Game keepers thumb refers to
 - a. Thumb metacarpophalangeal joint ulnar collateral ligament rupture
 - b. Thumb metacarpophalangeal joint radial collateral ligament rupture
 - c. Thumb interphalangeal joint ulnar collateral ligament rupture
 - d. Thumb interphalangeal joint radial collateral ligament rupture
22. The primary pathology in athletic pubalgia is?
 - a. Hamstring strain
 - b. Abdominal muscle strain
 - c. Gluteus medius strain
 - d. Rectus femoris strain
23. Most common cause of insertional tendonitis of tendoachilles is?
 - a. Overuse
 - b. Runners & jumpers
 - c. Steroid injections
 - d. Improper shoe wear
24. A teen-aged girl complains of anterior knee pain on climbing stairs and on getting up after prolonged sitting. Which of the following is the most likely diagnosis?
 - a. Chondromalacia Patellae
 - b. Plica syndrome
 - c. Bipartite Patella
 - d. Patello femoral osteoarthritis
25. Muscle most commonly affected by congenital absence is
 - a. Pectoralis major
 - b. Semimembranosus
 - c. Teres minor
 - d. Gluteus maximus
26. Finkelstein test is used for the diagnosis of?
 - a. Thoracic outlet syndrome
 - b. De Quervain disease
 - c. Dupuytren's contracture
 - d. Carpal Tunnel Syndrome

AMPUTATIONS, PROSTHETICS AND ORTHOTICS

1. Which of the following is the ideal length of bone for a below knee stump
 - a. 12.5 cm to 17.5 cm
 - b. Less than 5 cm long
 - c. 7.5 cm to 10 cm long
 - d. 20 cm long
2. Procedure contraindicated in diabetics?
 - a. Ray amputation
 - b. Forefoot amputation
 - c. Syme's amputation
 - d. Below knee amputation
3. Best treatment modality for post amputation neuroma is?
 - a. Compression bandage
 - b. Ultrasound
 - c. Infrared
 - d. Interferential therapy
4. Pain due to post-amputation neuroma is best treated by:
 - a. Infrared therapy
 - b. Interference therapy
 - c. Ultrasound therapy
 - d. Surgical Excision
5. Pain due to post-amputation neuroma can be managed by all except
 - a. Infrared therapy
 - b. Interference therapy
 - c. Ultrasound therapy
 - d. Stump bandaging

6. An amputation through fore arm where you make a fork of the two fore arm bones is k/a
 - a. Chopart's amputation
 - b. Krukenberg amputation
 - c. Pirogoff amputation
 - d. Syme's amputation
7. Energy consumption in an above knee amputation is approximately
 - a. 20 %
 - b. 40%
 - c. 55%
 - d. 65%
8. Regarding SACH foot, all are true except?
 - a. Solid ankle cushion heel
 - b. Prosthesis
 - c. Squatting is easy
 - d. Does not look like a normal foot
9. In flap method of amputation which structure is kept shorter than the level of amputation
 - a. Bone
 - b. Muscles
 - c. Nerves
 - d. Skin
 - e. Vessels
10. Myodesis is employed in amputations for all of the following indications except
 - a. Trauma
 - b. Tumor
 - c. Children
 - d. Ischemia
2. Watson Jones approach is used for?
 - a. Neglected Club foot
 - b. Muscle paralysis
 - c. Valgus deformity
 - d. Hip replacement
3. All of the following are used for giving traction except?
 - a. Bohier's stirrup
 - b. Steinmann's
 - c. K wire
 - d. Rush pin
4. Action of intramedullary 'k' nail is?
 - a. Compression
 - b. 2 point fixation
 - c. 3 point fixation
 - d. Weight concentration
5. Which of the following approaches is best suited for performing Triple Arthrodesis at the ankle?
 - a. Ollier's approach
 - b. Gatellier and chastang's approach
 - c. Posterior approach to the ankle
 - d. Colonna's approach
6. In Anterolateral approach for Hip surgery after retracting tensor fascia lata which structure comes before reaching to Hip?
 - a. G. Maximus
 - b. G. Minimus
 - c. G. Medius
 - d. Gemellus
7. All indicate that the intramedullary Kuntscher nail is properly seated except
 - a. Slot facing posteromedially
 - b. The distal end at about the level of the superior end of patella
 - c. Eye faces posteromedially
 - d. The proximal end about 2.5 cm proximal to the trochanter
8. Kocher Langenbeck approach is useful in acetabular fracture in all mentioned situations except
 - a. Open fractures of acetabulum
 - b. Sciatic nerve injury
 - c. Recurrent dislocation despite of closed reduction
 - d. Morel Lavelli lesion

RECENT ADVANCES

1. Which of the following is an absolute contraindication for total joint replacement?
 - a. Very young patients
 - b. Recent or current joint sepsis
 - c. Osteoporotic bone
 - d. Limb length inequality
2. After knee replacement surgery, proprioceptors of joints are altered. Effect is
 - a. Loss of sensation at joint in dynamic stage
 - b. Complete loss of sensation at joint in resting stage
 - c. Normal movement
 - d. All sensations lost
3. Most common cause of death after total hip replacement is
 - a. Infection
 - b. Pulmonary embolism
 - c. Deep vein thrombosis
 - d. Pneumonia
4. Aseptic loosening in cemented total hip replacement, occurs as a result of hypersensitivity response to
 - a. High density polythene debris
 - b. Titanium debris
 - c. N,N- Dimethyltryptamine
 - d. Free radicals
5. Metal on Metal articulation should be avoided in
 - a. Osteonecrosis
 - b. Young female
 - c. Inflammatory arthritis
 - d. Revision surgery
6. Tourniquet paralysis is an unfortunate complication that often leads to
 - a. Neuropraxia
 - b. Axonotmesis
 - c. Neurotmesis
 - d. None of the above
7. Bone cement setting time is
 - a. 30 sec
 - b. 1-2 min
 - c. 8-10 min
 - d. >30 min
8. Anterolateral arthroscopy of knee is done
 - a. to see Posterior cruciate ligament
 - b. to see anterior portion of lateral meniscus
 - c. to look for patella-femoral articulation
 - d. to see the periphery of posterior horn of medial meniscus

ORTHOPEDIC SURGERIES

1. Watson jones procedure is done for?
 - a. Polio
 - b. Neglected clubfoot
 - c. Chronic ankle instability
 - d. Muscle paralysis
2. What surgery would you offer to treat the shown deformity?
 - a. Milch osteotomy
 - b. Pauwel osteotomy
 - c. French osteotomy
 - d. McMurray osteotomy

PICTURE QUIZ

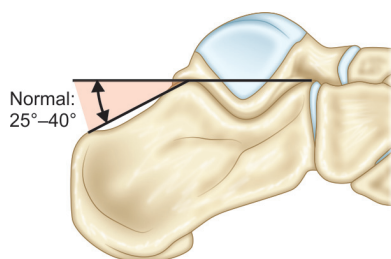
1. Nerve most commonly injured in the dislocation shown below is



2. What surgery would you offer to treat the shown deformity?



3. Name the angle drawn in the figure

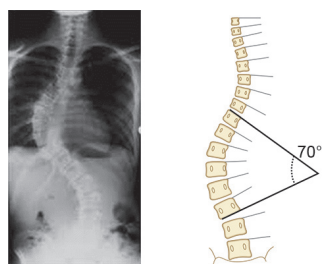


- a. Gissane's angle
b. Neutral angle
c. Bohler's angle
d. Kite's angle

4. This X-ray picture of osteosarcoma is the result of



- a. Periosteal reaction
b. Calcification along blood vessels
c. Callus due to pathological fracture
d. None of these
5. The X-ray below shows a patient with scoliosis. What is the angle to measure the severity of curve called as?



- a. Resisser's angle
b. Boston's angle
c. Cobb's angle
d. Milwaukee's angle

6. Identify this X-ray sign of TB hip



- a. Wandering acetabulum
b. Pestle and mortar appearance
c. Babcock's sign
d. Ward's sign

7. Shown in the figure below is a bone cyst. The arrow in the figure is indicating



- a. Fallen fragment
b. Ground glass appearance
c. Shepherd crook fragment
d. Thurston Holland fragment
8. Figure below shows the treatment of a 3-month-child who had congenital diaphragmatic hernia (CDH). What is the apparatus in use called as?



- a. Von Rosen splint
b. Pavlik harness
c. Petrie's orthosis
d. Boston brace
9. What is this mode of treatment called as?



- a. Russell's traction
b. 90-90 traction
c. Buck's traction
d. Gallows traction
10. What is the probable diagnosis?



- a. Ankylosing spondylitis
b. Diffuse idiopathic skeletal hyperostosis (DISH)
c. OA spine
d. Osteopetrosis

11. The child in this figure probably has



- a. Juvenile chronic arthritis
 - b. Pseudoarthrosis of tibia
 - c. Hyperparathyroidism
 - d. Rickets
12. Identify the disease from the X-ray



- a. Keinböck's disease
 - b. Freiberg's disease
 - c. Scheuermann's disease
 - d. Severe disease
13. What is this child being treated for?



- a. Elbow flexion deformity
 - b. Supracondylar humerus fracture
 - c. Shaft humerus fracture
 - d. Unreducible elbow dislocation
14. The line marked in the figure is



- a. Shenton's line
- b. Shoemaker's line
- c. Nelaton's line
- d. Chinese line

15. A CT cross-section of a patient is shown in the figure below. Which of the following is not a routine treatment option for this lesion?



- a. Vertebroplasty
 - b. Excision
 - c. Embolization
 - d. Radiotherapy
16. Identify the tumor in the X-ray



- a. Osteosarcoma
 - b. GCT
 - c. ABC
 - d. Ewing's sarcoma
17. The shape of the femur as shown below may be seen in all of the following conditions except



- a. Achondroplasia
 - b. Osteopetrosis
 - c. Pyle's disease
 - d. Langerhan cell histiocytosis
18. What would be the diagnosis if the clinical test depicted in the figure is positive?



- a. Trigger thumb
- b. Intersection syndrome
- c. De Quervain's disease
- d. Tennis elbow

19. Which muscle is being tested by the examiner in the figure?



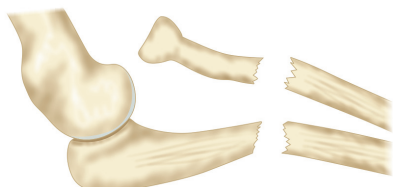
- a. Supraspinatus
- b. Infraspinatus
- c. Teres Minor
- d. Subscapularis

20. This deformity of the proximal femur could be a result of all of the following conditions except



- a. Fibrous dysplasia
- b. Multiple Myeloma
- c. Paget's disease
- d. Osteogenesis imperfecta

21. Based on Bado classification, the Monteggia fracture shown below will be classified into



- a. Type III
- b. Type I
- c. Type IV
- d. Type II

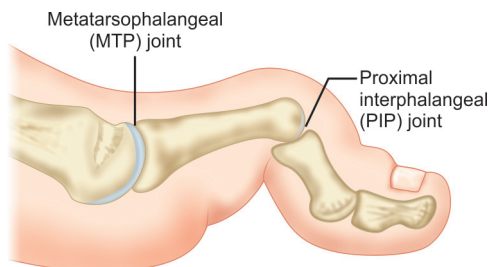
22. Shown below is X-ray of a 45 years old male who sustained injury 4 weeks back. What would be the best treatment option for this patient?



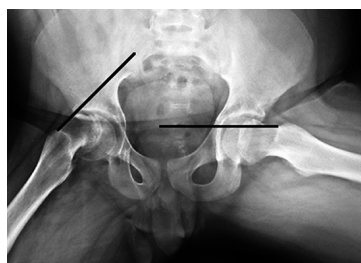
- a. McMurray's osteotomy
 - b. Hemiarthroplasty
 - c. THR
 - d. Fixation with Cannulated cancellous screws
23. If a hand X-ray of a patient has an appearance as shown below, all of the following can be differentials except



- a. Marble bone disease
 - b. Sickle cell disease
 - c. Masada syndrome
 - d. Paget's disease
24. The deformity of the toe shown below is



- a. Claw toe
 - b. Hammer toe
 - c. Mallet toe
 - d. Hallux valgus
25. Shown below is an X-ray of a patient with SCFE. The radiological sign shown is called as



- a. Metaphyseal blanch sign
- b. Sagging rope sign
- c. Gage sign
- d. Trethowan sign

ANSWERS KEY

GENERAL ORTHOPEDICS

- 1. b (P-9, Col-I)
- 2. d (P-7, Col-I)
- 3. c (P-18, Col-II)
- 4. a (P-17, Col-2)
- 5. b (P-13)

- 6. a (P-13); Healing is generally normal in osteoporotic patients. The problem is with fixation of an osteoporotic bone that leads to increased non-union rates
- 7. b (P-17, Box 1.6)
- 8. b (P-17)
- 9. b

10. a (P-16, Col-1); The best site for taking a cancellous graft is posterior superior iliac spine
 11. c > D (P-11)
 12. a (P-11, High-yield points); Most consistent sign of a fracture is tenderness (pain is a symptom) while the most pathognomonic sign of a fracture is abnormal mobility > crepitus
 13. c (P-20) 14. a 15. b
 16. b, d (P-20, Col-2, High-yield Points)
 17. b; (P-18, Col-2) Angulation remodels better than rotation and metaphysis being cancellous active vascular bone remodels best
 18. b (P-20, Box 1.7) 19. b (P-19)
 20. d (P-18, Col-2) 21. d (P-22)
 22. None; Thomas splint can be used in all these conditions for a temporary stabilization
 23. d 24. c (P-28, Col-1)
 25. a, b, c, d, e All procedures are used in different situations in management of intra-articular fractures;
 26. c 27. a 28. b (P-9, Col-2) 29. c (P-37, Table 1.14)
 30. b (P-36) 31. b 32. b (P-34) 33. b
 34. d 35. d (P-40, High-yield Points)
 36. d > c (P-40, High-yield Points) 37. c (P-40, High-yield Points)
 38. a (P-18, Col-1, High-yield Points) 39. c
35. b (P-77, Col-2) 36. c
 37. c (P-69, Col-2) 38. c (P-77, Col-2) 39. d
 40. c; Lateral condylar physis will be disrupted if the fragment is excised, hence excision is never an advised treatment in such patients
 41. d 42. b (P-70, Col-2)
 43. d (P-70, Col-2; P-72)
 44. d; Most of the recent studies are reporting that Radial length is the most important factor to be restored post surgery and is the major determinant to functional recovery
 45. d (P-72, Col-2); Term 'Causalgia' simply means burning pain. It is a symptom of Sudeck's osteodystrophy
 46. b 47. d 48. b 49. a (P-79, Col-2)
 50. c 51. c (P-81, Col-2)
 52. d (P-81, Col-2) 53. b (P-82)
 54. b (P-80, Col-1, High-yield points) 55. c (P-84)

HIP EXAMINATION

1. c (P-95, Col-2) 2. b (P-99) 3. a (P-96)
 4. c (P-100, Col-1) 5. b (P-98, Col-1)

POLYTRAUMA

1. b (P-43, Col-2) 2. a (P-151, Table 2.34) 3. b (P-86, Col-2)
 4. b (P-41); Stabilize cervical spine > maintain airway
 5. d (P-42, Col-2) 6. c > d (P-41, Col-2)
 7. b (P-41, Col-2) 8. d (P-43, Col-2) 9. c (P-151, Table 2.34)
 10. b; Airway maintenance > Pelvic fracture stabilization (immediately be a pelvic binder and earliest by external fixator)
 11. C; 5th, 6th and 7th ribs are mostly fractured during CPR
 12. a (P-86, Col-2) 13. b (P-85)

UPPER LIMB TRAUMATOLOGY

1. a 2. d 3. c (P-56, Col-1)
 4. c Velpeau bandage can be used in proximal humerus fractures, immobilizing after reducing dislocated shoulder and in acromioclavicular dislocation. The last is the most specific use.
 5. d (P-56, Col-2) 6. c (P-57) 7. a (P-46)
 8. b 9. b (P-47, Col-1) 10. d (P-48, Col-2)
 11. d (P-50) 12. b (P-53)
 13. c In all varieties of shoulder dislocation, circumflex branch of axillary nerve is injured most commonly
 14. d (P-50, Col-2) 15. b (P-54, Table 2.3) 16. b (P-67)
 17. a Median nerve is commonly injured in simple elbow dislocation while Ulnar nerve is more commonly involved in complex elbow dislocation (elbow dislocation with an associated fracture);
 18. a (P-68, Col-1)
 19. a (P-67); Physeal injuries are common during growth spurts as during this time the physis is relatively weaker; however elbow is an exception to the rule where physeal injuries are more common during first decade. The peak incidence of elbow dislocation is seen in adolescents and it is the commonest dislocation in children and adolescents
 20. d (P-58, Col-2) 21. d (P-58, Col-1)
 22. a (P-64, Col-2, High-yield Points) 23. b (P-60, 61)
 24. b AIN > median > ulnar;
 25. d (P-62) 26. c 27. a (P-64, Col-1, High-yield Points)
 28. c 29. c (P-60, Col-1) 30. d (P-60, Col-2)
 31. c (P-65, Col-2); The patient has developed Tardy ulnar nerve palsy
 32. a 33. c (P-61, Col-2)
 34. b (P-58, Col-1); The question does not seem to be very authentic. However, authors feel that three point relationship involves olecranon process of ulna apart from the two distal epicondyles of humerus, it can be disturbed in fractures where ulna (olecranon) is involved. A weak posterior capsule may lead to posterior dislocation of elbow and thereby disturb the relationship

PELVIS AND LOWER LIMB TRAUMA

1. d (P-92, Fig. 2.96) 2. a (P-92, Col-2) 3. d
 4. b (P-94, 95) 5. d (P-94, 95) 6. c (P-91, Col-1)
 7. d (P-91, Col-1) 8. b (P-105, Table 2.17) 9. c
 10. b; Patient is likely to have fracture neck of femur. Occult fractures are best diagnosed by MRI.
 11. d; If age mentioned is 60-70 years prefer to mark intracapsular neck femur and if patient is more than 80 years old individual, then go with intertrochanteric fracture as the diagnosis in case there is limited information provided in the question, as in this one. If partial external rotation of lower limb and limited shortening is mentioned, then it is intracapsular fracture neck femur and if there is complete external rotation such that lateral border of the foot touches the couch then intertrochanteric fracture is the better possibility
 12. b 13. b (P-101, Table 2.13) 14. c
 15. d; Since the a mass (head) is felt in the gluteal region, it seem like a posterior dislocation of hip. When there is an associated acetabular fracture in a posteriorly dislocated hip external rotation deformity is also possible
 16. a; Pipkin Type IV femoral head fracture is associated with a dislocated hip with acetabular wall fracture (same situation as above)
 17. b (P-110, Col-2) 18. d (P-103, Table 2.14)
 19. a (P-104, 105) 20. b 21. c (P-104, 105)
 22. c (P-104, 105); SP nail—An outdated implant that was used to fix neck femur fractures in the past
 23. b (P-104, 105) 24. b (P-104, 105) 25. a, c, d
 26. d (P-108, Col-2); If on X-ray the physis is open, then Austin Moore's pins are the preferable choice. However, the option is not there in the question (rather the option is Austing Moore's prosthesis which is for hemiarthroplasty), so most appropriate choice would be (d)
 27. a (P-108, Col-2, High-yield Points) 28. b, c, d
 29. d; AVN changes start in the sub-chondral area of femoral head; however the complication is most commonly seen with sub capital variety of intracapsular femoral neck fracture
 30. a 31. b 32. a (P-111, Table 2.19) 33. c (P-115, Col-1)
 34. c (P-113, Col-2) 35. c (P-100, Col-2) 36. a
 37. b (P-115, Col-2, High-yield points)
 38. a (P-128, Col-2, High-yield Points)
 39. c (P-132); Cylindrical cast may be given for undisplaced patellar fracture
 40. d (P-132, Col-1) 41. c (P-137, Col-1)
 42. b (P-130, Col-2) 43. b (P-142, Table 2.33)

LIGAMENT INJURIES OF KNEE

1. b (P-116, Col-2)
2. a (P-121, Col-2 and Fig. 2.169) 3. b (P-119)
4. b (P-117, Col-1); The postero lateral bundle of ACL is tight in extension. Laxity in extension indicates the bundle is torn.
5. b (P-126, Table 2.28)
6. a; ACL is attached to intercondylar area and a fracture in the area clearly means that the ligament is avulsed
7. b (P-127, Col-1, High-yield Points) 8. d (P-121, Col-1)
9. a (P-126, Table 2.28) 10. c (P-121, Col-1)
11. c (P-127, C-1, High-yield Points) 12. b (P-117)
13. a (P-109, Col-2; P-120, Col-2) 14. c 15. b.
16. c; Meniscus is injured by rotation/twisting force. Knee is locked in extension. Rotation is possible only on flexion;
17. c (P-125, Col-1) 18. d 19. b (P-125, Table 2.27)

SPINE

1. a (P-167, Col-1, High-yield Points)
2. d; Spinal cord injury is upper motor neuron lesion so there would be hyper-reflexia below the level of lesion
3. b (P-157, Table 3.3) 4. a (P-159, Col-2)
5. b (P-160, Col-1); The complication here seems to be Neurogenic shock seen in injuries above T6 level. So site of injury is above T6. Now head injuries are most commonly associated with lower cervical spine injuries, so lower cervical spine seem to be best choice
6. c (P-161, Col-2)
7. c; Commonest level of spinal fracture is T12 vertebra
8. a (P-176, Col-2; Pa-177, High-yield Points)
9. b; Holdsworth classification was the earlier version of Denis three column concept
10. d (P-175, Col-1, High-yield Points) 11. d (P-167, Col-2)
12. a (P-173, Col-1); More appropriate answer would be Flexion distraction (Chance fracture)
13. d (P-158, Col-2) 14. a (P-415, Col-2)
15. d; Priapism is seen after spinal cord injury 16. c (P-183, Col-2)
17. d; Disk prolapse L4-L5 will compress L5 nerve root and myotome of L5 is EHL
18. a (Pa-191) 19. d (P-187, Col-2)
20. b (P-158) 21. b (P-175) 22. c (P-173, Col-1) 23. c
24. b; Even in cervical spine in disk prolapse always the lower level nerve root is involved
25. c (P-182, Col-1) 26. a (P-327, Col-2)
27. b (P-315) 28. d (P-175) 29. c
30. d; Most dangerous is Translation > Flexion rotation > Flexion distraction
31. a (P-167, Col-1) 32. b (P-171, Col-1) 33. a (P-167, Col-2)
34. b (P-160, Col-2, High-yield Points)

PERIPHERAL NERVE INJURIES

1. c (P-197, Col-2; P-198) 2. d (P-218, Col-2, High-yield Points)
3. a (P-199, Col-2, High-yield Points) 4. b
5. c; Femoral nerve seems to best explain the picture. The nerve supplies the quadriceps. Although rare but if there is isolated sudden transaction of this nerve, the quadriceps will be paralyzed. This will lead to buckling of the knee as it cannot be extended and kept straight. The patient will fall onto the side of the injury and get injuries on single side of the body which has impacted the ground
6. c (P-213, Col-2)
7. b (P-220); The presentation is matching with lower plexus injury. The presence of supracondylar humerus fracture here is likely co-incidental

8. d (P-211, Col-2); Biceps & brachialis paralysis may cause some degree of elbow flexion weakness.
9. a (P-202, Col-1)
10. b (P-206, Col-2); Clasp sign, Pointing index and Pope sign are all synonymous terms
11. d (P-209, Col-2) 12. b (P-218, Col-2, High-yield Points)
13. a (P-196, Col-2) 14. b 15. d (P-215, Col-2)
16. c (P-220, Col-1) 17. d (P-220)
18. c (P-220, Table 4.3) 19. a
20. c (P-204, Fig. 4.15); Flexor pollicis longus is supplied by AIN, branch of median nerve given in proximal forearm and will cause flexion of thumb. Adductor pollicis will cause adduction as it is supplied by the ulnar nerve. Abductor pollicis brevis (producing abduction of the thumb) and opponens pollicis (producing opposition of the thumb) are paralysed in low median nerve palsy (carpal tunnel syndrome). Abduction of the thumb is also carried out by abductor pollicis longus supplied by radial nerve so it will be maintained.
21. a (P-203, Col-2) 22. c (P-202, Col-2) 23. c
24. d (P-223) 25. a (P-222) 26. c
27. c (P-206, Col-2) 28. b (P-203, Col-1)
29. d; Ulnar nerve supplies fine movements of the hand hence the result of injury is worse. A low lesion causes more of clawing (Ulnar paradox) and hence outcome of a low lesion is worst
30. c (P-202, Fig. 4.9)
31. d; Sensations will be carried by the superficial branch while the hypothenar muscles will be supplied by the deep branch. So, lesion is proximal to the division as both are lost
32. c (P-234, Col-2) 33. b (P-208, Fig. 4.23) 34. a (P-216)
35. a (P-216, Col-2) 36. d (P-218, Col-1)
37. d (P-218, Col-1) 38. d (P-217, Col-1)
39. a; Guillain Barre is a demyelinating disease and a transient condition. Rest all other conditions involve permanent damage to nerves
40. a (P-216, Col-1, High-yield Points)
41. c; Carpal tunnel syndrome (Median nerve) is a common problem in patients involved in repetitive strain activities like typing etc. (Read "Cumulative trauma disorders" from P-377 High-Yield Points).

INFECTIONS

1. a (P-249, Col-1); It is tuberculosis of phalanges (Tubercular dactylitis)
2. c (P-249, Col-1)
3. c; Facet joint > Spinous process are least involved structures in Posterior TB
4. a (P-245, Col-2, High-yield Points) 5. c
6. a (P-225, Col-1) 7. a (P-245, Col-2, High-yield Points)
8. d (P-246, Col-2) 9. b (P-248, Col-1)
10. a (P-237, Col-2) 11. b (P-237, Col-2; P-238, Col-1)
12. b (P-226) 13. a
14. b (P-228, Col-2, High-yield Point) 15. b 16. a
17. d; Order of investigation in inflammatory joint swelling: X-Ray → USG guided aspiration of joint fluid → MRI
18. d (P-231, Col-1)
19. a; The deformity Flexion, Abduction and External rotation points more towards TB hip. In AVN more commonly the problem would have been restricted abduction and internal rotation in early stages
20. b (P-231, 232) 21. a (P-235, Col-2)
22. c (P-229, High-yield Points)
23. c; Prefer Transient synovitis over Perthes disease if it is there in the options
24. c 25. d (P-241, Col-1) 26. b (P-249, Col-1)
27. a, b, c (P-245, Table 5.2) 28. a (P-246) 29. d (P-242)

30. a, c, d; In TB arthritis ends in fibrous ankylosis while spondylitis ends in bony ankylosis. Although bony ankylosis is rare in osteoarthritis, it can occur in the joints of the fingers

TUMORS

1. b (P-251, Table 6.2, 6.3) 2. d (P-257, Col-1)
3. b (P-263, Col-2)
4. c 5. b (P-271, Col-2, High-yield Points) 6. a (P-257, Col-1)
7. c; Both eosinophilic granuloma and osteoid osteoma can have the described picture. But since there is no mention of endosteal scalloping and considering the relative incidence, better to opt for choice (c)
8. a (P-255, Col-2)
9. a; Prefer Osteosarcoma > Osteoid Osteoma if there in choices
10. d; Some degree of hyperglycemia is associated with all malignant bone tumors. Chondrosarcoma is relatively best choice here.
11. c (P-255, Col-2)
12. b (P-261, Col-1, High-yield Points); The closest variant of GCT can be taken as ABC although the authors could not find it anywhere in literature. The similarities include aggressive nature, lytic expansile lesion, same site (GCT in young age is metaphyseal) and both have giant cells on biopsy and lack calcification that could be seen in cartilaginous lesions like Chondroblastoma
13. d (P-266, Col-1) 14. b (P-272) 15. b (P-265, Col-1)
16. b (P-269, Col-1); This seems to be case of Glomus tumor
17. b (P-268, Col-2)
18. b (P-273, Col-2, High-yield Point)
19. c 20. a (P-250, Fig. 6.1)
21. a (P-269, Table 6.8)
22. c (P-250, Table 6.1)
23. b (P-266, Col-1, High-yield Point)
24. d (P-259, Col-1)
25. c (P-272) 26. b (P-254, Fig. 6.10)
27. c; Although osteoblastoma can occur at this site, lytic and expansile appearance goes in favor of ABC
28. b; Osteosarcoma is very rare in the small bones of hand and feet
29. d 30. b (P-264, Table 6.6)
31. b (P-265, Col-2) 32. b
33. b (P-266, Col-2) 34. a (P-268, Col-2) 35. b, c, d
36. d (P-269) 37. a 38. d (P-270, Table 6.9)
39. d; It could be metastasis, more likely than multiple myeloma, considering the site, the age and the incidence.
40. a; Preference order in the case should be: X-ray > MRI > Bone biopsy
41. d (P-270, Table 6.9)
42. a; The patient can have metastasis from prostatic carcinoma or the back pain could simply be due to degenerative spine disease. Alkaline phosphatase will confirm presence of skeletal metastasis and thereafter if levels are raised, work up for prostatic carcinoma can be taken up. Going for Acid phosphatase will only detect prostatic carcinoma but not indicate whether it has metastasized or not
43. b 44. a (P-258, Col-1)
45. a, b, c, e; GCT commonly involves the epiphysis and metaphysis but rarely erodes the articular surfaces. Even while it expands it is mostly covered by a thin shell of reactive bone. So some covering will remain as the tumor will expand
46. b 47. a (P-258, Col-1)
48. d (P-252, Col-1)
49. b (P-265, Col-2)
5. d (P-119, Col-2); This is Segond's fracture
6. d (P-287, Col-1)
7. a (P-307, Col-2)
8. d (P-303)
9. c (P-302) 10. d (P-301, Col-1)
11. d; Age, limp and restricted abduction and internal rotation, all go in favor of Perthes disease
12. c (P-299, Col-2)
13. c (P-294, Col-1) 14. d
15. b (P-290, 291)
16. b; If there is an in born external twist in tibia (External tibial torsion), the patient will walk with feet pointing outwards (Charlie Chaplin gait)
17. a (P-288, Col-1)
18. d; Rocker bottom foot can occur after congenital vertical talus or improper treatment in CTEV and can be associated with syndromic conditions like Arthrogryposis, Neurofibromatosis, Trisomy 13-15 and 18, Spina bifida and Prune Belly syndrome.
19. a 20. b (P-278, Col-2)
21. b (P-280, Col-2)
22. a (P-275, Col-2 and Table 7.1) 23. c
24. d (P-303-305); Although no choice is appropriate choice (d) seems to be best to choose. The fractures don't unite easily as the bone fixation is difficult although many studies say that the healing is normal
25. b 26. d (P-306, Col-1, High-yield Points)
27. d (P-285, Col-1); There is overriding or under riding of first/great toe over second toe
28. c 29. a (P-295, Col-2, see High-yield Points)
30. b; Even the slightest possibility of septic arthritis needs to be ruled out in this case. So first Ultrasound should be done and if it shows any collection then it should be immediately aspirated under ultrasound guidance
31. c (P-305)
32. b Although difficult to conclude answer, Genu valgum may not be present bilaterally in these cases and is not a uniform association, so best choice to choose will be (b)
33. d (Read "Congenital dislocation of knee" from P-290, High-yield Points)
34. b; Most common cause of genu valgum in a child is idiopathic > rickets
35. d (P-288)
36. a, c, d, e (see explanation of Q 18 for conditions where there can be Rocker bottom foot. Choice b is not correct as Grice Green procedure is a surgical treatment option for Congenital Vertical Talus, a cause of Rocker Bottom foot)
37. a (P-278, Col-2)
38. b (P-279, Col-2) 39. d
40. c (P-302) 41. c (P-303-305)
42. d (P-306, Col-2)
43. None; Caffey's disease is self limiting. Steroids and Indomethacin are used during the acute flare ups
44. d (P-286, Col-1)
45. c; Lateral condyle humerus is a physeal fragment. Excision will lead to growth disturbance
46. b (P-289, Col-2, High-yield Points)
47. a (P-286)

NEUROMUSCULAR DISORDERS

1. c (P-312, Col-2)
2. a (P-312, Col-2 and Fig. 8.5) 3. b
4. d (P-314, Col-2); Tendon transfers in polio should be done atleast after 2 years of onset of disease as some spontaneous recovery is possible till then. However, the child must be atleast 4 years or more in age so that he can comply with the surgical rehabilitation programme.

PEDIATRIC ORTHOPEDICS

1. a (P-276, Col-1); Poliomyelitis is a cause of secondary (acquired CTEV)
2. c 3. d (P-290, 291) 4. a (P-299, Col-2)

5. c; Tibialis anterior is dorsiflexor while Gastro-soleus is planterflexor. The former is stronger so foot will go into calcaneus. Also peronei are weak so foot will be pulled into inversion (Strong Tibialis anterior will also assist in inversion) leading finally to calcaneovarus
6. d (P-312, Col-2)
7. c (P-312, Col-2)

GENETIC AND DEVELOPMENTAL DISORDERS

1. b (P-316, Col-1, Paragraph 1)
2. d (P-318, Col-2); Here actually all options are correct, but few studies have shown fracture healing is normal and poor results are seen in fractures needing fixation. The latter is difficult due to distorted hard bone structure. So choice (d) is best to choose
3. d (P-322, Col-1); Scoliosis is the commonest of these
4. d (P-322, Col-2, *see* High-yield points)
5. b (P-318) 6. d (Fig. 320, Col-1) 7. b (P-317, Col-1)
8. a (P-319, Col-2) 9. c (P-316, Col-1)
10. c (P-322, Col-2, *see* High-yield points)
11. a (P-321, Col-2) 12. a (P-317, Col-1 and Fig. 9.2)
13. c (P-317, Col-1) 14. b (P-323, Table 9.3)

METABOLIC BONE DISEASES

1. a (P-327, Col-2)
2. d (P-328, Col-2, *see* High-yield points)
3. d (P-337, Col-2) 4. a (P-326, Col-2, Paragraph 1)
5. a, c 6. d (P-328, Col-2, *see* High-yield points)
7. d (P-325, Col-1) 8. a (P-337) 9. a (P-324, Table 10.1)
10. c (P-333, Col-1) 11. d; Steroids cause osteoporosis
12. d (P-327, Col-2) 13. a (P-338) 14. b (P-338)
15. b (P-335, Col-1)
16. b (P-329, Col-2); Long bones of legs get deformed only after the child starts weight bearing
17. d (P-334) 18. c (P-335, Col-2 and Fig. 10.11 C)
19. d (P-335, Col-2)
20. d (P-329, Col-2 and *see* High-yield points)
21. c (*See* Metacarpal sign page 336, Col-2, High-yield points);
22. d (P-328, Col-2) 23. c
24. a; Bone density increases in fluorosis
25. c 26. a (P-338, Col-2) 27. a
28. a; Paget's disease can have asymptomatic presentation with high ALP, normal calcium and phosphate. Multiple myeloma will have normal ALP levels while osteomalacia and hyperparathyroidism will have abnormalities in calcium and phosphorous levels
29. b 30. c (P-328, Col-1)
31. c (P-333, Col-2, *see* High-yield points)
32. d (P-328, Col-1) 33. a
34. b (Bone resorption is seen in phalanges)
35. d; (Age, raised calcium, low phosphate and markedly increased alkaline phosphatase, all suggest diagnosis of Hyperparathyroidism) 36. c
37. d; Deafness can occur due to both cranial nerve compression and otosclerosis. The former is not consistently present and hence otosclerosis is a better choice.
38. c 39. a 40. d (P-324, Table 10.1) 41. d
42. b; Drug of choice for both senile and postmenopausal osteoporosis are Bisphosphonates. However, where osteoporosis is resistant to bisphosphonates, Teriparatide has shown good results.
43. d; Adequate vitamin D is required in the body for absorption of calcium.
44. d (P-333, Flowchart 10.9) 45. a

ARTHRITIS AND RELATED DISORDERS

1. c (P-341, Col-1) 2. b (P-340, Table 11.1)
3. c (P-340, Table 11.1) 4. d (P-340, Col-1)
5. b (P-358, Fig. 11.25) 6. a (P-193, Col-2)
7. b (P-357, Fig. 11.24, Table 11.6) 8. b (P-349, Col-2)
9. b; All spondyloarthropathies may be associated with calcaneal spur formation 10. c
11. b; Osteoclasts is surgical fracture of bone performed to correct malunion of a fractured bone 12. b
13. b (*See* Martel sign Page 354, Col-2 and Fig. 11.21 B);
14. b (P-356, Col-1) 15. a
16. a (P-364, Col-2, *see* High-yield points)
17. b; Commonest cause of loose body in knee in elderly and overall is osteoarthritis while in young patients it is osteochondritis dissecans
18. c (P-357, Table 11.6) 19. d (P-357, Table 11.6)
20. b (Involvement of distal hand joints in 30-50 years age is classical of Psoriatic arthropathy; P-352, P-357 Table 11.6)
21. d; RA can involve cervical spine causing instability in the C1-C2 region
22. b; Earliest X-ray sign of RA is Soft tissue swelling > Periarticular osteopenia
23. d (P-357, Table 11.6)
24. d; Deformities in RA are characteristic of disease but not pathognomic
25. c (P-343, Fig. 11.3b)
26. c (P-343, Col-2 and Fig. 11.6); Wind swept deformity may be seen in both RA and Rickets; conventional use is for Rickets
27. d (P-351, Col-2); Most common cause of Reactive arthritis is Chlamydia > Shigella
28. b (Raised ESR, restricted chest movements, syndesmophytes suggest Ankylosing Spondylitis although age is unfavorable. DISH is a possibility but *see* P-350, Table 11.5 to *see* differences between AS and DISH and reasons to rule out DISH); Ankylosing hyperostosis is same as DISH
29. d (P-352, Col-2 and Fig. 11.19 b) 30. a (P-361)
31. b 32. a 33. a 34. b (P-359)
35. a (P-359, Table 11.8)
36. d; There are very few reports regarding elbow involvement by Charcot's disease
37. a (P-354, Col-2) 38. c (P-354, Col-2)
39. c (*See* P-356 Col-1 for causes of chondrocalcinosis)
40. d; Detection of CPPD crystals is diagnostic of CPPD arthropathy. It is often associated with hypothyroidism
41. a (*See* Tumoral Calcinosis on P-356, Col-2, High-Yield Points);
42. c (P-352, Col-2)
43. c; Arthritis in SLE and Behcet's disease is non-erosive
44. a (The first line drug for osteoarthritis is Paracetamol/acetaminophen) 45. d (P-358, Col-2)
46. b (A history of steroid intake, restricted abduction and internal rotation at hip is pointing towards AVN)
47. a (P-362, Col-2) 48. d (P-362, Col-2) 49. d
50. b 51. a 52. c 53. a (P-343, Fig. 11.3A) 54. d
55. a (P-345, Col-2); Extra-articular manifestations warrant steroids in RA
56. a 57. c (P-348, Col-1) 58. a
59. a (P-361, Col-2)
60. c; Hemophilia is a relative contraindication as there is risk of uncontrolled haemorrhage
61. a 62. c 63. a 64. a, b, c, d
65. b (P-364, Col-2, High-yield points) 66. d
67. b (P-353, Col-2) 68. d 69. c
70. b; Anterolateral part of superior weight bearing zone of head is first region to be involved
71. c (*See* Articular cartilage injuries on P-125)

72. c (P-366, Col-2, High-Yield Points); Limitation of abduction & internal rotation is a characteristic clinical feature in AVN that occurs due to alteration in shape of femoral head. Use of protease inhibitors in HIV patients is an associated risk factor for AVN.
73. b 74. a, d (P-346, Col-2, High-yield points)
75. a, c, e; Extra-articular manifestations may be seen in up to one third patients of Rheumatoid arthritis
76. a (P-346, Col-2, High-Yield Points)
77. d (P-346, Col-2, High-Yield Points)
78. d (P-345, Col-2) 79. a
80. b; Xanthine oxidase inhibitor (Allopurinol) is rather a treatment drug in gout
81. b 82. b (P-351, Col-2) 83. c
84. a (P-345 Col-2 and P-346 Col-1)
85. d; (Read extra-articular manifestations of Ra from P-344, Col-1)
86. b (P-356, Col-1 and Page 357, Col-2, High-yield points); APE are manifestation of chondrocalcinosis in monkeys

SOFT TISSUE DISORDERS

1. a (P-380, Col-1 and Fig. 12.29) 2. a (P-376, Col-2)
3. a (P-372, Col-1, *see* High-yield points)
4. c; No reference is there in literature. Since subscapularis tears are mostly overlooked it could be the forgotten muscle.
5. a 6. c (P-375, Col-2 and Fig. 12.20 B)
7. b (P-377, Col-1 and Fig. 12.23)
8. b 9. a (P-368, Col-2, *see* High-yield points)
10. a (P-376); The likely diagnosis is Frozen shoulder and the treatment is conservative as it is a self-limiting condition.
11. a (P-362) 12. b (P-379, Col-2 and Fig. 12.25)
13. b 14. a (P-368, Col-2)
15. b (P-372); The likely cause is Tennis elbow.
16. d (P-371, Col-2) 17. a (P-371, Col-2)
18. a (Fig. 370, Col-2) 19. d (Fig. 370, Col-2)
20. a 21. a (P-369) 22. b (P-381, Col-2) 23. a
24. a; This is movie sign of Chondromalacia patellae (P-362)
25. a 26. b (P-370, Col-1 and Fig. 12.8)

AMPUTATIONS, PROSTHETICS AND ORTHOTICS

1. a (P-383, Col-2)
2. d; A below knee amputation is avoided in diabetics due to vascular issues
3. d (P-385, Col-1); but if TENS is a choice, it should be preferred
4. d
5. c; Least effective of the mentioned modalities is ultrasound
6. b (P-384) 7. d (P-385, Col-2, *see* High-Yield Points)
8. c (P-386, Col-2) 9. a (P-384, Col-2) 10. d (P-384, Col-2)

RECENT ADVANCES

1. b (P-397, Col-1) 2. c (P-398, Col-2, *see* High-yield points)

3. b; Most common cause of death after THR is MI > Pulmonary embolism
4. a (P-397, Col-2) 5. b (P-397, Col-2) 6. a
7. c (P-390, Col-2 and P-391)
8. d (P-395, Col-1)

ORTHOPEDIC SURGERIES

1. c; Jones tendon transfer is for radial nerve palsy; Watson-Jones approach is for lateral exposure of hip as may be required during hip replacement surgery; modified Jones procedure is done in claw toes for deformity correction; And Watson Jones procedure is also a treatment option for chronic ankle instability.
2. d (P-407, Col-2)
3. d (P-402, Col-2); Rush pins are used for fixation of fracture shaft femur in children
4. c (P-403, Col-2)
5. a (P-407, Col-2)
6. c; No answer is absolutely correct but Gluteus medius seems to be most appropriate
7. a (P-403, Col-2)
8. d Morel Lavelli lesion (P-91, *see* High-Yield Points); is present over lateral side while Kocher Langenbeck is a posterior approach

PICTURE QUIZ

1. a; The attitude depicted in of Inferior dislocation of shoulder
2. c; The child has cubitus varus deformity secondary to malunited supracondylar humerus fracture
3. c
4. a; The X-ray is showing sun ray appearance
5. c
6. a 7. a
8. b 9. d
10. a; The X-ray is showing classical Bamboo spine appearance
11. d; The child in picture has a wind swept deformity
12. c
13. b; The patient has been put on a modified Dunlop traction
14. a
15. b; CT scan is depicting the classical polka dot pattern seen in vertebral hemangioma
16. b; The X-ray is showing soap bubble appearance classical of a Giant cell tumor. Moreover, distal end of radius is a very common site of affection
17. d; The X-ray is showing Erlenmeyer flask deformity
18. c; The examiner is performing Finkelstein's test
19. d; The lift off test is being performed
20. b; Proximal femur has a shepherd crook deformity
21. b; Anterior angulation and anterior dislocation of head are seen in Type I
22. a; X-ray is showing intracapsular neck femur fracture
23. c; X-ray is showing the classical bone within bone appearance
24. b 25. d