

William C. Wood
Charles A. Staley
John E. Skandalakis
Editors

Anatomic Basis of Tumor Surgery



Second Edition

 Springer

William C Wood · C. A. Staley
John E. Skandalakis (Eds.)

Anatomic Basis of Tumor Surgery

William C. Wood, MD, FACS, FRCS Eng [Hon], FRCPS GLASG.

Distinguished Joseph Brown Whitehead Professor
Emory University School of Medicine
Department of Surgery
1365 Clifton Road
Atlanta, GA 30322
USA

Charles A. Staley, MD, FACS

Holland M. Ware Professor of Surgery and
Chief, Division of Surgical Oncology
Emory University School of Medicine
1364 Clifton Road
Atlanta, GA 30322
USA

John E. Skandalakis, MD, PhD, FACS†

Michael Carlos Professor of Surgery and
Director, Centers for Surgical Anatomy and Technique
Emory University School of Medicine
1462 Clifton Road
Atlanta, GA 30322
USA

† Deceased August, 2009, as this book went to press

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Dedication

To our best friends

Judy, Kim, and Mimi

who bring joy to every day

Preface

The old saying that “the best anatomist makes the best surgeon” is but a variation on the venerable saw that “you have to know the territory.” Neoplastic disease has no respect for anatomical boundaries, making detailed familiarity with anatomy that exists beyond the margins of a standard surgical method a great facilitator for many surgical procedures. The biology of cancer and knowledge of all modalities appropriate for its management continues to define new approaches to both common and rare cancers.

We are pleased to present this update of *Anatomic Basis of Tumor Surgery*, the 2nd edition of the book that interweaves the form of an atlas, the shape of an anatomy text, and a pervasive understanding of multimodality therapy in light of the expanding knowledge of oncologic biology. In addition to welcoming many new authors to this edition, Charles Staley has joined us as an editor. We also honor John Skandalakis for holding aloft the torch of surgical anatomy with so many contributions over the nearly ninety years of his life.

Many thanks are owed to Sean Moore, Editor for the Department of Surgery at Emory, whose diligent reviews and persistent efforts brought this book to completion.

Atlanta, Georgia, USA

William C. Wood
Charles A. Staley
John E. Skandalakis †

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Contributors

Albert J. Aboulafia, MD

Orthopaedic Surgeon, Lapidus Cancer Institute, 2401 W. Belvedere Avenue, Baltimore, MD 21215, USA
Former Assistant Professor, Department of Orthopaedic Surgery, Emory University School of Medicine, Atlanta, GA 30322, USA

Gene D. Branum, MD

General and Laparoscopic Surgeon, Harrisonburg Surgical Associates Ltd., Harrison Plaza, 1
01 N. Main Street, Harrisonburg, VA 22802, USA
Former Assistant Professor, Department of Surgery, Emory University School of Medicine, Atlanta,
GA 30322, USA
gebra60@yahoo.com

John Bostwick III†

Grant W. Carlson, MD

Wadley R. Glenn Professor of Surgery, Department of Surgery, Emory University School of Medicine,
Atlanta, GA 30322, USA
Associate Program Director, Division of Plastic Surgery, Department of Surgery, Emory University
School of Medicine, Atlanta, GA 30322, USA
Professor of Surgery, Department of Otolaryngology, Emory University of Medicine,
Atlanta, GA 30322, USA
Winship Cancer Institute, 1365C Clifton Road NE, Atlanta, GA 30322, USA
carlson@emory.edu

Amy Y. Chen, MD, MPH

Associate Professor, Department of Otolaryngology, Emory University School of Medicine,
Emory Otolaryngology, 1365A Clifton Rd NE, Atlanta, GA 30322, USA
amy.chen@emory.edu

Dr. George W. Daneker, MD

Georgia Surgical Associates, 5667 Peachtree Dunwoody Road NE, Suite 170, Atlanta, GA 30342, USA
Former Assistant Professor, Division of Surgical Oncology, Department of Surgery, Emory University
School of Medicine, Atlanta, GA 30322, USA

S. Scott Davis, Jr., MD

Assistant Professor of Surgery, Department of Surgery, Division of General and GI Surgery,
Emory University School of Medicine, Emory University Hospital, Room H-124, 1364 Clifton Road NE,
Atlanta, GA 30322, USA
s.scott.davis@emory.edu

John M. DelGaudio, MD

Associate Professor, Department of Otolaryngology, Emory University School of Medicine,
Emory Otolaryngology, 1365A Clifton Rd NE, Atlanta, GA 30322, USA
jdelgau@emory.edu

Keith A. Delman, MD

Assistant Professor of Surgery, Department of Surgery, Division of Surgical Oncology, Emory University
School of Medicine, Atlanta, GA 30322, USA
Associate Program Director, General Surgery Residency Program, Emory University
School of Medicine, Atlanta, GA 30322, USA
Winship Cancer Institute, 1365 Clifton Road NE, Suite C2004, Atlanta, GA 30322, USA
keith.delman@emory.edu

Rizk E.S. El-Galley, MB, BCh, FRCS

Associate Professor, Department of Surgery, Division of Urology, University of Alabama at Birmingham
School of Medicine, Birmingham, 1802 6th Avenue South, AL 35249, USA

Seth D. Force, MD

Assistant Professor of Surgery and McKelvey Fellow in Lung Transplantation, Department of Surgery,
Division of Cardiothoracic Surgery, Emory University School of Medicine, Atlanta, GA 30322, USA
Surgical Director, Adult Lung Transplant Program, Emory University Hospital, Atlanta, GA 30322, USA
seth.force@emory.edu

Roger S. Foster, Jr., MD

Professor Emeritus, Department of Surgery, Emory University School of Medicine, Atlanta,
GA 30322, USA
395 Stevenson Road, New Haven, CT 06515, USA

Sheryl G.A. Gabram-Mendola, MD

Director, AVON Comprehensive Breast Center, Grady Health System, Atlanta, GA 30322, USA
Professor of Surgery, Department of Surgery, Division of Surgical Oncology, Emory University School
of Medicine, Atlanta, GA 30322, USA
Winship Cancer Institute, 1365-C Clifton Rd, NE, Atlanta, GA 30322, USA
sgabram@emory.edu

John R. Galloway, MD

Professor of Surgery, Department of Surgery, Division of General and GI Surgery, Emory University
School of Medicine, Atlanta, GA 30322, USA
Director, Nutritional Metabolic Services, Emory University Hospital, Atlanta, GA 30322, USA
Medical Director of Transplant and Surgical Intensive Care Unit, Emory University Hospital,
1364 Clifton Road NE, Suite H-122, Atlanta, GA 30322, USA
Associate Section Chief for Critical Care, Nutrition and Metabolic Support, Emory University Hospital,
Atlanta, GA 30322, USA
galloway@emory.edu

Ira R. Horowitz, MD

Willaford Ransom Leach Professor of Gynecology and Obstetrics and Director, Department of Gynecology
and Obstetrics, Division of Gynecologic Oncology, Emory University School of Medicine, Woodruff
Memorial Building, Room 4307, Atlanta, GA 30322, USA
Member, Winship Cancer Institute, Emory University School of Medicine, Atlanta, GA 30322, USA
Chief Medical Officer, Emory University Hospital, Atlanta, GA 30322, USA
ihorowi@emory.edu

John G. Hunter, MD

Mackenzie Professor and Chairman, Department of Surgery, Oregon Health and Science University, 3181 S.W. Sam Jackson Park Road, L223, Portland, OR 97239, USA

Thomas E. Keane, MB, BCh, FRCS

Professor and Chairman, Department of Urology, Medical University of South Carolina, 96 Jonathan Lucas Street, CSB 644, PO Box 250620, Charleston, SC 29425, USA

David A. Kooby, MD

Assistant Professor of Surgery, Department of Surgery, Division of Surgical Oncology, Emory University School of Medicine, Atlanta, 1365C Clifton Rd, NE, 2nd Floor, Atlanta, GA 30322, USA
dkooby@emory.edu

Robert B. Lee, MD

Cardiovascular Surgical Clinic, Jackson, MS, USA
Former Assistant Professor, Division of Cardiothoracic Surgery, Department of Surgery, Emory University School of Medicine, Atlanta, GA 30322, USA
501 Marshall Street, Suite 100, Jackson, MS 39202-1655, USA
bobleemd@aol.com

Edward Lin, DO

Associate Professor of Surgery, Department of Surgery, Division of Gastrointestinal and General Surgery, Emory University School of Medicine, Atlanta, GA 30322, USA
Director, Emory Endosurgery Unit for Minimally Invasive Surgery, Emory University School of Medicine, Atlanta, GA 30322, USA
Director, Gastroesophageal Treatment Center and Esophageal Physiology Lab, The Emory Clinic, Atlanta, GA 30322, USA
Surgical Director, Emory Bariatric Center, Emory Healthcare, Atlanta, GA 30322, USA
elin2@emory.edu

Albert Losken, MD

Associate Professor of Surgery, Department of Surgery, Division of Plastic and Reconstructive Surgery, Emory University School of Medicine, Atlanta, GA 30322, USA
Director of Research, Department of Surgery, Division of Plastic and Reconstructive Surgery, Emory University Hospital Midtown, Medical Office Tower, 550 Peachtree Street, SE, 8th Floor, Suite 4300, Emory University School of Medicine, Atlanta, GA 30322, USA
Chief, Plastic Surgery Services, Children's Healthcare of Atlanta at Egleston, Atlanta, GA 30322, USA
alosken@emory.edu

Fray F. Marshall, MD

Professor of Urology and Chairman, Department of Urology, The Emory Clinic B, Suite 1405, Emory University School of Medicine, 1365 Clifton Road, Atlanta, GA 30322, USA
fmarsha@emory.edu

Mira Milas, MD

Associate Professor of Surgery, Section of Endocrine Surgery, Cleveland Clinic Lerner College of Medicine of Case Western University, 9500 Euclid Avenue A80, Cleveland, OH 44195, USA
milasm@ccf.org

Daniel L. Miller, MD

Kamal A. Mansour Professor of Thoracic Surgery, Department of Surgery, Division of Cardiothoracic Surgery, Emory University School of Medicine, Atlanta, GA 30322, USA
Chief, General Thoracic Surgery, Department of Surgery, Emory Healthcare, Atlanta, GA 30322, USA
Associate Program Director, Cardiothoracic Surgery Residency Program, Emory University School of Medicine, Atlanta, GA 30322, USA
Surgical Director, Thoracic Oncology Program, Winship Cancer Institute, Emory University, Atlanta, GA 30322, USA
dlmill2@emory.edu

David K. Monson, MD

Assistant Professor, Department of Orthopaedic Surgery, Emory University School of Medicine, Atlanta, GA 30322, USA
59 Executive Park South, Suite 2000, Atlanta, GA 30329, USA

Peter T. Nieh, MD

Associate Professor of Urology, Department of Urology, Emory University School of Medicine, Atlanta, GA 30322, USA
Director, Uro-Oncology Center, The Emory Clinic B, Suite 1483, 1365 Clifton Road NE, Atlanta, GA 30322, USA
pnieh@emory.edu

Kenneth Ogan, MD

Associate Professor, Department of Urology, Emory University School of Medicine, Atlanta, GA 30322, USA
Department of Urology, Emory Clinic, Room B5100, 1365 Clifton Road NE, Atlanta, GA 30322, USA
kogan@emory.edu

Shervin V. Oskouei, MD

Assistant Professor of Orthopaedic Oncology, Orthopaedic Surgery Residency Program, Emory University School of Medicine, Atlanta, GA 30322, USA
59 Executive Park South, Suite 2000, Atlanta, GA 30329, USA
svoskou@emory.edu

John G. Pattaras, MD

Assistant Professor of Urology, Department of Urology, Emory University School of Medicine, Atlanta, GA 30322, USA
Director of Minimally Invasive Surgery, The Emory Clinic B, Suite 1479, 1365 Clifton Road NE, Atlanta, GA 30322, USA
jpattar@emory.edu

William S. Richardson, MD

Director of Laparoscopic Surgery, Ochsner Health Center, 1514 Jefferson Highway, Jefferson, LA 70121, USA

Daniel T. Saint-Elie, MD

Resident, Department of Urology, Room B5100, Emory University School of Medicine, Atlanta, GA 30322, USA
dstelie@yahoo.com

Juan M. Sarmiento, MD

Assistant Professor of Surgery, Department of Surgery, Division of General and GI Surgery, Emory University School of Medicine, Atlanta, GA 30322, USA
jsarmie@emory.edu

Jyotirmay Sharma, MD

Assistant Professor of General and Endocrine Surgery, Department of Surgery, Division of General and GI Surgery, Emory University School of Medicine, Atlanta, GA 30322, USA
jsharm3@emory.edu

John E. Skandalakis, MD, PhD†**Lee J. Skandalakis, MD**

Attending Surgeon, Piedmont Surgical Associates LLC, Atlanta, GA, USA
Former Clinical Associate Professor of Surgical Anatomy and Technique, Centers for Surgical
Anatomy and Technique, Emory University School of Medicine, Atlanta, GA 30322, USA
95 Collier Road, Suite 6015, Atlanta, GA 30309, USA

Panagiotis N. Skandalakis, MD

Clinical Associate Professor, Centers for Surgical Anatomy and Technique, Emory University School
of Medicine, 1462 Clifton Road NE, Suite 303, Atlanta, GA 30322, USA

C. Daniel Smith, MD

Professor of Surgery and Chair, Department of Surgery, Mayo Clinic, 4500 San Pablo Road,
Jacksonville, FL 32224, USA

Hadar Spivak, MD

HS Laparoscopy, Park Plaza Hospital Medical Bldg, 1200 Binz, Suite 1470, Houston, TX 77004, USA

Charles A. Staley, MD

Holland M. Ware Professor of Surgery and Chief, Department of Surgery, Division of Surgical Oncology,
Emory University School of Medicine, Atlanta, GA 30322, USA
Winship Cancer Institute, 1365C Clifton Road, Atlanta, GA 30322, USA
charles.staley@emory.edu

Panagiotis N. Symbas, MD

Professor Emeritus, Department of Surgery, Emory University School of Medicine,
Atlanta, GA 30322, USA
3661 Cloudland Drive, NW, Atlanta, GA 30327, USA

Nikolas P. Symbas, MD

Urology Associates, 55 Whitcner Street, Suite 250, Marietta, GA, USA

John F. Sweeney, MD

W. Dean Warren Distinguished Professor of Surgery and Chief, Department of Surgery, Division
of General and GI Surgery, Emory University School of Medicine, Atlanta, GA 30322, USA
Emory University Hospital, Room H-124, 1364 Clifton Road NE, Atlanta, GA 30322, USA
jfsween@emory.edu

Collin J. Weber, MD

William C. McGarity Professor of Surgery, Department of Surgery, Emory University School of Medicine,
Atlanta, GA 30322, USA
Vice Chairman, Clinical Affairs, Department of Surgery, Emory University School of Medicine, Atlanta,
GA 30322, USA
Director, Elizabeth Brooke Gottlich Diabetes Research and Islet Transplant Laboratory, Emory University,
Atlanta, GA 30322, USA
cweber@emory.edu

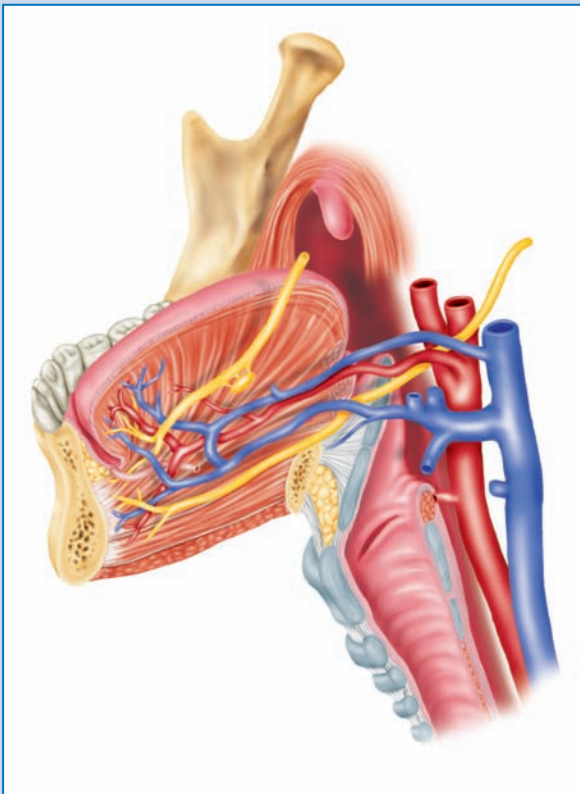
William C. Wood, MD

Distinguished Joseph Brown Whitehead Professor, Department of Surgery,
Emory University School of Medicine, Winship Cancer Institute, 1365 Clifton Road,
Atlanta, GA 30322, USA
wwood@emory.edu

Oral Cavity and Oropharynx

John M. DelGaudio

Amy Y. Chen



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Introduction

Malignant tumors of the oral cavity and oropharynx are predominantly (greater than 90–95%) squamous cell carcinomas. Less common tumors include minor salivary gland tumors (especially on the hard palate), verrucous carcinomas, lymphomas, melanomas, and sarcomas. The most common risk factors are tobacco, smoked and smokeless, and alcohol abuse. Less common factors include poorly fitting dentures, poor dentition with irregular surfaces, and poor oral hygiene. Nonsmokers can also be diagnosed with oral cavity and oropharynx cancer. Among nonsmokers, human papillomavirus (HPV) has recently been associated with malignancies of the oropharynx, and may portend better outcomes when compared to those without HPV infection. Malignancies of the oral cavity and oropharynx account for approximately 4% of all newly diagnosed nonskin malignancies, with a 2:1 male predominance. Approximately 34,000 new cases are diagnosed each year. Two-thirds of these are in the oral cavity and one-third in the oropharynx. Oral cancer accounts for an estimated 7,550 deaths yearly (Cancer Facts and Figures, 2007).

While oral cavity and oropharynx cancer accounts for only a small number of all new cancers, the functional problems created by these tumors and their treatment are significant. Oral cavity and pharyngeal dysfunction affects speech, oral competence, the first and second (oral and pharyngeal) phases of swallowing, and in some instances, the ability to adequately protect the airway. Even small tumors may result in significant weight loss due to pain, dysphagia, and odynophagia, resulting in malnutrition. Dysarthria affects interpersonal communication and frequently results in withdrawal from public situations.

An important consideration in the treatment of oral cavity and oropharyngeal malignancies is the high incidence of second primary tumors. These tumors may be synchronous or metachronous, and occur in approximately 20% of patients. More than half of these second primary tumors are found in the upper airway and digestive tract, most commonly in the esophagus, larynx, oral cavity, and pharynx, as a result of the widespread carcinogenic effects of tobacco and alcohol. Second primary cancers of the lung are also common and for the same reasons. Pretreatment evaluation with chest radiography or computed tomography (CT), positron emission testing (PET), and rigid laryngoscopy and esophagoscopy, is advised to fully stage these tumors.

Staging of oral cavity and oropharyngeal tumors is based on the TNM staging system. Treatment options include surgery, radiation, and combined modality treatment. In general, early squamous cell carcinomas of the oral cavity and oropharynx (i.e., T1 and T2) are treated equally effectively with either surgery or radiation therapy. When deciding on the appropriate treatment modality the physician needs to take into account patient characteristics such as age, overall health, and whether the patient will continue using tobacco or alcohol. Those patients who will continue smoking and drinking are better served with surgical treatment, to reserve radiation

Table 1.1 Clinical classification of squamous cell carcinoma of the oral cavity and oropharynx**Oral Cavity staging****Primary tumor (T)**

- TX: Primary tumor cannot be assessed
- T0: No evidence of primary tumor
- Tis: Carcinoma in situ
- T1: Tumor 2 cm or less in greatest dimension
- T2: Tumor more than 2 cm but not more than 4 cm in greatest dimension
- T3: Tumor more than 4 cm in greatest dimension
- T4: (lip) Tumor invades adjacent structures (e.g., through cortical bone, inferior alveolar nerve, floor of mouth, skin of face) (oral cavity) Tumor invades adjacent structures (e.g., through cortical bone, into deep [extrinsic] muscles of tongue, maxillary sinus, skin. Superficial erosion alone of bone/tooth socket by gingival primary is not sufficient to classify as T4)

Regional lymph nodes (N)

- NX: Regional lymph nodes cannot be assessed
- N0: No regional lymph node metastasis
- N1: Metastasis in a single ipsilateral lymph node, 3 cm or less in greatest dimension
- N2: Metastasis in a single ipsilateral lymph node, more than 3 cm but not more than 6 cm in greatest dimension; or in multiple ipsilateral lymph nodes, none more than 6 cm in greatest dimension; or in bilateral or contralateral lymph nodes, none more than 6 cm in greatest dimension
 - N2a: Metastasis in a single ipsilateral lymph node more than 3 cm but not more than 6 cm in dimension
 - N2b: Metastasis in multiple ipsilateral lymph nodes, none more than 6 cm in greatest dimension
 - N2c: Metastasis in bilateral or contralateral lymph nodes, none more than 6 cm in greatest dimension
- N3: Metastasis in a lymph node more than 6 cm in greatest dimension

Distant metastasis (M)

- MX: Presence of distant metastasis cannot be assessed
- M0: No distant metastasis
- M1: Distant metastasis

Overall stage

Stage 0 Tis, N0, M0

Stage I T1, N0, M0

Stage II T2, N0, M0

Stage III

- T3, N0, M0
- T1, N1, M0
- T2, N1, M0
- T3, N1, M0

Stage IVA

- T4a, N0, M0
- T4a, N1, M0
- T1, N2, M0
- T2, N2, M0
- T3, N2, M0
- T4a, N2, M0

Stage IVB

- Any T, N3, M0
- T4b, any N, M0

Oropharynx Staging**Tumor**

- T1 - confined to nasopharynx
- T2 - extends to soft tissues
 - T2a - extends to oropharynx and/or nasal cavity without parapharyngeal extension
 - T2b - any tumor with parapharyngeal extension (i.e. beyond the pharyngobasilar fascia)
- T3 - involves bony structures and/or paranasal sinuses
- T4 - intracranial extension and/or involvement of cranial nerves, infratemporal fossa, hypopharynx, orbit, or masticator space

(continued)

Table 1.1 (continued)

Nodes	
•	N1 - unilateral nodes, 6 cm or less, above the supraclavicular fossa
•	N2 - bilateral nodes, 6 cm or less, above the supraclav fossa
•	N3a - lymph node greater than 6 cm
•	N3b - extension to the supraclav fossa (defined as the triangular region described by Ho, bounded by the superior margin of the sternal head of the clavicle, the superior margin of the lateral end of the clavicle, and the point where the neck meets the shoulder. This includes some of level IV as well as V.)
Overall stage	
•	I - T1 N0
•	IIA - T2a N0
•	IIB - T1-T2 N1, T2b N0 (i.e. T2b or N1)
•	III - T3 N0-2, or T1-3 N2 (i.e. T3 or N2)
•	IVA - T4 N0-2
•	IVB - N3
•	IVC - M1

From American Joint Committee on Cancer. Manual for staging of cancer, 6th ed. Springer Verlag 2002; pp. 23–25 (Oral Cavity staging), pp. 33–37 (Oropharynx staging)

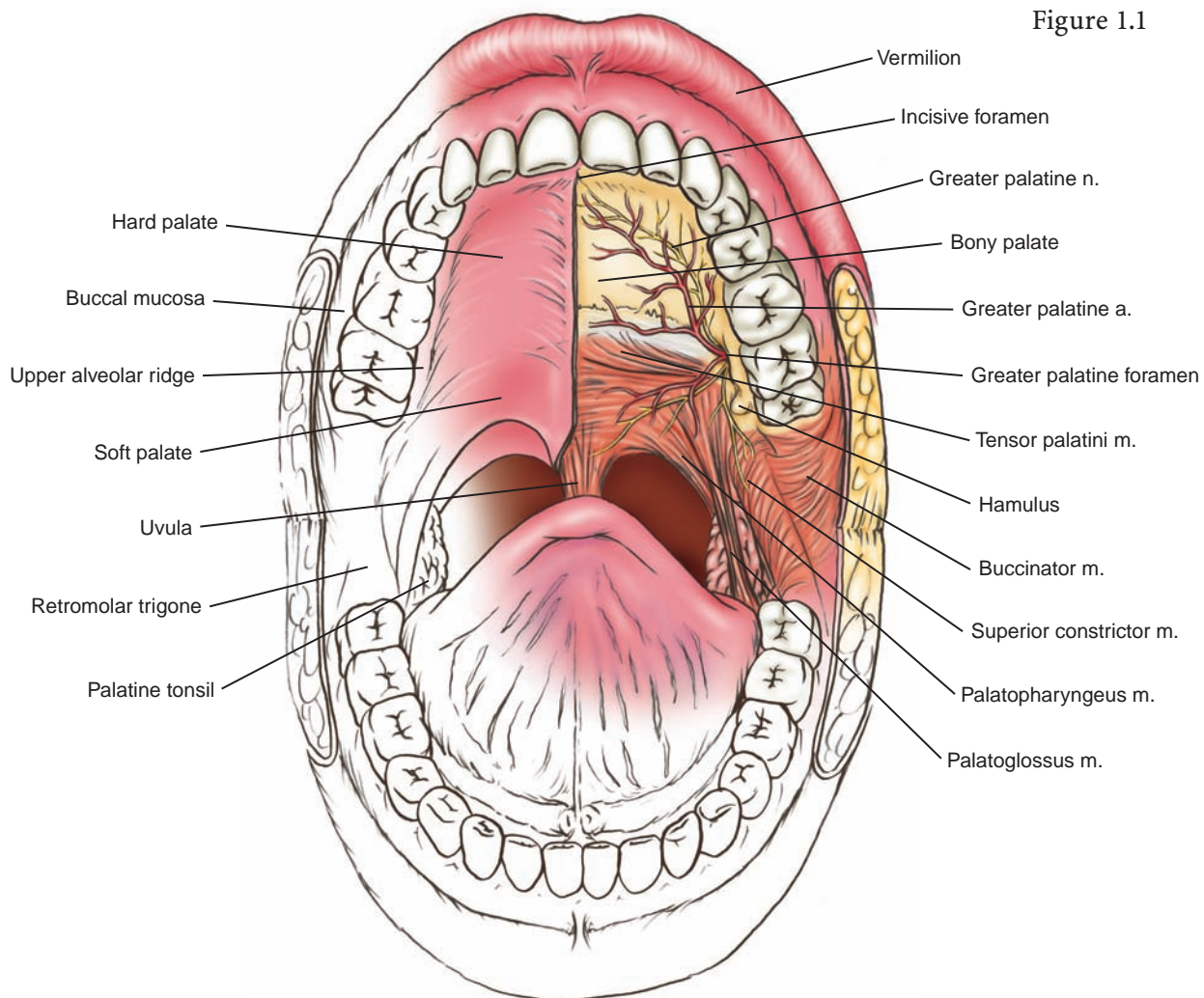
therapy for possible future primary tumors or recurrent lesions. It is also important to consider the functional morbidity related to treatment (i.e., the consequences of surgical resection or reconstruction). Advanced tumors, T3 or T4, or N+, are best treated with primary surgical resection and postoperative radiation therapy. Bone invasion mandates surgical resection because of the poor response of these tumors to radiation therapy. CT scanning is helpful in assessing the presence and degree of bone invasion. When cervical nodal metastases are present, neck dissection is indicated. Also, when the risk for occult metastases exceeds 30%, prophylactic treatment of the neck, whether with surgery or radiation therapy, should be included in the treatment plan. Concurrent chemoradiotherapy is also employed for advanced stage cancers of the oropharynx. Concurrent chemoradiotherapy was found to be superior to induction chemotherapy followed by radiation in RTOG 91–11 for laryngeal cancer, and the results were extrapolated to oropharyngeal cancer. Posner's recent study in NEJM details the effectiveness of induction chemotherapy followed by chemoradiation in improvement of survival.

Cetuximab is the only new agent approved by the Food and Drug Administration for use in head and neck cancer in 40 years. Erbitux blocks epidermal growth factor, which is expressed among most epithelial-based cancers, such as squamous cell carcinoma. A randomized clinical trial demonstrated the superiority of Erbitux and radiation to radiation alone for head and neck cancers. Unfortunately, no comparison can be made to the other chemotherapy given concurrently with radiation, such as cisplatin. Other small molecule inhibitors, such as tyrosine kinase inhibitors, are also being investigated as effective agents in ongoing Phase I and Phase II clinical trials. The role of chemotherapy continues to be under evaluation.

Adjuvant Treatment

Adjuvant treatment may be necessary after surgery for head and neck cancers. Recently published articles detail the advantage of postoperative concurrent cisplatin with radiation for lesions with extracapsular extension in the lymph nodes or positive margins on resection. Postoperative adjuvant radiation is indicated for lesions demonstrating pathologic perineural invasion or with more than one regional lymph node involved with cancer.

Surgical Anatomy



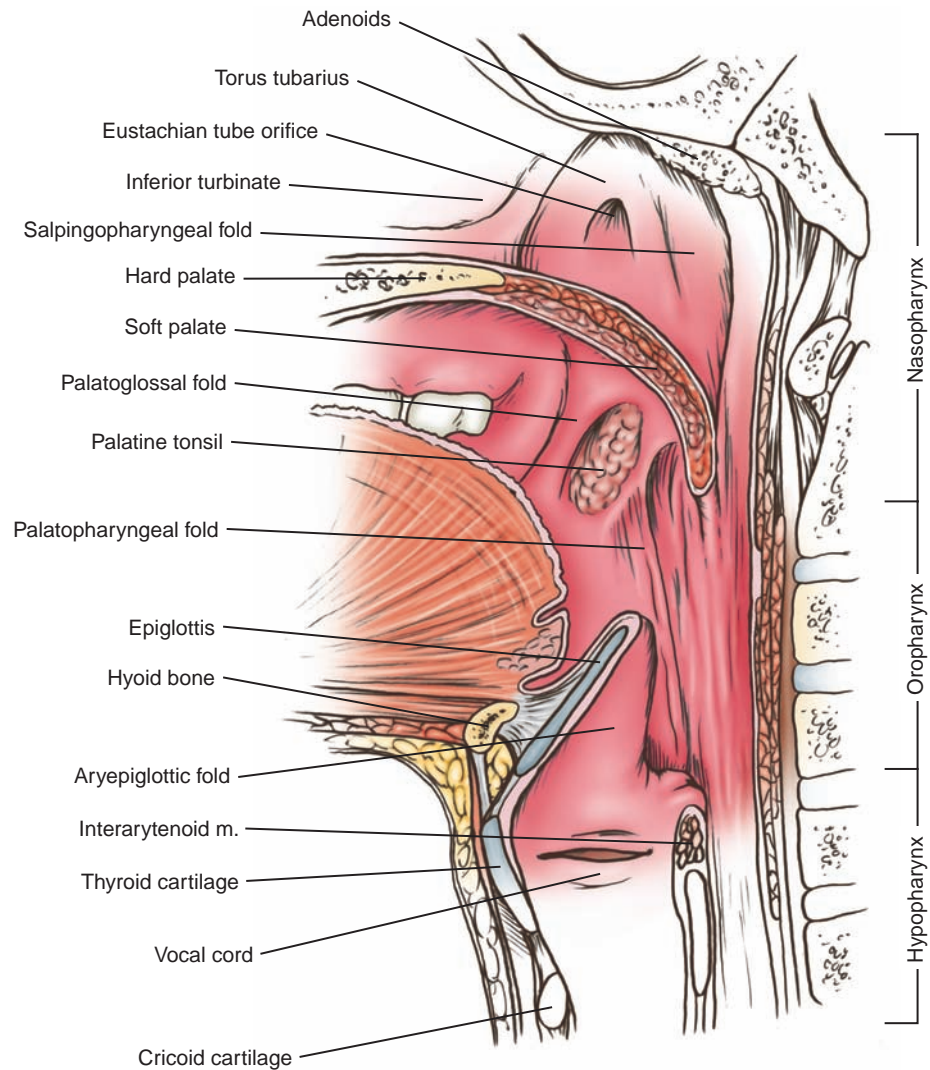


Figure 1.2

The oral cavity extends posteriorly from the lips to the junction of the hard and soft palates superiorly, the anterior tonsillar pillars laterally, and the line of the sulcus terminalis and circumvallate papillae of the tongue inferiorly. The oral cavity is subdivided into multiple entities: lips, oral tongue, floor of the mouth, buccal mucosa, lower alveolar ridge, retromolar trigone, hard palate, and upper alveolar ridge.

The oropharynx is a posterior continuation of the oral cavity and extends superiorly to the level of the soft palate and inferiorly to the level of the hyoid bone. The oropharynx is subdivided into multiple sites: the tonsils, soft palate, tongue base, valleculae, and posterior pharyngeal wall. Each component of the oral cavity and pharynx is discussed individually because each presents unique problems with regard to surgical resection and reconstruction.

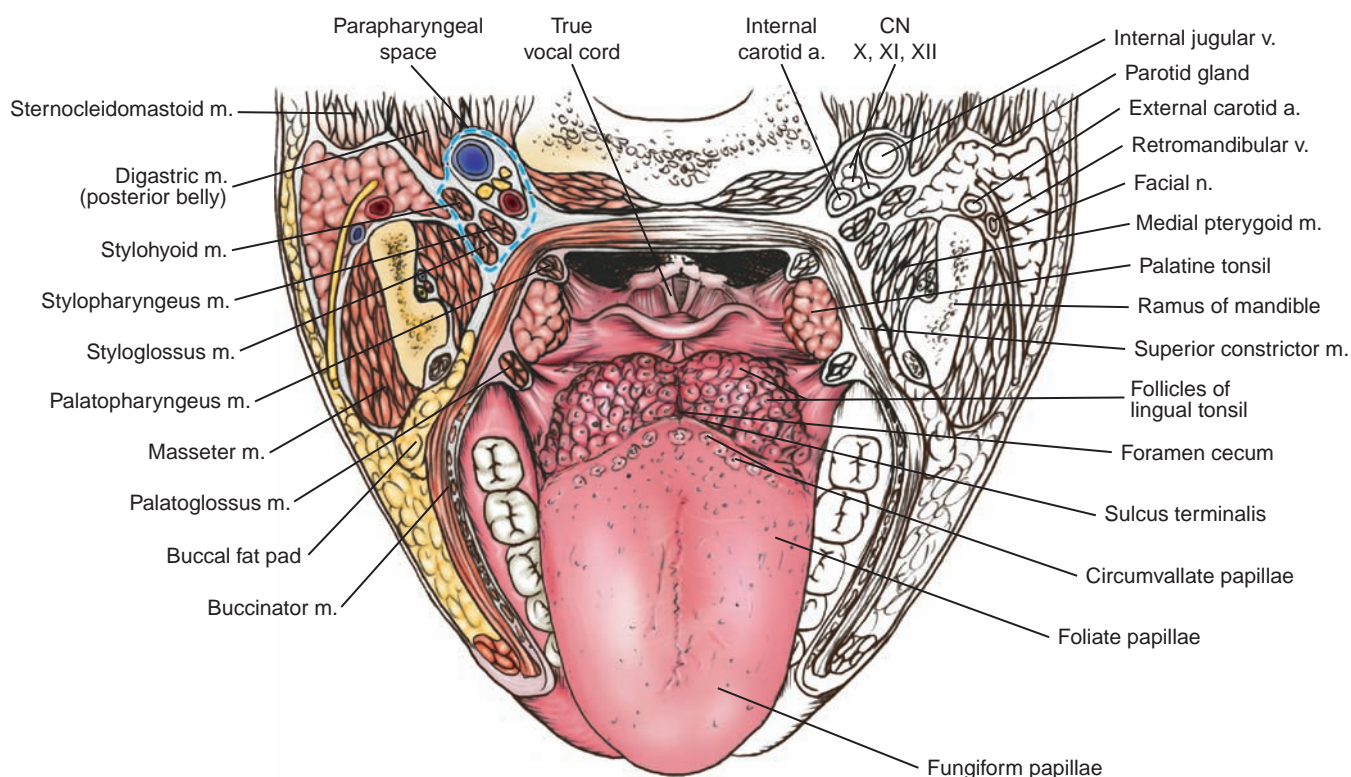
Oral Cavity

The tongue occupies portions of both the oral cavity and the oropharynx. The mobile anterior two-thirds is part of the oral cavity and is referred to as the oral tongue. The fixed posterior one-third occupies the oropharynx and is referred to as the tongue base. The line of demarcation of the oral tongue and the tongue base is at the sulcus terminalis, which is a V-shaped groove just behind the circumvallate papillae. The dorsum, or upper surface, of the tongue is velvety because it is covered by numerous filiform papillae, with interspersed larger fungiform papillae. Just anterior to the sulcus terminalis are a row of large circumvallate papillae, which contain the taste buds. The foramen cecum, a small blind pit at the apex of the sulcus terminalis, represents the site of origin of the thyroid gland, and it may also be the site of ectopic thyroid tissue or a true lingual thyroid gland. The dorsum of the tongue base is covered by lymphoid tissue, which represents the lingual tonsils. The mucosa of the ventral tongue, or undersurface, is smooth and transitions into the floor of the mouth mucosa anteriorly and laterally. Anteriorly, the lingual frenulum attaches the tongue to the anterior floor of the mouth. More posteriorly is the root of the tongue, which is the attached part of the tongue through which the extrinsic muscles reach the body of the tongue.

The tongue is a muscular structure composed of three sets of paired intrinsic muscles and three sets of paired extrinsic muscles. The intrinsic muscles are the longitudinal

Tongue

Figure 1.3



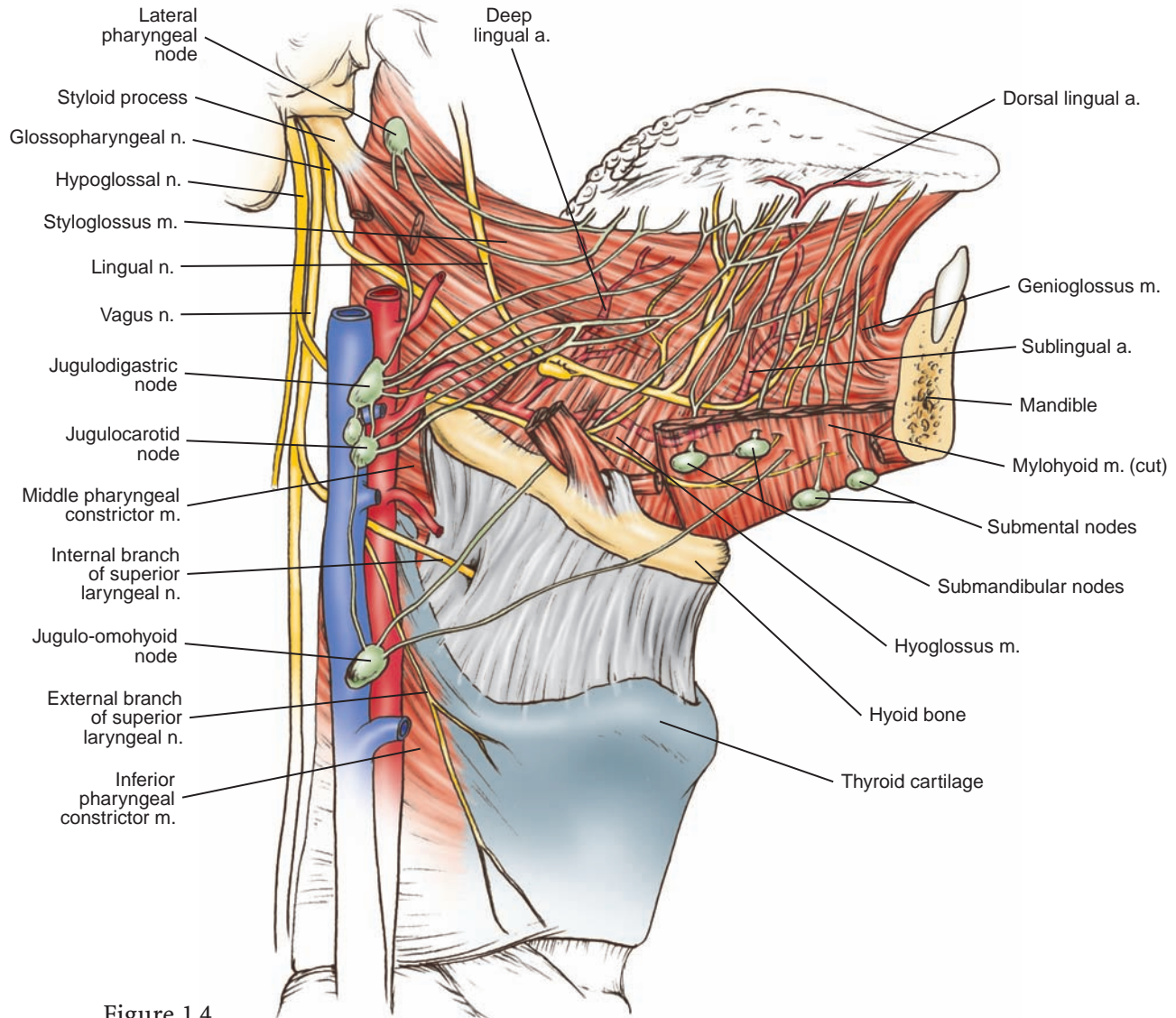


Figure 1.4

(superior and inferior), vertical, and transverse muscles. These muscles make up the body of the tongue and function to alter the shape of the tongue during speech and swallowing. The extrinsic muscles include the paired genioglossus, hyoglossus, and styloglossus muscles, which serve to move the tongue and change its shape.

The hyoglossus is a flat muscle that rises from the body and greater horn of the hyoid bone, partly above and partly behind the mylohyoid muscle, and extends superiorly and anteriorly into the tongue, interlacing with fibers of the other muscles. The styloglossus muscle originates from the styloid process and stylohyoid ligament, and runs anteroinferiorly and medially to insert into the side of the tongue. The genioglossus muscle originates from the mental spine on the inner surface of the mandible, immediately above the geniohyoid muscle, and fans out as it extends posteriorly. The lower fibers insert into the body of the hyoid bone, but the majority of fibers run superiorly and posteriorly to insert into the tongue, from the base to the

tip. The palatoglossus muscles, which insert into the posterolateral tongue, probably do not function in tongue movement (see section on soft palate). The area through which these muscles enter the tongue to attach to the body is the root. The midline of the tongue has a fibrous septum that attaches it to the hyoid bone posteriorly and provides an avascular plane that separates the two sides of the tongue. The septum is present through the entire tongue but does not reach the dorsum.

The connective tissue that separates the muscular bundles of the tongue provides a weak barrier to the spread of tumor. This results in deep invasion of the tongue by malignant tumors because significant symptoms do not occur until speech or swallowing are affected or the lingual nerve is invaded. Tumors of the tongue frequently are large before diagnosis. Also, the deeply invasive nature of carcinoma of the tongue results in greater difficulty in obtaining clear resection margins without resecting large portions of the tongue. It is recommended that approximately 2 cm of normal tissue be resected around tongue cancers and that frozen-section sampling of the margins be performed. This is especially true in tongue-base tumors, which grow large before becoming symptomatic, frequently invading the root of the tongue. With invasion of the root of the tongue, surgical extirpation requires total glossectomy because all attachments of the tongue are transected with removal of the root.

The relationship of the oral tongue to the floor of mouth is important in maintaining tongue mobility. Squamous cell carcinoma of the oral tongue is most commonly located on the lateral surface of the middle third of the tongue, in proximity to or involving the floor of mouth. After resection of tumors of the tongue or floor of mouth, attempts should be made to reconstitute a sulcus between the tongue and the mandibular alveolus to prevent or minimize tethering of the tongue, allowing optimum postoperative rehabilitation of speech and swallowing. With resection of up to half of the tongue, primary closure, healing by secondary intention, skin grafting, or a thin pliable flap (i.e., platysma flap, free radial forearm) will accomplish this goal and allow better tongue function postoperatively. More extensive resection of the tongue presents more difficult problems and usually requires reconstructive techniques to restore bulk to the tongue (i.e., pectoralis major or other pedicled myocutaneous flap, or free tissue transfer). A bulky or sensate flap is necessary for reconstruction of the tongue base to prevent or minimize aspiration.

The arterial supply to the tongue is from the paired lingual arteries, which originate from the external carotid artery at the level of the greater horn of the hyoid bone. The lingual artery passes deep to the hyoglossus muscle and gives off one or two deep lingual branches that supply the tongue base. The sublingual artery originates near the anterior border of the hyoglossus muscle and continues forward between the mylohyoid and genioglossus muscles to supply these muscles, the geniohyoid muscle, and the sublingual gland. The remainder of the lingual artery proceeds forward as a dorsal lingual artery between the genioglossus and longitudinal muscles. It reaches the ventral surface of the tongue just deep to the mucosa, where it is accompanied by the deep lingual vein, which can be seen through the thin mucosa of the ventral tongue. The remainder of the venous drainage accompanies the arterial branches, ultimately joining the deep lingual vein to form the lingual vein, which empties into

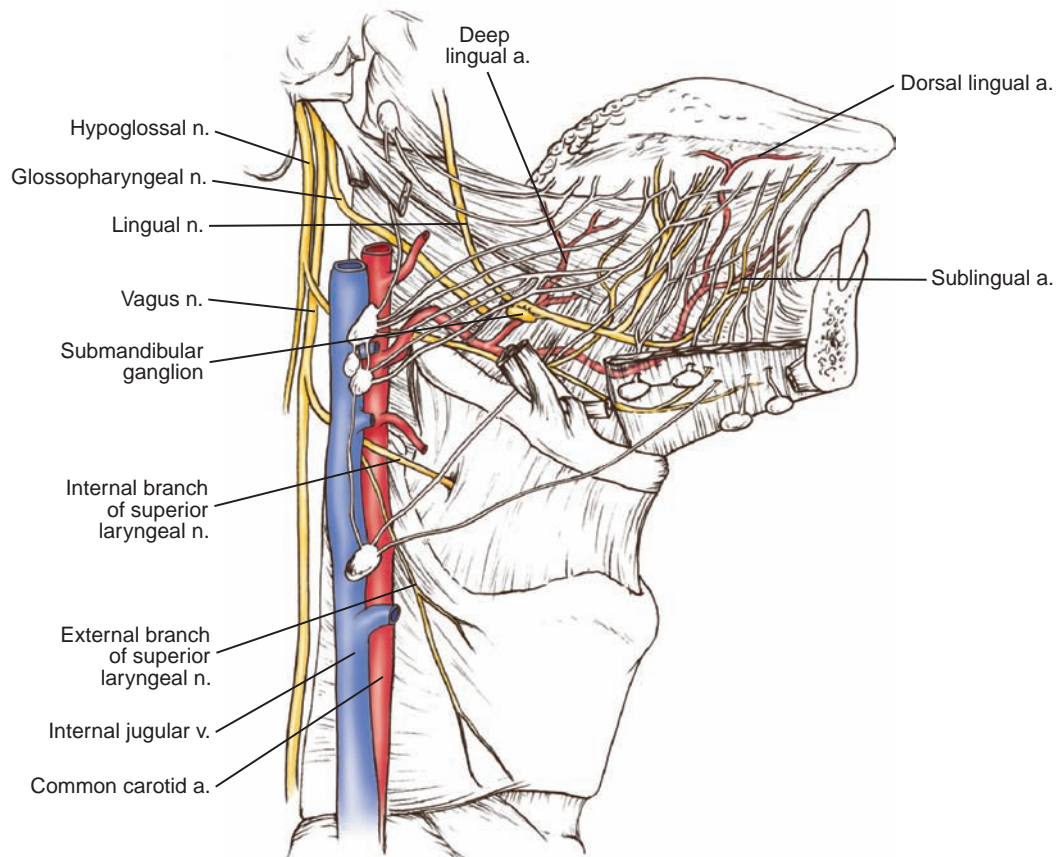


Figure 1.5

the internal jugular vein. Only at the tip of the tongue is there any anastomosis across the midline between the lingual arteries.

The hypoglossal nerve (cranial nerve XII) supplies motor innervation to the extrinsic and intrinsic muscles of the tongue. As it travels beneath the lateral fascia of the hyoglossus muscle, it innervates the extrinsic muscles, and as it reaches the anterior border of this muscle, it penetrates the tongue around the midportion of the oral tongue to supply the intrinsic muscles. Sensory innervation of the tongue is from the lingual nerve (a branch of V3) and the glossopharyngeal nerve (cranial nerve IX). The lingual nerve travels in the floor of the mouth above the hypoglossal nerve, between the mylohyoid and hyoglossus muscles, to innervate the anterior two-thirds of the tongue and floor of mouth. The chorda tympani branch of the facial nerve travels with the lingual nerve and supplies taste to the anterior two-thirds of the tongue. Sensation and taste are supplied to the base of the tongue by the glossopharyngeal nerve. This nerve enters the oropharynx laterally through the interspace between the superior and middle pharyngeal constrictor muscles and enters the base of the tongue posterior to the hyoglossus muscle.

During glossectomy, preservation of at least one hypoglossal nerve is necessary to maintain some tongue mobility and prevent severe oral dysfunction. Referred otalgia to the ipsilateral ear is a common symptom of carcinoma of the tongue because V3 (the mandibular division of the trigeminal nerve) also provides sensory branches

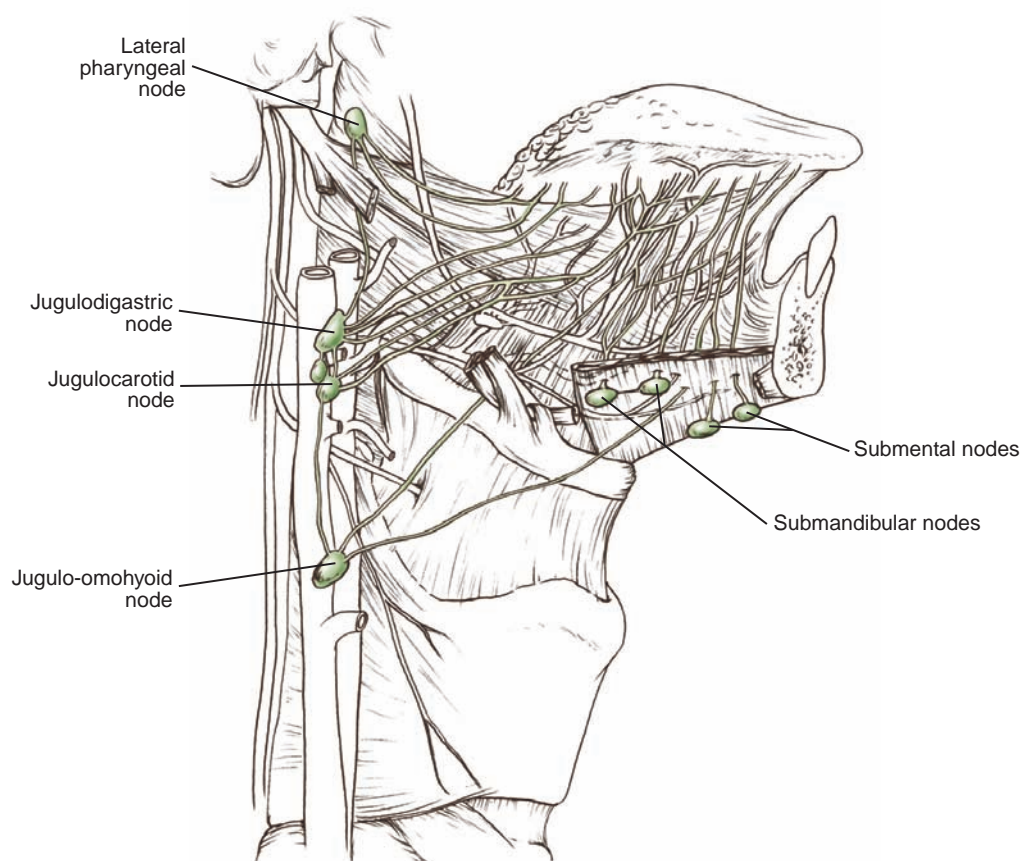


Figure 1.6

to the external auditory canal, tympanic membrane, and temporomandibular joint through the auriculotemporal nerve. The glossopharyngeal nerve also provides sensation to the middle ear via Jacobsen's nerve.

The tongue has an extensive submucosal lymphatic plexus that ultimately drains to the deep jugular lymph-node chain. In general, the closer to the tip of the tongue the lymphatic vessels arise, the lower the first echelon node. The tip of the tongue drains to the submental nodes, the lateral tongue to the submandibular and lower jugular nodes (jugulo-omohyoid), and the tongue base to the jugulocarotid and jugulodigastric nodes. In addition, there is communication of lymphatic vessels across the midline of the tongue, which results in a high incidence of bilateral metastases of tumors of the tip of the tongue and the base of the tongue and tumors that approximate the midline of the tongue. The rich lymphatic network results in early metastases to cervical lymph nodes, even from small tumors (T1 or T2). Therefore, consideration of treatment of one or both sides of the neck, either by neck dissection or radiation therapy, is advised in most tongue cancers.

The floor of the mouth is a crescent-shaped region of the oral cavity extending from the root of the tongue to the lower gingiva. Posteriorly it ends at the level where the anterior tonsillar pillar meets the tongue base. Anteriorly it is divided into two sides by the lingual frenulum. On either side of the lingual frenulum are the papillae of

Floor of Mouth

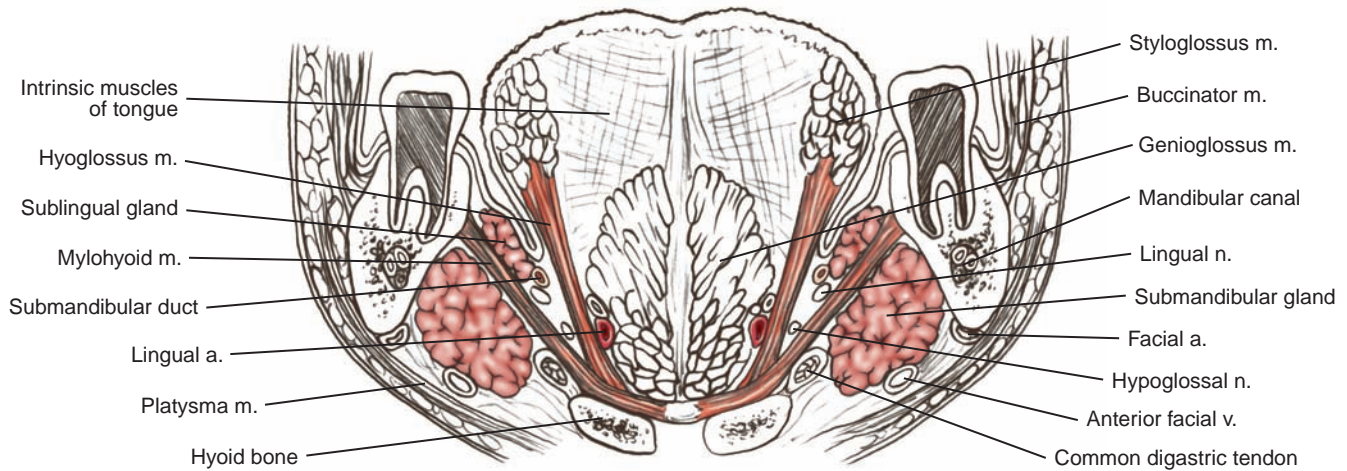


Figure 1.7

the submandibular ducts. Posterolateral to these papillae lie the sublingual folds, elevated areas of mucosa over the sublingual glands.

The floor of mouth is supported by a muscular sling composed of the mylohyoid, genioglossus, and hyoglossus muscles. The paired mylohyoid muscles extend from the mylohyoid line on the inner surface of the mandible to insert on the hyoid bone, meeting in the midline as a median raphe. It is innervated by the mylohyoid branch of the lingual nerve. The hyoglossus muscle lies posterior and deep to the mylohyoid muscle, extending from the greater horn and body of the hyoid bone to insert into the body of the tongue. This muscle partly supports the posterior floor of mouth. The genioglossus muscles, which are paired triangular muscles extending from the apex of the mental spine of the mandible to the body of the hyoid bone, are located in the midline floor of mouth superficial to the mylohyoid muscles but deep to the hyoglossus muscles. Their lateral borders are in contact with the mylohyoid muscle. These muscles function in laryngeal elevation with speech and swallowing and are innervated by V3.

The submandibular gland lies mostly superficial to the mylohyoid muscle. The space between the mylohyoid and hyoglossus muscles is an important surgical area. Posteriorly these muscles are separated by the tail of the submandibular gland, which wraps around the posterior border of the mylohyoid muscle before sending the submandibular duct anteriorly to open in the floor of mouth next to the lingual frenulum. The posterior part of the submandibular duct is surrounded by the sublingual gland. The lingual nerve, which gives sensory innervation to the floor of mouth, enters the floor of mouth superiorly to the submandibular duct and crosses it laterally before ascending on the medial surface of the duct adjacent to the hyoglossus muscle. The hypoglossal nerve always lies along the most inferior part of this plane deep to the fascia of the hyoglossus muscle.

Deep to the plane of the hyoglossus muscle lie three structures: the lingual artery, which supplies the floor of mouth, and more posteriorly the glossopharyngeal nerve and the stylohyoid ligament. The floor of mouth musculature, specifically the

mylohyoid muscle, provides a fairly good barrier to the deep spread of tumor in the floor of mouth.

The lymphatic drainage in the floor of mouth arises from an extensive submucosal plexus. The anterior floor of mouth drains into the submental and preglandular submandibular nodes, with the medial anterior floor of mouth having cross-drainage to the contralateral side of the neck. The posterior floor of mouth drains directly to the ipsilateral jugulodigastric and jugulocarotid nodes.

Treatment of tumors of the floor of mouth greater than 2 cm should include treatment of the neck because of the approximately 40% risk for occult cervical metastases. For midline lesions, consideration should be given to bilateral prophylactic selective (supraomohyoid) neck dissection.

Tumors of the floor of mouth usually spread superficially to adjacent structures such as the root of tongue and the mandible prior to invading deeply into the floor of mouth. It is important to perform bimanual palpation to evaluate the depth of invasion and to determine whether the lesion is fixed to the mandible. This will allow adequate surgical planning, with resection, including a 1.5–2-cm margin of normal tissue around the tumor. This frequently includes resection of a portion of the tongue and may require cortical, rim, or segmental mandibular resection. The depth of invasion is important for planning reconstruction after tumor ablation, as reconstruction options are vastly different if the resection results in a full-thickness defect, connecting the oral cavity to the neck. Primary closure is sometimes possible for full-thickness defects, but more commonly pedicled flaps (i.e., platysma, sternocleidomastoid, nasolabial, and pectoralis major) or free tissue transfers (radial forearm or lateral arm) are necessary to reconstitute the floor of mouth and prevent tethering of the tongue.

In resecting floor of mouth tumors attention must be given to the position of the submandibular duct. Tumors may spread along the submandibular duct to involve the submandibular triangle. In this instance, the submandibular duct and gland should be resected along with the primary tumor, usually as part of a neck dissection. If the submandibular duct is not involved but excision of floor of mouth tumor results in transecting the submandibular duct, the duct should be reimplanted into the remaining floor of mouth mucosa or the submandibular gland should be removed.

The buccal mucosa forms the lateral wall of the oral cavity. It consists of the mucous membranes lining the internal surface of the cheeks and lips, extending posteriorly to the pterygomandibular raphe and vertically to the mucosa of the alveolar ridges. Topographically, the only structure present is the papillae of the parotid gland duct (Stensen's duct), which opens into the buccal mucosa opposite the second maxillary molar. The buccinator muscle, which originates in the superior constrictor muscle posteriorly and inserts into the perioral musculature, forms the lateral muscular wall of the oral cavity. The buccinator muscle assists in providing oral competence. Lateral to this muscle lie the buccal fat pad and the buccal branches of the facial and trigeminal nerves.

The motor innervation of the buccinator muscle is through the buccal branch of the facial nerve. Sensory innervation to the buccal mucosa is from the buccal branch of the

Buccal Mucosa

trigeminal nerve, with the infraorbital nerve and the mental branches of V3 supplying the anterior buccal mucosa. The vascular supply is from the facial vessels. Lymphatic drainage of the buccal mucosa is into the submental and submandibular nodes.

Deep invasion of the buccal mucosa by squamous cell carcinoma can result in invasion of the buccal fat pad. When this occurs, full-thickness resection of the cheek is necessary to obtain adequate surgical margins. Also, with deep cheek invasion consideration should be given to performing a parotidectomy to remove intraparotid lymph nodes, which may be at risk for metastases. Reconstruction of full-thickness defects of the cheek may be accomplished with pedicled flaps, rotational flaps, or more pliable fasciocutaneous free flaps.

Lower Alveolar Ridge

The lower alveolar ridge is the mucosa and alveolar process of the mandible in the oral cavity. It is bounded by the junctions with the floor of mouth mucosa on the lingual surface and the buccal mucosa. It extends posteriorly to the retromolar trigone. The mucosa of the alveolar ridge, or gingiva, is tightly adherent to the underlying periosteum and bone. The periosteum provides the first line of defense against tumor spread into the mandible. The healthy dentulous mandible provides a barrier to tumor invasion into bone because of the tight periodontal ligaments. In the edentulous mandible, as is frequently the case with oral cavity cancer, cortical remodeling of the alveolus results in vertical loss of height of the mandible and areas of incomplete cortical bone that can be a site of tumor invasion.

The vascular supply of the lower alveolar ridge and teeth is by the inferior alveolar artery, a branch of the internal maxillary artery. Sensory innervation of the mandibular teeth is from the inferior alveolar nerve, a branch of V3. These structures enter the mandible on the medial aspect of the ramus through the mandibular foramen, travel through the inferior alveolar canal, and exit at the mental foramen, opposite the second bicuspid, as the mental nerve and artery. The gingiva of the lower alveolus receives sensory innervation from the lingual nerve on the lingual aspect and from the buccal and mental branches crowded on the buccal aspect. The lymphatic drainage for the lower alveolus is through the submental, submandibular, and upper jugular nodes.

The alveolar ridge is more often involved with tumor as a result of extension from adjacent structures than by primary tumor involvement. This is true of the underlying mandible also. Treatment of mandible and oral cavity cancers is an important consideration with respect to both oncologic resection and reconstruction, and oral rehabilitation. When oncologically safe, the best function and cosmesis are provided with mandible-sparing procedures, either completely sparing the mandible or resecting a partial thickness, thus preserving mandibular arch continuity. Tumors with radiologically demonstrable or gross invasion are best treated with segmental resection and sampling of the margin of the inferior alveolar nerve to ensure clear margins. If invasion is superficial and does not involve the medullary canal, a rim or cortical mandibular resection can be considered, although segmental resection is oncologically safer. Tumors that are fixed to the mandibular periosteum but are not invading bone can be safely treated with a rim or cortical mandibulectomy, in which the alveolar process and medullary cavity are removed, saving an inferior cortical rim.

For tumors within 1 cm of the mandible but not involving the periosteum, stripping the periosteum and evaluating this as a surgical margin on frozen section may be adequate. If the periosteum is involved, partial bony resection is indicated. For patients who have had previous radiation therapy to the oral cavity, segmental resection of the mandible is the recommended treatment for tumors that invade the periosteum or bone. Partial-thickness resection brings with it the risk of osteoradionecrosis.

The need for mandibular reconstruction after segmental resection of the mandible is dependent on multiple factors. Lateral mandibular defects do not require reconstitution of the bony arch, in most circumstances, for adequate function and cosmesis. Patients with full dentition should undergo reconstruction of the lateral arch to restore postoperative dental occlusion. With anterior mandibular arch defects, reconstruction is necessary for adequate function and cosmetic results. This is best accomplished with free tissue transfer (fibular or iliac crest free flaps), although pedicled myocutaneous flaps and reconstruction plates may work in some cases.

The retromolar trigone is the portion of the alveolar gingiva overlying the ramus of the mandible. Its anterior base is posterior to the last molar. The superior apex lies at the maxillary tuberosity. It is laterally bounded by the oblique line of the mandible as it extends up to the coronoid process and is medially bounded by a line from the distal lingual cusp of the last molar to the coronoid process. This small triangular area blends laterally with the buccal mucosa and medially with the anterior tonsillar pillar. The mucosa of the retromolar trigone is tightly adherent to the underlying bone, which allows malignant tumors to infiltrate the mandible at an early stage. Also, the lingual nerve enters the mandible just posterior and medial to the retromolar trigone and may become involved with tumor relatively early. By the time of diagnosis, tumors of the retromolar trigone commonly invade surrounding structures, including the tonsil, soft palate, buccal mucosa, floor of mouth, and tongue. Conversely, the retromolar trigone is frequently involved with tumors extending from these adjacent areas. This makes it difficult to determine where the tumor originated.

Sensory innervation of the retromolar trigone is through the branches of the glossopharyngeal and lesser palatine nerves (V2). The blood supply is similar to that of the nearby tonsil, predominantly from the tonsillar and ascending palatine branches of the facial artery, with contributions from the dorsal lingual, ascending pharyngeal, and lesser palatine arteries. Venous drainage is to the pharyngeal plexus and common facial vein. Lymphatic drainage is to the upper deep jugular chain.

The upper alveolar ridge is the mucosa and alveolar process of the maxilla. It is bounded laterally by the gingivobuccal sulcus and medially is continuous with the hard palate. The hard palate is the roof of the oral cavity, extending from the alveolar ridge to its junction with the soft palate posteriorly. The hard palate is composed of mucosa covering the bony hard palate. The bony palate consists of the premaxilla, which is the part anterior to the incisive foramen and includes the incisor teeth. The secondary palate is posterior to the incisive foramen and is formed by the paired palatine processes of the maxilla and the horizontal plates of the palatine bones.

Retromolar Trigone

Hard Palate and Upper Alveolar Ridge

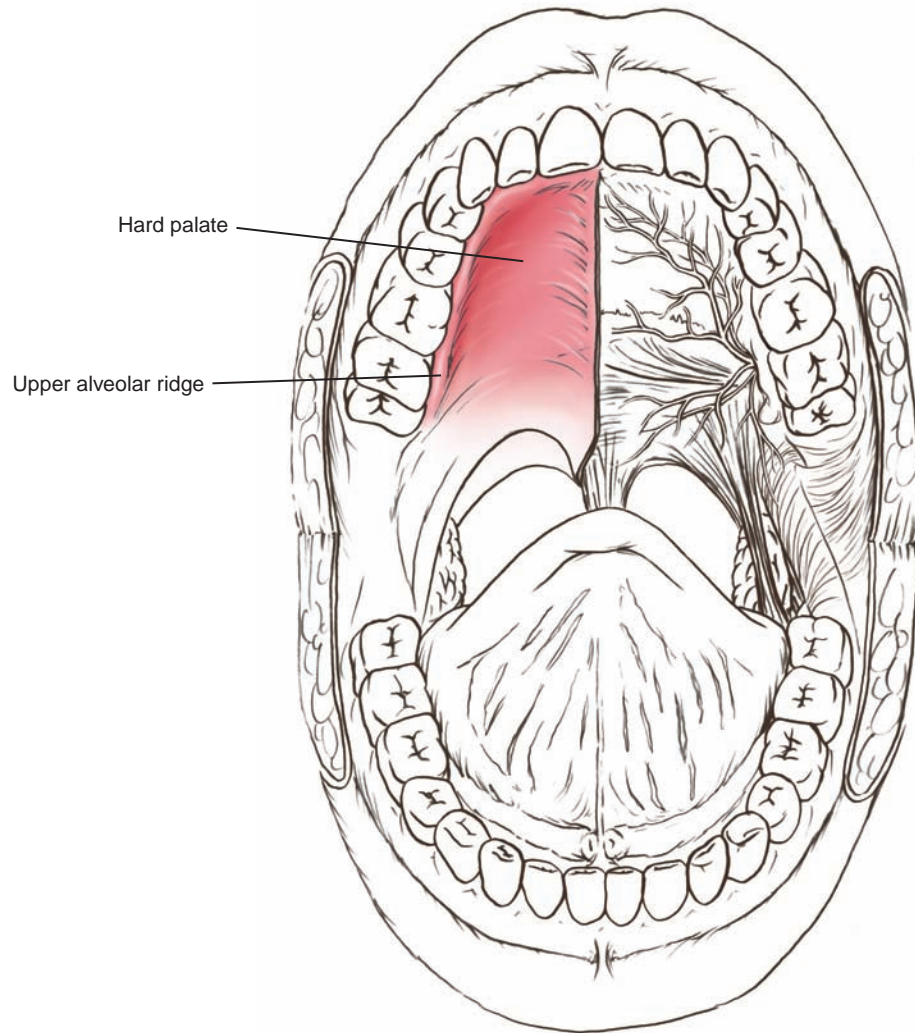


Figure 1.8

Multiple foramina are present in the hard palate and transmit the neurovascular bundles. The incisive foramen transmits the nasopalatine nerve and the posterior septal artery from the anterior nasal cavity to supply the premaxilla and lingual surface of the premaxillary gingiva.

Posterolaterally, near the junction of the hard and soft palates, are the greater and lesser palatine foramina, which transmit the greater and lesser palatine nerves and blood vessels from the pterygopalatine fossa. The greater palatine nerve and vessels supply the hard palate and lingual surface of the upper alveolus, excluding the premaxilla. Different neurovascular bundles supply the teeth and the buccolabial surfaces of the upper alveolus. The posterosuperior alveolar vessels, which descend on the infratemporal surface of the maxilla, supply the upper alveolar teeth and the buccolabial gingiva. Sensory innervation to the maxillary teeth and the buccolabial gingiva posterior to the premaxilla is from the posterosuperior alveolar nerves. The labial gingiva of the premaxilla is supplied by the branches of the infraorbital nerve. All of these nerves and vessels are terminal branches of the maxillary nerve (V2) and the sphenopalatine branch of the internal maxillary artery, respectively.

Lymphatic vessels of these structures, especially the hard palate, are sparse compared with other sites in the oral cavity. Lymphatic drainage from the hard palate and lingual surface of the upper alveolus is to the upper jugular or lateral retropharyngeal nodes. The premaxilla also drains to the submandibular nodes. The buccolabial surface of the upper alveolus drains to the submandibular nodes. The sparse lymphatics draining the hard palate result in infrequent cervical metastases from malignancies of the hard palate (10–25%). For this reason, neck dissection is reserved for clinically positive lymph nodes.

The foramina of the hard palate provide pathways of extension of malignancy to the nasal cavity through the incisive foramen, and the pterygopalatine fossa through the palatine foramina. Evaluation of tumors of the hard palate and upper alveolus requires radiologic evaluation for possible perineural spread to the skull base. Magnetic resonance imaging (MRI) with gadolinium is useful for this purpose.

Although squamous cell carcinoma is the most common malignancy found in the hard palate, minor salivary gland tumors are nearly as frequent. Adenoid cystic carcinomas are the most common lesions, followed by mucoepidermoid carcinomas. These tumors have a higher likelihood of neural spread.

Treatment of hard palate and upper alveolar ridge malignancies, except in small tumors or those superficial tumors limited to the mucosa, may require partial or total maxillectomy. This results in communication of the oral and sinonasal cavities. Unlike other areas of the oral cavity where flap reconstruction is usually performed, palatal rehabilitation is best achieved with use of a palatal obturator or modified denture to restore oral competence.

Oropharynx

Along with being continuous with the oral cavity anteriorly, the oropharynx forms a tube continuous with the nasopharynx superiorly and the hypopharynx inferiorly. The oropharynx is first considered as part of the larger structure, the pharynx, and then separately. The pharynx is constructed of a myofascial framework that encloses the pharyngeal lumen and its contents. The external surfaces of the pharynx make up portions of the borders of important deep neck spaces involved in various disease processes, such as the parapharyngeal space.

The pharyngeal wall is composed of stratified squamous epithelium that covers the internal surface of the myofascial layer, which extends from the skull base superiorly to the level of the inferior border of the cricoid cartilage inferiorly. This myofascial layer is composed of three paired muscles, which are U-shaped with the opening anteriorly. These muscles form a telescoping structure, with the lower muscles overlapping the upper muscles at the inferior border. All three sets of muscles insert posteriorly on a midline posterior pharyngeal raphe, which is suspended superiorly from the pharyngeal tubercle of the basiocciput.

These paired pharyngeal constrictor muscles (superior, middle, and inferior) are covered internally and externally by fascial layers. Internally the constrictor muscles are covered by the pharyngobasilar fascia, which is thick superiorly and thin inferiorly and covers the constrictor muscles the length of the pharynx. Superiorly the pharyngobasilar fascia is attached to the pharyngeal tubercle of the occiput, extends along the petrous portion of the temporal bone, and attaches anteriorly to the medial pterygoid plate and the pterygomandibular raphe. This upper, thick portion of the fascia suspends the superior constrictor muscle from the skull base. The external surface of the pharyngeal constrictor muscle is covered by the buccopharyngeal fascia, which covers the pharynx at the level of the superior constrictor muscle and fuses below this level with the middle layer of deep cervical fascia, which forms the remainder of the external fascial covering of the pharynx.

The superior pharyngeal constrictor muscle originates from the medial pterygoid plate and pterygomandibular raphe anteriorly, its fibers extending posteriorly in a horizontal and slightly superior and inferior direction to insert on the posterior pharyngeal midline raphe. This muscle surrounds the oropharynx.

Between the overlapping layers of pharyngeal constrictor muscles are intervals through which structures enter the pharynx. The interval between the superior and middle constrictor muscles is traversed by the stylopharyngeus muscle, which extends from the styloid process and extends inferiorly and anteriorly in an oblique fashion to attach to the medial aspect of the middle constrictor muscle. The glossopharyngeal nerve, which supplies sensory innervation to the base of tongue and the pharynx, also traverses this interspace and, along with the lingual artery, runs deep to the hyoglossus muscle. The stylohyoid ligament, which attaches to the lesser cornu of the hyoid bone, also traverses this interval. This interval between the superior and middle pharyngeal constrictor muscles lies at the inferior pole of the tonsil and provides a pathway of extension of tumor to the parapharyngeal space, which lies lateral to the superior constrictor muscle.

The motor innervation of the pharyngeal muscles is from the pharyngeal plexus, which is composed of the pharyngeal branches of the glossopharyngeal and vagus nerves. The glossopharyngeal nerve supplies only the stylopharyngeus muscle and the vagal contribution supplies all the other muscles, including the muscles of the soft palate (with the exception of the tensor palatini muscle, which is supplied by the mandibular branch of the trigeminal nerve).

The vascular supply of the oropharyngeal mucosa is from the ascending pharyngeal artery, a branch of the external carotid artery. The venous drainage of the pharynx is through the pharyngeal plexus on the posterior surface of the pharynx, which drains into the pterygoid plexus, the superior and inferior thyroid veins, and the facial vein, and directly into the internal jugular vein. The lymphatic drainage of the oropharyngeal mucosa varies depending on the anatomic level. The posterior drainage is through the retropharyngeal lymph nodes (nodes of Rouvier), located behind the pharynx at the level of the carotid bifurcation. Drainage of the lateral pharyngeal structures is to the jugulodigastric and midjugular lymph nodes in the deep jugular chain.

The oropharynx is located at approximately the level of the second and third cervical vertebrae. Its boundaries extend superiorly from the junction of the hard and soft palates to the inferior margin at the level of the plane of the hyoid bone. Anteriorly it extends to the junction of the anterior two-thirds and posterior third of the tongue, at the level of the circumvallate papillae. The oropharynx contains the soft palate and uvula, palatine tonsils and tonsillar fossae, base of tongue, valleculae, and lateral and posterior oropharyngeal walls.

The soft palate is a dynamic muscular structure that extends from the level of the hard palate anteriorly and ends posteriorly in a midline protuberance, the uvula. Laterally the soft palate blends with the tonsillar area. The soft palate closes off the oropharynx from the nasopharynx during speech and swallowing to prevent nasopharyngeal reflux of air and food.

Soft Palate

The soft palate is composed of stratified squamous mucosa covering a muscular framework composed of five muscles. All of these muscles, with the exception of the tensor veli palatini muscles, are innervated by the vagus nerve contribution to the pharyngeal plexus.

The levator veli palatini muscle forms most of the bulk of the soft palate. It arises from the floor of the petrous portion of the temporal bone and the medial portion of the cartilaginous eustachian tube, medial to the pharyngo-basilar fascia. It travels inferomedially in an oblique fashion to fuse with the contralateral muscle in the posterior portion of the soft palate. Its function is to elevate the soft palate.

The tensor veli palatini muscle is the only soft palate muscle innervated by the mandibular branch of the trigeminal nerve and not the vagus nerve. It arises from the medial pterygoid plate, spine of the sphenoid bone and lateral portion of the cartilaginous eustachian tube, lateral to the pharyngobasilar fascia. It descends inferiorly to hook around the hamulus on the pterygoid bone and extends medially as a narrow tendon to insert on the posterior hard palate as the palatine aponeurosis. This muscle functions to laterally tense the palate and to open the eustachian tube orifice. Resection of the soft palate therefore frequently results in eustachian tube dysfunction and serous otitis media.

The musculus uvulae arise from the posterior hard palate and palatine aponeurosis on each side of the midline, extend posteriorly, and fuse as they form the uvula. Their function is to draw the uvula upward and forward.

The palatoglossus muscle forms the anterior tonsillar pillar, which is the anterior border of the tonsillar fossa, and demarcates the anterior margin of the lateral oropharynx. This thin muscle arises from the inferior portion of the soft palate, where it is fused to the contralateral palatoglossus muscle, and it projects inferiorly to attach to the lateral and dorsal tongue. Its function is to draw the palate down and narrow the pharynx.

The palatopharyngeus muscle forms the posterior tonsillar pillar and part of the posterior portion of the tonsillar fossa. It arises as two heads, from the hard palate and palatine aponeurosis and more posteriorly from the contralateral palatopharyngeus muscle. The muscle inserts on the fascia of the lower constrictor muscles. The

palatopharyngeus muscle draws the palate down and narrows the pharynx, in addition to elevating the pharynx.

Sensory innervation of the soft palate is through the lesser palatine branches of the maxillary division of the trigeminal nerve. Blood supply is from the lesser palatine arteries, which are branches of the internal maxillary artery and travel with the nerve through the lesser palatine foramen.

As with the hard palate, resection of tumor involving the soft palate creates a defect that allows communication of the upper respiratory tract (i.e., the nasopharynx) and the oral cavity. These defects are best addressed with use of a palatal obturator or modified denture to close the soft palate defect.

Tonsil (Palatine Tonsil)

The palatine tonsil, commonly referred to as the tonsil, is a lymphatic structure containing indentations called crypts. It resides in the tonsillar fossa. This fossa is bound anteriorly by the palatoglossal arch and posteriorly by the palatopharyngeal arch, containing the muscles of the corresponding name and referred to as the anterior and posterior tonsillar pillars, respectively. The tonsillar fossa is bound superiorly by the soft palate and inferiorly by the base of tongue mucosa. Tonsillar tissue frequently extends superiorly and inferiorly into these structures. Laterally the tonsil has a capsule formed by the pharyngo-basilar fascia. A layer of loose connective tissue separates the capsule from the superior constrictor muscle. Lateral to the superior constrictor muscle is the parapharyngeal space, of which the lateral border consists of the medial pterygoid muscle and angle of the mandible. Extension of a tumor through the buccopharyngeal fascia results in parapharyngeal space involvement. This may result in trismus because of the direct irritation or invasion of the medial pterygoid muscle.

The inferior pole of the tonsil lies at the level of the interspace between the superior and middle constrictor muscles. The glossopharyngeal nerve traverses this interspace between the superior and middle constrictor muscles at the inferior pole of the tonsil and is at risk in deep dissection during tonsillectomy.

The blood supply of the tonsil consists of five sources, all branches of the external carotid artery system. The main supply is inferiorly from the tonsillar branch of the facial artery. The ascending pharyngeal, dorsal lingual, ascending palatine branch of the facial artery, and descending palatine artery also supply the tonsil. Sensory innervation of the tonsil is through the glossopharyngeal nerve and from the greater and lesser palatine branches of the maxillary division of the trigeminal nerve. The phenomenon of referred otalgia in tumors of the tonsil is mediated through common projections of the oropharyngeal fibers of the glossopharyngeal nerve and Jacobsen's nerve (the tympanic branch of the glossopharyngeal nerve), which innervates the middle ear mucosa. Lymphatic drainage of the tonsils is primarily to the jugulodigastric lymph nodes.

Base of Tongue

The base of tongue is the posterior portion of the tongue, posterior to the circumvallate papillae and sulcus terminalis. It extends posteriorly to the level of the valleculae and is laterally continuous with the inferior pole of the tonsils. The base of tongue contains submucosal lymphatic collections referred to as lingual tonsils,

which together with the palatine tonsils and adenoids (pharyngeal and tubal tonsils) form Waldeyer's ring, a first line of immunologic defense. This is an uncommon area of primary lymphoma presentation.

The sensory innervation of the base of tongue is through the glossopharyngeal nerve, which supplies general and special visceral afferent fibers for taste. The base of tongue musculature is innervated by the hypoglossal nerve. The arterial supply of the base of tongue is through the lingual arteries. The base of tongue has a rich sub-mucosal lymphatic drainage system primarily to the jugulodigastric lymph nodes. Lymphatic drainage to both sides of the neck is common. This necessitates addressing both the ipsilateral and contralateral neck when treating tumors of the base of tongue because of the likelihood of bilateral metastases, even with small tumors.

The base of tongue extends posteriorly into paired concavities called the valleculae along the base of the lingual surface of the epiglottis. The valleculae are separated in the midline by a median glossoepiglottic fold and are bounded laterally by lateral glossoepiglottic folds, which attach the epiglottis to the base of tongue.

The remainder of the oropharynx consists of the posterior pharyngeal wall and the lateral pharyngeal wall posterior to the posterior tonsillar pillar.

Pharyngeal Relationship to Deep Neck Spaces

The oropharynx has important relationships to surrounding potential deep neck spaces, including the retrovisceral spaces and the parapharyngeal space (lateral pharyngeal space). Although not part of the pharynx, these spaces may be involved with disease that originates in the pharynx or encroaches on the pharynx. Knowledge of the anatomy of these spaces and their relationship to the pharynx is integral to understanding the surgical approaches to these spaces and the perils and pitfalls of these approaches.

Parapharyngeal Space (Lateral Pharyngeal Space)

The parapharyngeal space is typically described as an inverted pyramid-shaped space located lateral to the pharynx. Its superior extent is at the skull base, including a small portion of the temporal bone and a fascial connection from the medial pterygoid plate to the spine of the sphenoid medially. It extends inferiorly to the level of the greater cornu of the hyoid bone at its junction with the posterior belly of the digastric muscle. The superior medial border is formed by the fascia of the tensor veli palatini and medial pterygoid muscles and the pharyngobasilar fascia. Inferiorly

the medial border is formed by the superior constrictor muscle. The anterior border is formed by the pterygomandibular raphe. The lateral boundaries are the medial pterygoid muscle, the mandible, the portion of the deep lobe of the parotid gland, and a small portion of the digastric muscle posteriorly. The posterior border is the prevertebral fascia.

The parapharyngeal space is divided into a prestyloid and a poststyloid compartment by fascia extending from the styloid process to the tensor veli palatini muscle. The prestyloid compartment contains lymphatic tissue, the internal maxillary artery, and branches of the mandibular division of the trigeminal nerve. The poststyloid compartment contains the carotid artery, the internal jugular vein, cranial nerves IX, X, XI, and XII, and the cervical sympathetic chain.

Masses in the parapharyngeal space are seen as fullness or bulging in the lateral pharyngeal wall, displacing the tonsil medially or the soft palate medially and inferiorly, with contralateral deviation of the uvula. Trismus is a frequent finding, especially with parapharyngeal space abscesses or large tumors, and is due to irritation or involvement of the medial pterygoid muscle, which forms the lateral extent of the parapharyngeal space. Removal of tumors in the parapharyngeal space should be performed by external approaches to ensure control of the great vessels and major nerves in the retrostyloid compartment, especially in the case of tumors that may be displacing the neurovascular structures.

Surgical Applications

The most important aspects of surgical resection of oral cavity and oropharynx tumors are adequate preoperative assessment of tumor extent and reconstructive needs, and good intraoperative exposure. Adequate tumor resection with a 1–2-cm margin of normal tissue and frozen-section control of margins requires appropriate exposure. Many approaches to the oral cavity and oropharynx are available and the choice depends on the location, size, and invasiveness of the tumor, along with the reconstructive considerations. The possible need for mandibular resection is an important consideration in choosing a surgical approach. The following sections will discuss surgical approaches to the oral cavity and oropharynx, indications for use of each approach, and specific procedures for tumor resection.

The range of approaches includes peroral, translabial, transmandibular, and transpharyngeal routes. Each has its merits and drawbacks. The head and neck oncologic surgeon should be familiar with all of these approaches and capable of utilizing the best approach for each individual case.

Perioral Resection

Resection using the perioral route is limited to those tumors that can be adequately exposed, removed with adequate margins, and reconstructed through the mouth without additional incisions. This mainly includes small anterior tongue tumors

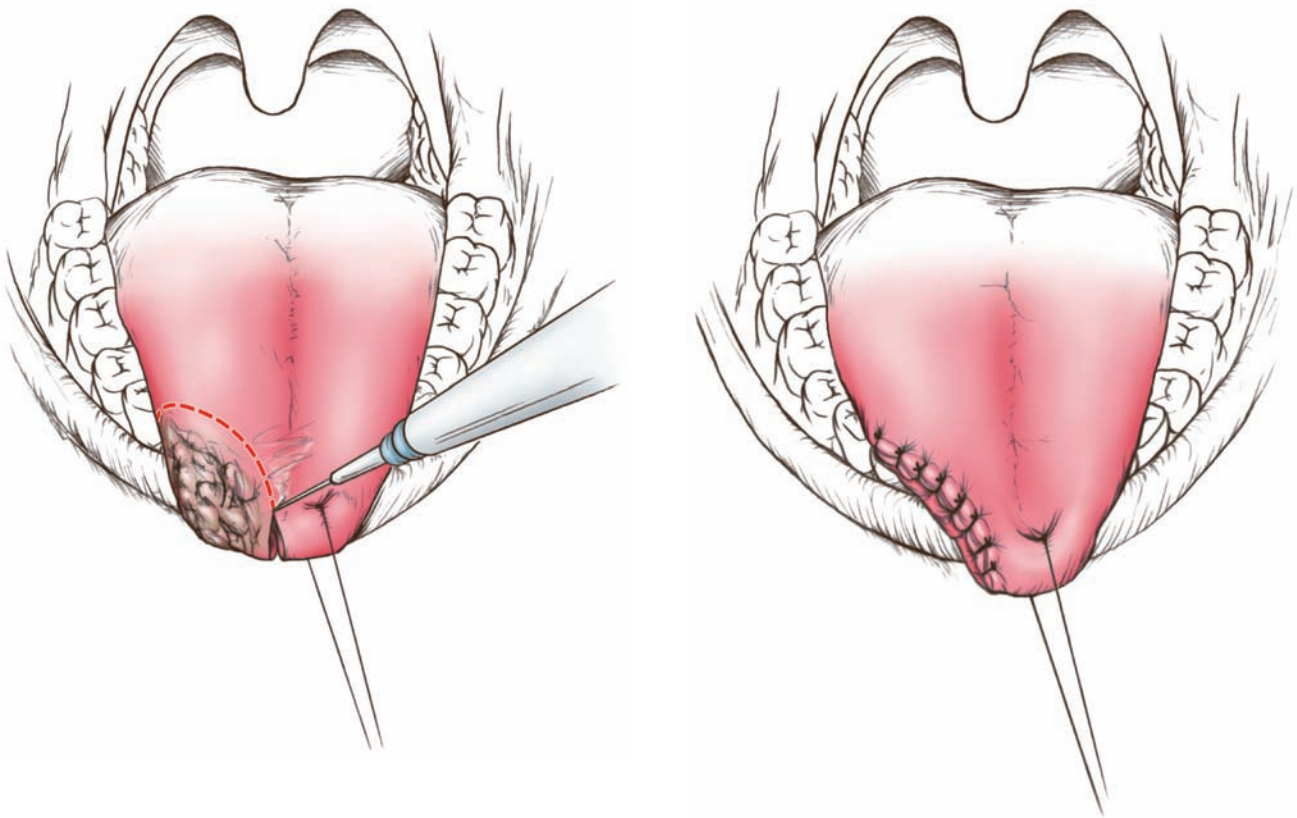
(T1 or T2), small floor of mouth tumors, small hard and soft palate lesions, and tonsil tumors. Limited anterior mandibular alveolar ridge resection in conjunction with floor of mouth resection may be performed periorally, although better exposure is afforded by translabial approaches. Peroral resection may be combined with neck dissections as indicated. Deeply invasive or advanced tumors, the need for mandibular resection, and posterior oral cavity and most oropharyngeal tumors are contraindications to perioral resection.

To optimize exposure of anterior oral cavity tumors, nasotracheal intubation is preferred. As with all head and neck tumors, prior to tumor resection a direct laryngoscopy and esophagoscopy are performed to rule out the possibility of a second primary tumor and to completely assess the extent of the primary lesion.

The jaws are opened using a side-biting oral retractor or an oral bite-block on the side opposite the lesion. The cheeks are retracted with army-navy or cheek retractors. The tongue is grasped with a towel clip or a silk suture placed through the tip of the tongue for anterior traction. When possible, palpation of the margins of the tumor with the thumb and forefinger of one hand is performed while the tumor is resected with an electrocautery. Care is taken not to bevel the cut toward the tumor to provide an adequate margin. For all but very superficial tumors or carcinoma in situ, obtaining a 1–2-cm cuff of normal tissue is preferred. Frozen-section margins are checked circumferentially and at the deep surface to ensure complete tumor removal.

Anterior Partial Glossectomy

Figure 1.9



Hemostasis is obtained with the electrocautery. Primary closure is accomplished with 3–0 chromic or Vicryl sutures in one or two layers for lateral tongue defects and two layers for midline tip of tongue defects.

Anterior Floor of Mouth Resection

Perioral resection of anterior floor of mouth tumors is generally reserved for T1 and T2 tumors and some T3 tumors that are not deeply invasive. Mandibular invasion must not be present to use this approach, although anterior rim mandibulectomy can be performed to resect tumors approximating or adherent to the periosteum.

The patient is under general anesthesia and nasotracheally intubated. Tracheotomy can be performed but is not usually necessary for transoral resection or early floor of mouth lesions. For all but superficial T1 tumors, unilateral or bilateral selective neck dissections are performed prior to addressing the floor of mouth primary tumor. The alveolar ridges are retracted apart using a posteriorly placed bite-block or side-biting oral retractor. The cheeks are retracted with cheek retractors. The tongue is retracted superiorly.

The electrocautery is used to make mucosal cuts circumferentially around the tumor with a 1–2-cm cuff of uninvolved mucosa. This frequently requires resection of a portion of the ventral tongue mucosa and musculature and possibly the lingual gingiva of the lower alveolar ridge. Submucosal dissection is carried through the sublingual glands down to the floor of mouth muscular sling (geniohyoid and mylohyoid muscles). These muscles usually provide a good barrier to deep spread of early tumors. One or both of the submandibular ducts may be transected during the deep resection. In most cases, unilateral or bilateral neck dissection will be performed

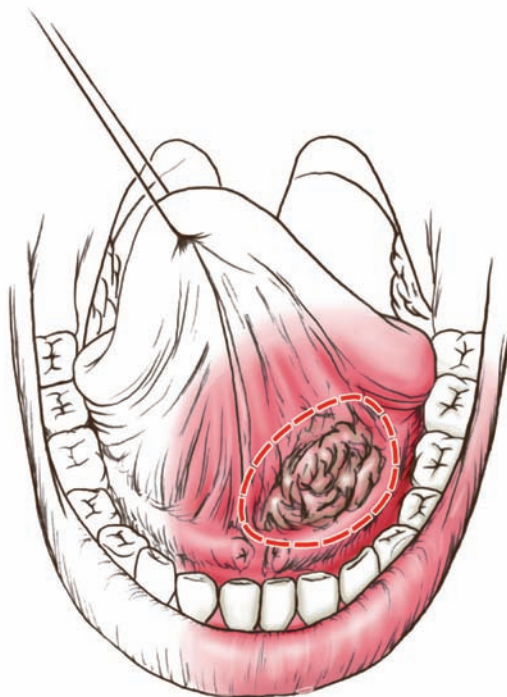


Figure 1.10

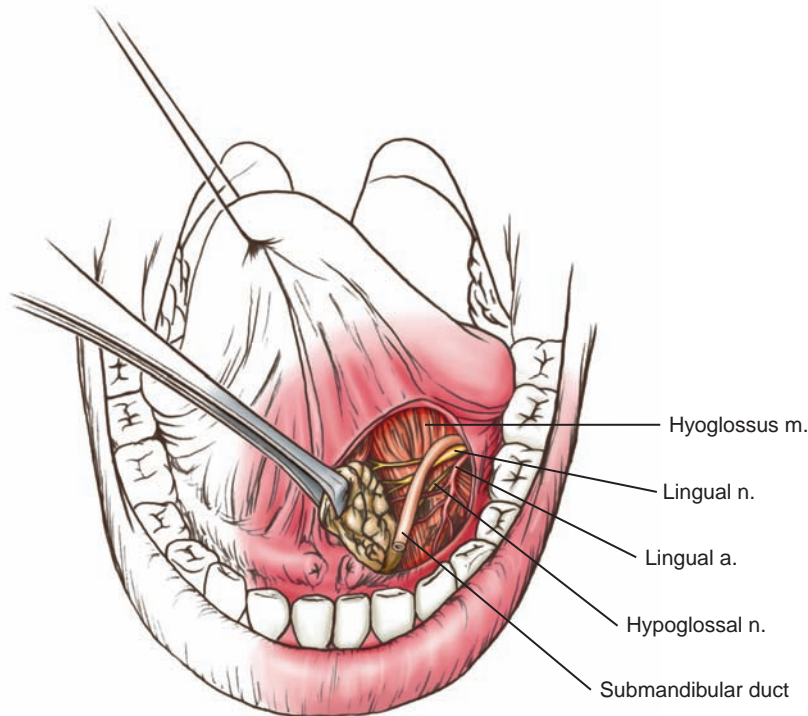


Figure 1.11

and the submandibular glands removed; therefore these ducts do not require repair. If the submandibular gland is not removed, the ducts should be reimplanted into the floor of mouth mucosa with fine (5-0 or 6-0) absorbable sutures.

Attempts to preserve the lingual and hypoglossal nerves should be made, identifying them in the neck deep to the mylohyoid muscle and following them into the floor of mouth.

Prior to removal, the specimen should be marked with sutures to alert the pathologist to the appropriate orientation of the tissue. Margins then are obtained for frozen-section analysis. A scalpel or sharp scissors is used to obtain circumferential mucosal margins and deep margins from the remaining defect, not from the specimen. Hemostasis is obtained.

For defects that are not through the floor of mouth muscular sling (i.e., communicating to the neck), several reconstructive options are available. When possible, primary closure of the mucosa is preferred, and this is performed with 3-0 chromic or Vicryl sutures. When primary closure is not possible or results in excess tethering of the tongue, healing by secondary intention is preferred. Split-thickness skin grafting may also be performed.

For anterior floor of mouth tumors approaching or involving the periosteum of the anterior mandibular arch without gross bony involvement, a marginal mandibulectomy can be performed periorally, removing the alveolar process of the mandible, after exposure is obtained as previously described. The portion of alveolar ridge to be resected is demarcated by making mucosal cuts through the buccolabial gingiva

Floor of Mouth Resection with Marginal Mandibulectomy

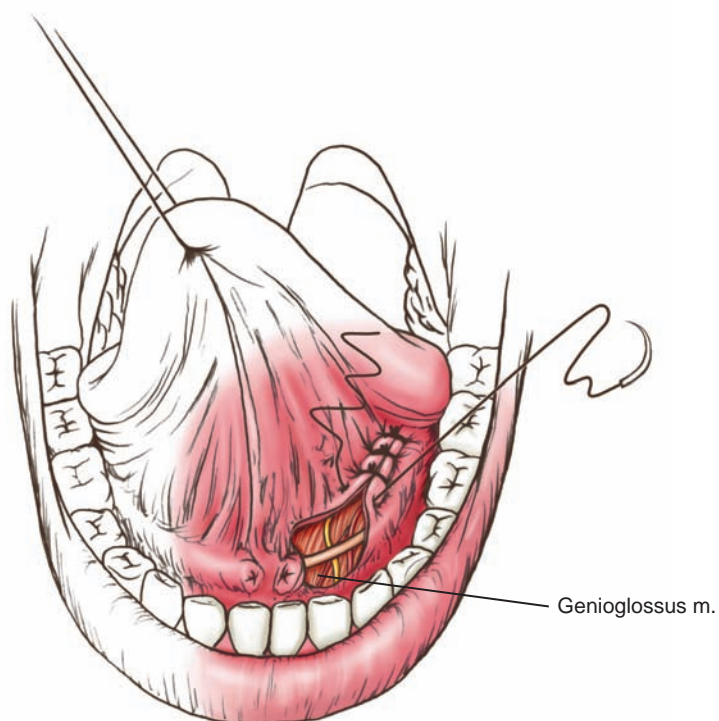


Figure 1.12

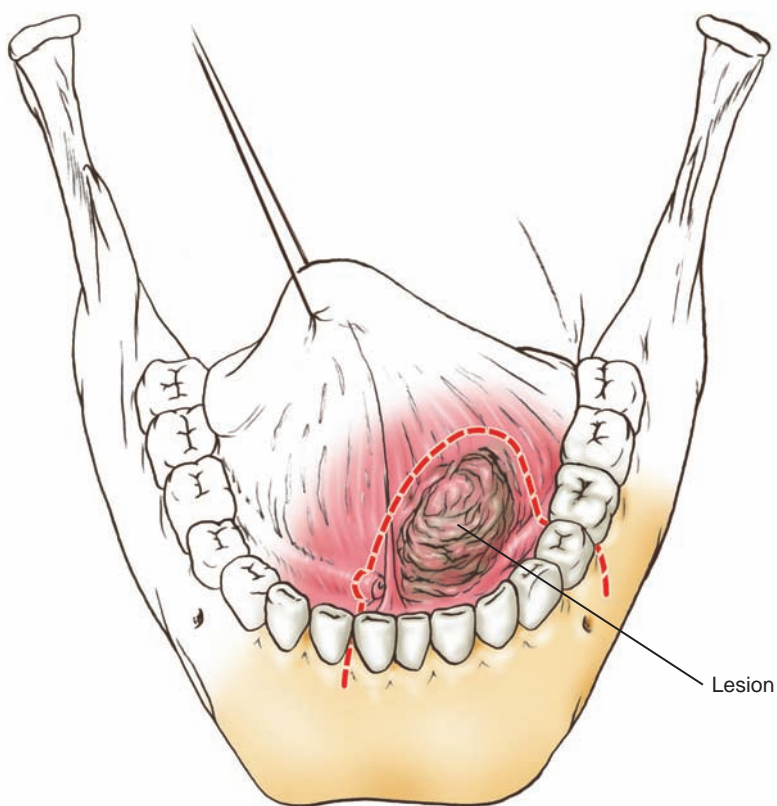


Figure 1.13

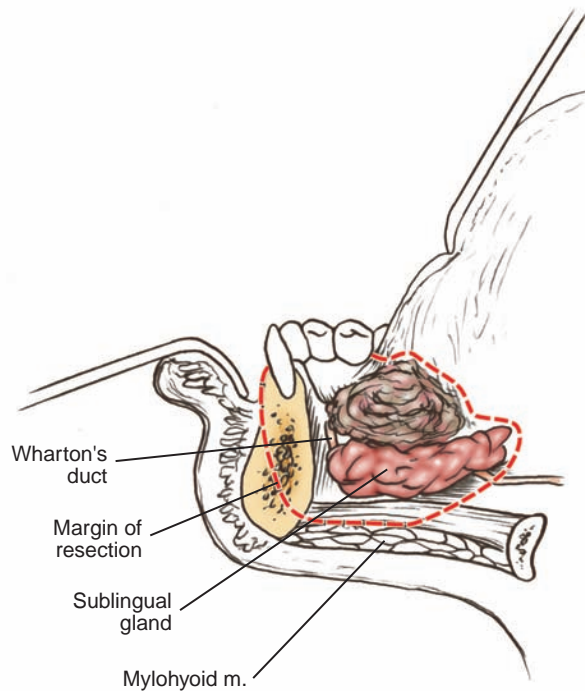


Figure 1.14

down to the mandibular bone. In the dentulous patient, the teeth in the line of the osteotomy sites are extracted so that the osteotomy can be made through the tooth socket. After the teeth are extracted, the mucosal cuts are made in the floor of mouth and ventral tongue mucosa. The mucoperiosteum of the mandible is elevated on either side of the osteotomy sites, taking care not to elevate the mucosa in the proximity of the tumor.

An oscillating saw is then used to make the bony cuts, with the inferior cut angled posteroinferiorly to remove more of the inner cortex of the mandible to increase the margin of safety of the resection. The bony cuts are made completely through the bone with the saw so that the resected segment is completely free. A rim of mandible of at least 1 cm should be preserved to retain adequate strength of the residual mandibular arch. Also, performing the inner cortical mandibular cut above the level of the mylohyoid line retains integrity of the floor of mouth muscular sling.

After the osteotomies are made, access to the floor of mouth mucosal cuts is improved and the resection proceeds as above. When possible, the lingual nerve is preserved.

Closure of this defect frequently requires use of a split-thickness skin graft, as primary closure may result in significant tethering of the tongue. A Zimmer dermatome is used to harvest a graft approximately 0.016-in. thick, from the upper lateral thigh. The graft should be large enough to cover all exposed floor of mouth and mandible surfaces without tenting the graft, allowing re-creation of the gingivolabial and gingivobuccal sulci. The split-thickness skin graft is sutured in place circumferentially with a 4-0 chromic running suture and deep quilting sutures are used to help immobilize the graft centrally. Piecrusting of the graft is performed to allow drainage areas for serum and blood.

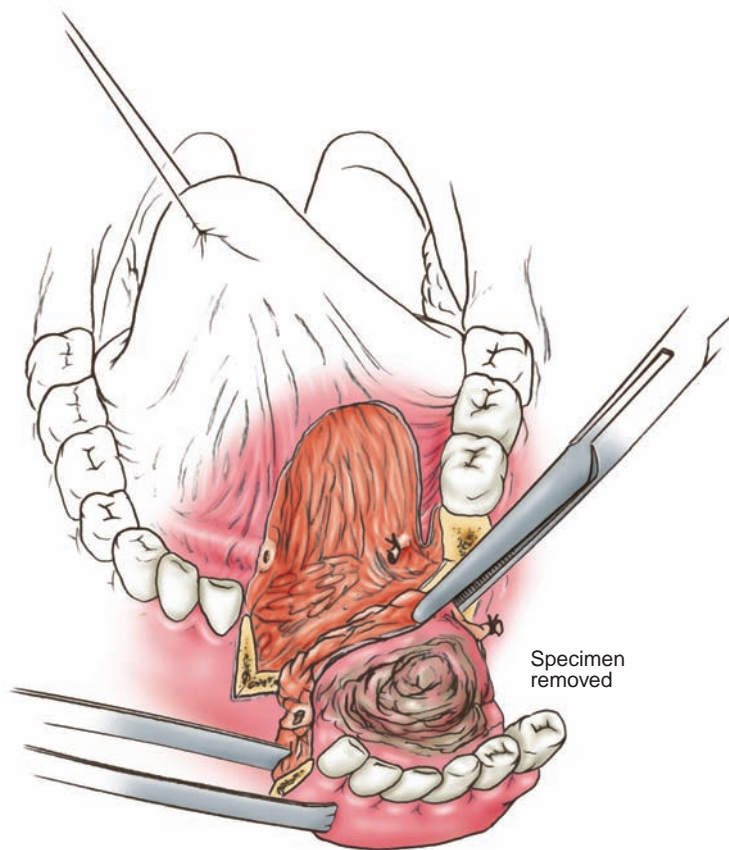


Figure 1.15

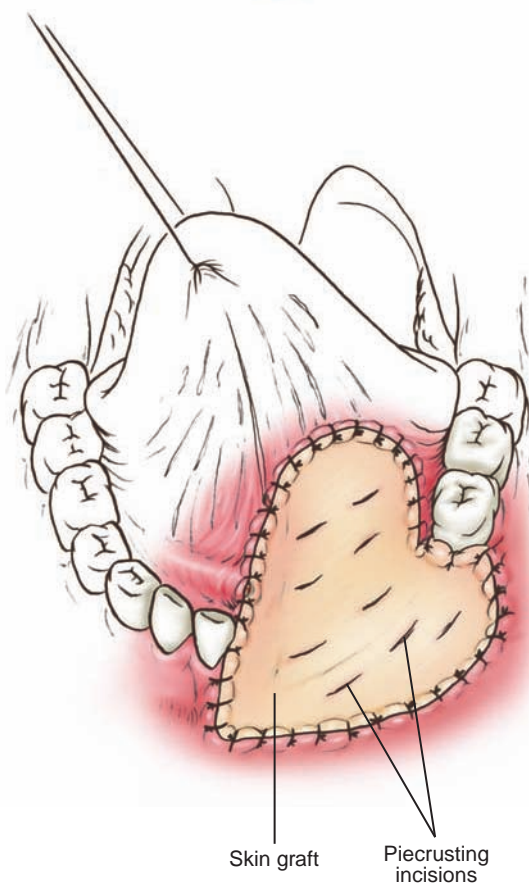


Figure 1.16

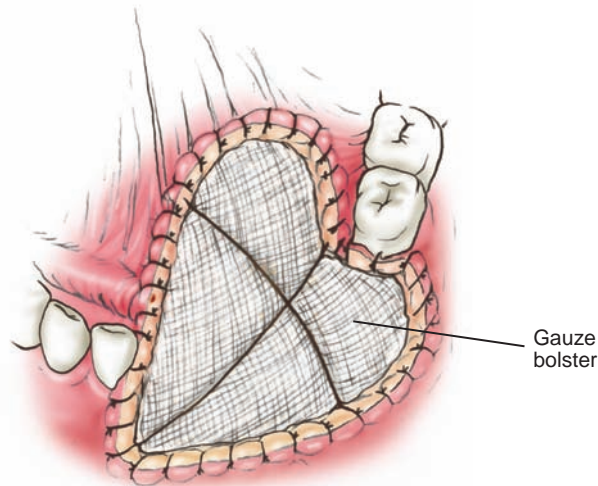


Figure 1.17

A bolster of Xeroform gauze is placed over the graft and sutured with 3-0 silk tieover sutures. This places pressure on the graft to increase the chances of graft take. The bolster should be left in place for 5 days and then removed.

Healing of the defect by secondary intention is possible, but attempts should be made to cover the exposed mandible with advancement of mucosa. Full-thickness defects that communicate with the neck may require flap closure with a platysma flap, sternocleidomastoid flap, or free tissue transfer.

Tracheotomy generally is not required unless a large amount of ventral tongue is removed, resulting in tongue edema, or a large bolster is necessary, resulting in posterior displacement of the tongue. The use of a temporarily placed nasopharyngeal trumpet to stent the oropharyngeal airway is an alternative to tracheotomy in managing the possibly narrowed upper airway after anterior floor of mouth resection. If there is any concern for possible airway compromise, tracheotomy should be performed.

Small (T1 and T2) posterior midline soft palate and uvula tumors can be resected easily through a perioral approach. Orotracheal intubation is performed, and the patient is placed supine with the head extended. A McIvor mouth gag is placed and opened as wide as possible. The soft palate is palpated to get an idea of the depth of invasion of the tumor. Local anesthetic consisting of 1% lidocaine with 1:100,000 epinephrine is injected into the soft palate at the proposed line of resection.

The uvula is grasped with a forceps and retracted inferiorly. The electrocautery is used to resect the soft palate, leaving a 1.5-cm margin of normal tissue. Care is taken to make the mucosal and muscular cuts through the soft palate perpendicular to the plane of the soft palate to avoid beveling, which can result in a closer margin than planned. Frozen-section control is performed, as with all head and neck tumors. If necessary, the resection can extend laterally to include one or both tonsils and tonsillar fossae. Hemostasis is obtained with cautery.

Soft Palate Resection

The mucosa is closed in a single layer with 3–0 Vicryl or chromic sutures when possible, or the wound can be left to granulate.

For limited resections, velopharyngeal insufficiency is not usually a permanent problem. Larger soft palate tumors that require more anterior soft palate resection result in permanent velopharyngeal insufficiency, which can be treated with the use of a palatal prosthesis to obturate the defect.

Tonsil Resection

Perioral resection of tonsil cancers is indicated for T1 and some T2 tumors that are not deeply invasive and do not involve the tongue. After direct laryngoscopy and esophagoscopy and, in the case of T2 tumors, selective neck dissection are performed, the patient is positioned supine with the neck extended. A McIvor mouth gag is placed and opened. Digital palpation is performed to determine the depth of invasion of the tumor. Local anesthetic is injected around the lesion for mucosal vasoconstriction.

The mucosal incisions are made with an electrocautery, while the tonsil is retracted medially with an Allis clamp, leaving a 1.5-cm margin around the tumor.

The superior pole of the tonsil or the superior mucosal resection edge is grasped with an Allis clamp and retracted medially. The dissection is then carried through the submucosa. At this point it is important to find the plane between the capsule of the tonsil and the musculature of the tonsil bed (superior constrictor muscle, palatoglossus and palatopharyngeus muscles), which allows a more bloodless dissection.

A Hurd elevator can be used to help bluntly find and dissect this plane by putting pressure on the tonsil from a lateral to medial direction. When this plane is identified, blood vessels are cauterized or ligated as they are encountered.

Dissection is carried out in a superior to inferior and anterior to posterior direction. For peroral resections, dissection is kept superficial to the superior constrictor muscle. If this muscle is involved with tumor, it should be resected. Since this muscle constitutes the medial border of the parapharyngeal space, which contains the great vessels and lower cranial nerves, resection of this area should be performed in combination with a neck approach for lateral exposure.

After the surgical specimen is removed, it is oriented with sutures for the pathologist. Meticulous homeostasis is obtained with the electrocautery and suture ligation with chromic sutures. Deep cautery in the tonsil bed is avoided because of proximity of the internal carotid artery. These wounds can be left to granulate, or smaller wounds may allow primary mucosal closure with 3–0 Vicryl or chromic sutures.

External Approaches

Tumors in the posterior oral cavity or oropharynx and larger tumors of the anterior oral cavity require additional surgical exposure than can be provided with peroral approaches. This requires mobilization of the soft tissue alone, or may also involve mandibular division or resection.

Lip-Splitting Incision

Surgical access to larger oral cavity and oropharyngeal tumors is limited by the size of the oral cavity opening. A lip-splitting incision frequently is used and allows

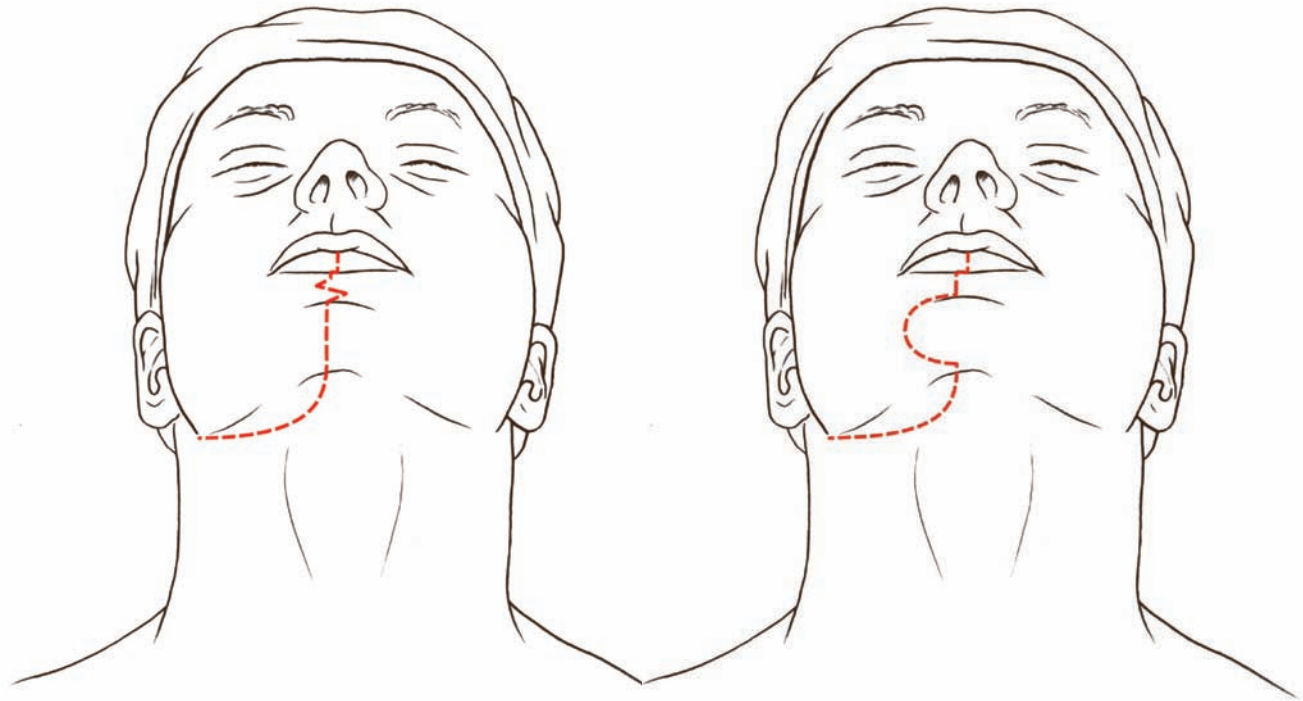


Figure 1.18

excellent exposure. This may be performed with elevation of the cheek flap to expose the lateroposterior oral cavity, body and angle of the mandible, and oropharynx, or combined with an anterior mandibulotomy without elevation of a cheek flap.

Since this type of access is nearly always performed in conjunction with neck dissection, the procedure begins with extension of the neck excision superiorly through the mental skin. The design of the translabial incision can be varied, either extending vertically through the midline of the mentum or curving around the mentum to follow the natural mental crease. I prefer to make a vertical excision through the mentum, incorporating a Z-plasty in the skin between the mental crease and the vermilion border, and a stair-step incision through the vermilion. This prevents vertical scar contraction and helps camouflage the incision. Reapproximation of the vermilion border at the time of closure is aided by incorporation of a small horizontal incision at the vermilion border. The incision through the mental skin is made down to the mandibular periosteum. The incision through the lip is performed with a fresh No. 11 blade. A stab incision is first carried through the full thickness of the lip at the horizontal limb of the vermilion border incision, followed by sharp vertical division of the lip. This transects the inferior labial artery, which runs deep to the mucosa, which can be cauterized or ligated. The limbs of the Z-plasty incision are then made with sharp stabs through the full thickness of the skin and mucosa. A mucosal incision is then made in the gingivobuccal sulcus, down to the mandible.

The gingivobuccal incision is carried posteriorly to the level of the mandibular ramus, transecting the mental nerve during flap elevation. The cheek flap will be continuous with the previously elevated neck flap.

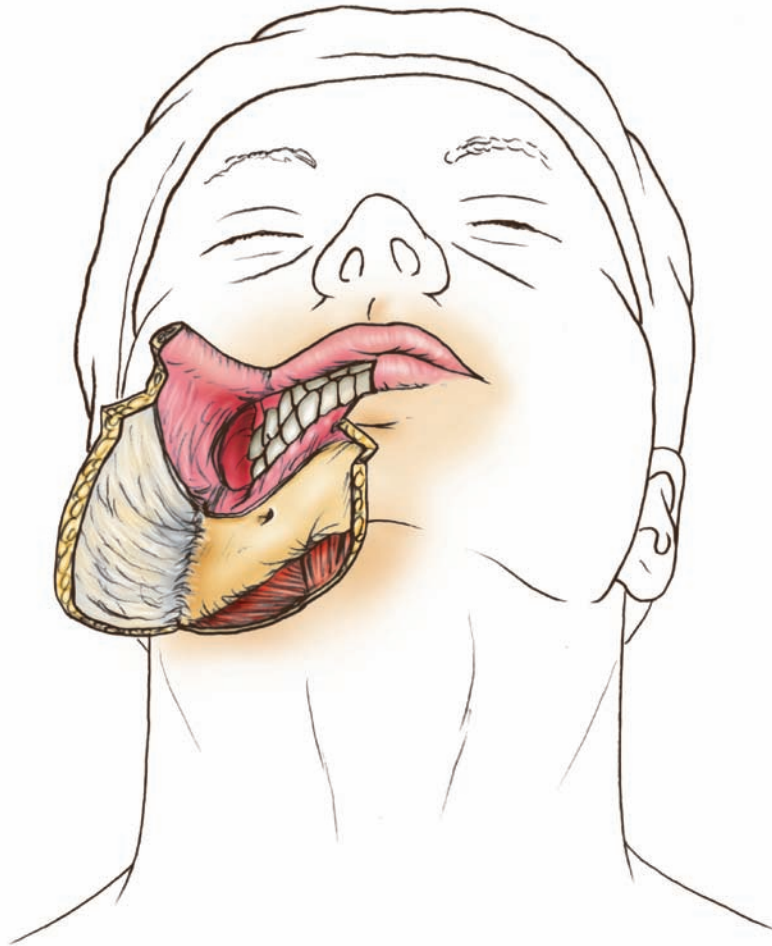


Figure 1.19

This approach provides access for resection of posterolateral oral cavity and oropharyngeal tumors and can be combined with rim mandibulectomy or segmental mandibular resection. After resection and reconstruction are complete, closure first involves reapproximation of the gingival and buccal mucosa with 3–0 Vicryl or chromic sutures. The lip is closed in three layers, with approximation of the lip musculature with 4–0 Vicryl sutures, mucosal closure with 4–0 chromic sutures, and meticulous approximation of the skin, particularly the vermilion border, with 5–0 fast-absorbing gut or Prolene sutures. The mental skin is closed with deep 4–0 Vicryl sutures. The Z-plasty incision is closed with interrupted 5–0 fast-absorbing gut sutures and the mentum with a running suture. Accurate approximation of the vermilion border and Z-plasty are of the utmost importance to prevent notching and contraction of the lower lip, respectively.

Visor Flap

The visor flap provides much more limited exposure than the lip-splitting incision, allowing access only to the anterior oral cavity. Its advantage is that facial incisions are not necessary. The major disadvantage, aside from limited exposure, is the need to transect both mental nerves, resulting in lower lip and chin anesthesia.

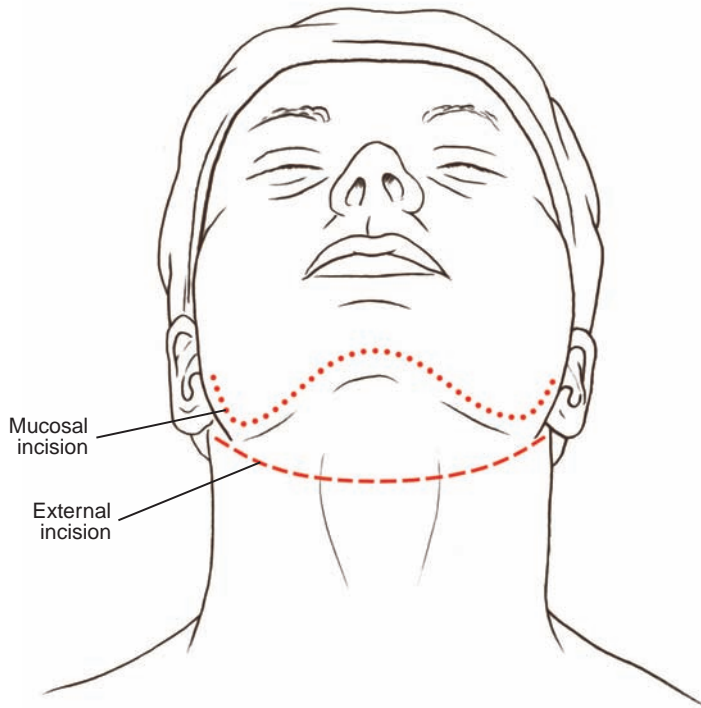


Figure 1.20

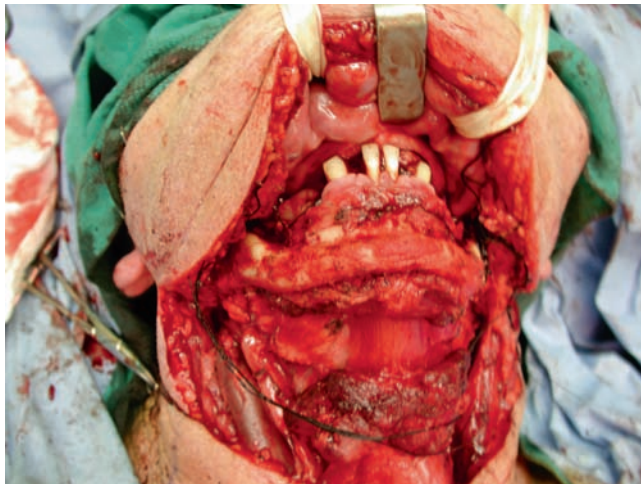


Figure 1.21

The visor flap procedure involves an external incision that extends between the angles of the mandibles, usually performed in conjunction with unilateral or bilateral neck dissection. The flap is elevated in a subplatysmal plane to the inferior rim of the mandible. An intraoral incision is then made with the electrocautery in the gingivobuccal sulcus from one angle of the mandible to the other. This mucosal incision is carried down to the mandible, transecting the mental nerves. This allows connection of the intraoral and external incisions.

Large Penrose drains are placed around each side of the lip for superior retraction. This allows exposure of the anterior oral cavity. This is especially useful for

larger floor of mouth cancers requiring segmental resection of the anterior mandibular arch. Unilateral visor flaps can be used for lateral mandible exposure for mandibulotomy, but exposure is more limited.

Closure is with 3–0 Vicryl sutures in the gingivobuccal sulcus to provide a watertight seal. The neck is closed as usual in two layers, including reapproximation of the platysma muscle and subcutaneous tissue and closure of the skin. Drainage is through the neck with suction drains through separate stab incisions.

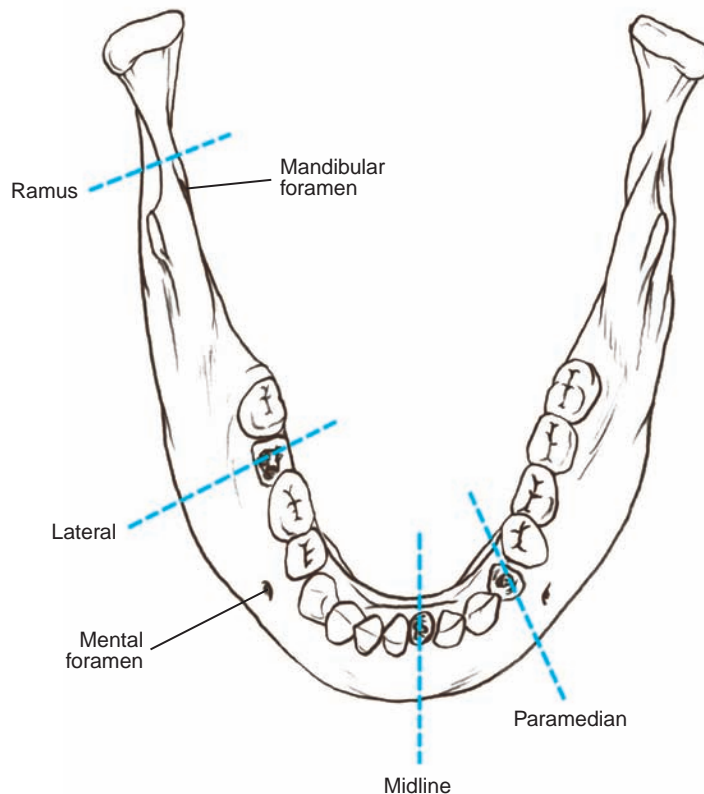
Mandibular Osteotomies

Further exposure of the posterior oral cavity, oropharynx, parapharyngeal space, and skull base is obtained with transmandibular approaches, involving transection or segmental resection of the mandible.

Mandibular osteotomies can be performed in the midline, paramedian (anterior to the mental foramen), or lateral (on the body or angle of the mandible) portions of the mandible or on the ascending ramus (posterior to the mandibular foramen). All but the ramus osteotomy require exposure through a lip-splitting incision or visor flap. Mandibular osteotomies also require a tracheotomy because of postoperative edema.

Mandibulotomies, whether lateral or medial, follow the same general principles. A midline mandibulotomy is depicted here. The mandible is exposed, usually by a lip-splitting incision. The mandibular periosteum on either side of the proposed incision is elevated with a periosteal elevator. In dentulous patients, the tooth in the line of the proposed osteotomy site is extracted (i.e., a molar for lateral osteotomies,

Figure 1.22



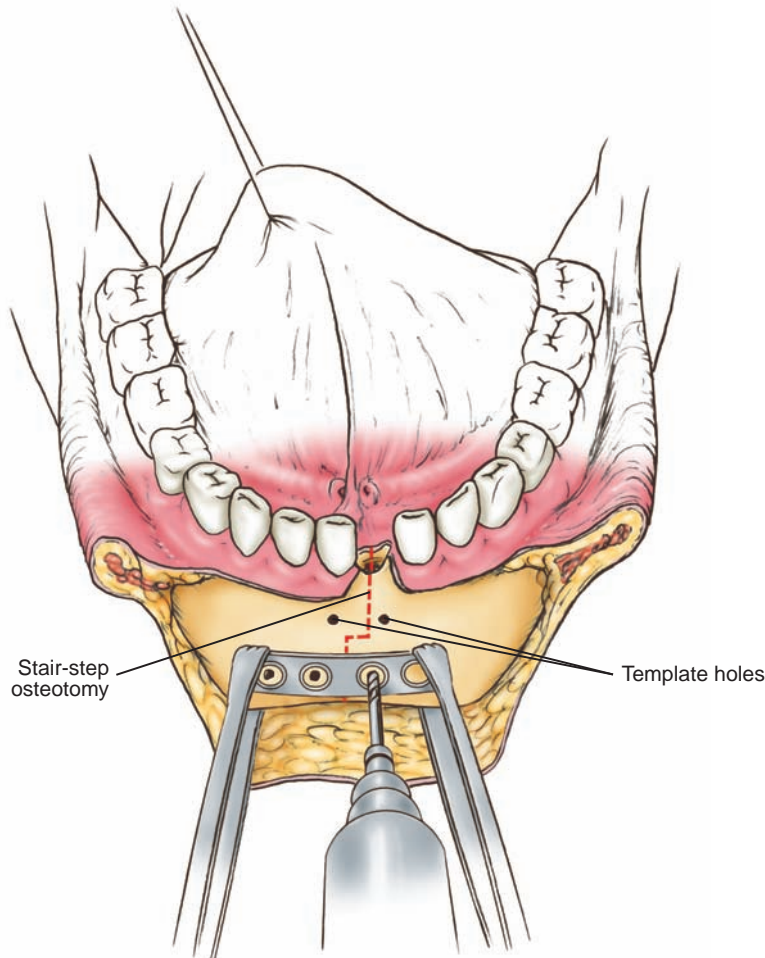


Figure 1.23

canine or premolar for paramedian osteotomies, and a central incisor for midline osteotomies). Osteotomies between adjacent teeth are not performed because of the risk of devitalizing both teeth. The bony cut is marked on the mandible, designed to extend through the extraction socket. A stair-step pattern affords a greater surface contact area for osteosynthesis.

Prior to making the bony cuts, mandibular fixation plates are fitted to the mandible and the holes are drilled and screws placed to allow better reapproximation of bone at the time of closure. At least two screws on either side of the osteotomy are needed for stabilization of the mandible. The screws and plates are then removed. An oscillating saw is used to make the bone cuts. Bleeding at the cut ends can be controlled with cautery or bone wax.

When the bone cuts are complete, the edges of the bone can be distracted away from each other. The lingual gingiva is then incised with an electrocautery, allowing exposure of the floor of mouth mucosa. Tumor excision is then performed as indicated.

After the resection and closure of the surgical defect the mandible is reapproximated using the previously fashioned fixation plates. The plates and screws are replaced, allowing reapproximation of the mandible and restoration of dental occlusion. The remainder of the closure is performed as previously described.

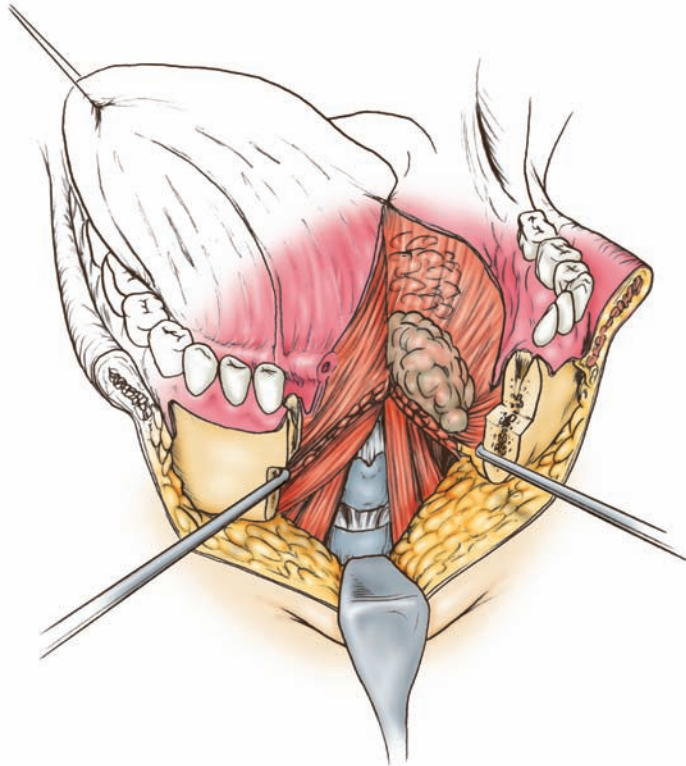


Figure 1.24

Lateral Mandibulotomy Approach to Tonsil Resection

Lateral mandibulotomy provides direct access to the posterior oral cavity and oropharynx, including the tonsil, retromolar trigone, base of tongue, soft palate, and posterior pharyngeal wall. It is particularly useful when the tumor approaches the mandible and the possibility exists for the need to perform a segmental mandibulectomy. The disadvantage is that it results in transection of the inferior alveolar nerve, with resultant lower alveolar and chin anesthesia. Here it is discussed in the context of resection of a tonsil cancer.

A tracheotomy and neck dissection are performed prior to addressing the oral cavity primary tumor. The best access for this approach is obtained with a lip-splitting incision and a lateral cheek flap, as previously described. The lateral mandibular approach can also be performed through a visor flap.

If tumor approaches or involves the periosteum of the mandible, marginal resection should be performed, leaving an intact inferior rim of mandible. If this is to be performed, care should be taken in elevating the cheek flap so that the mucosal incision does not approach within 2 cm of the lateral extent of the gingival or retromolar trigone tumor margin. A mucosal incision is made with an electrocautery, leaving a 1.5–2-cm margin of normal tissue around the tumor.

The portion of bone to be removed is determined and the appropriate teeth extracted so that the vertical limbs of the osteotomy can proceed through the extraction sockets. The periosteum is elevated along the lateral aspect of the osteotomy site inferiorly, only so as not to elevate the periosteum over the upper alveolus, which will

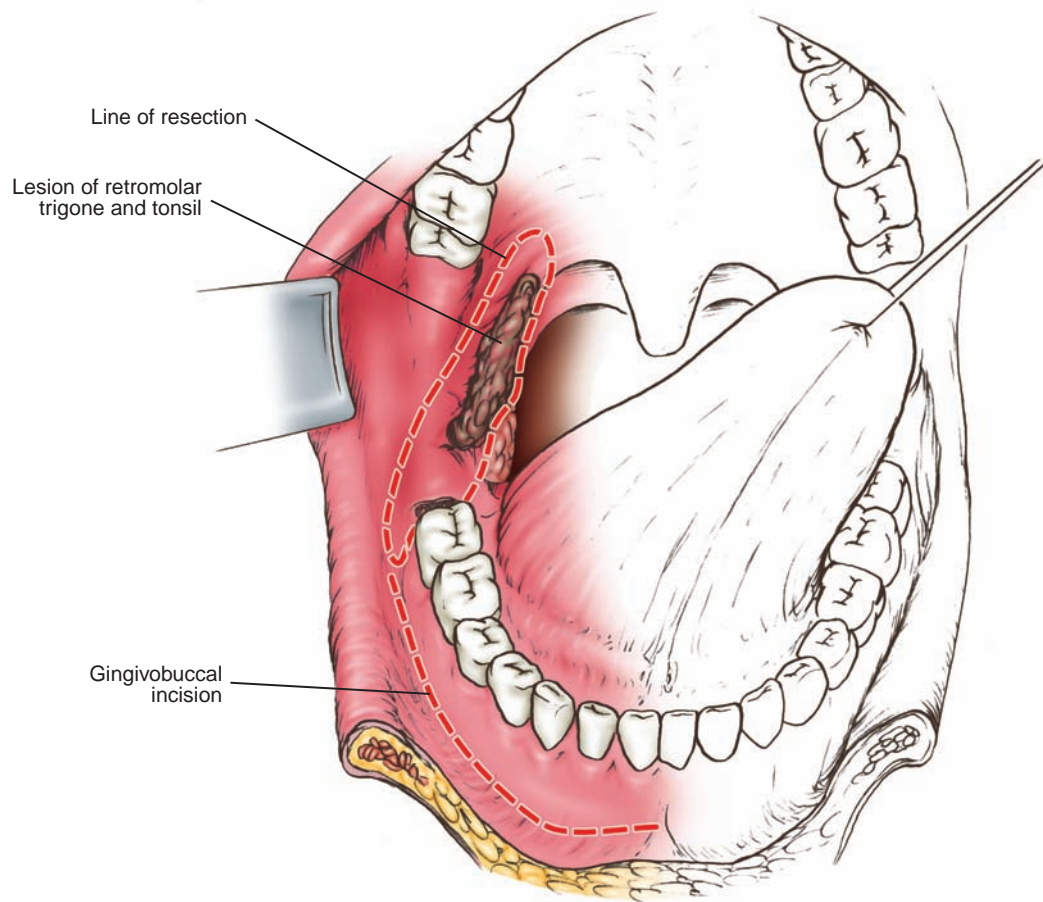


Figure 1.25

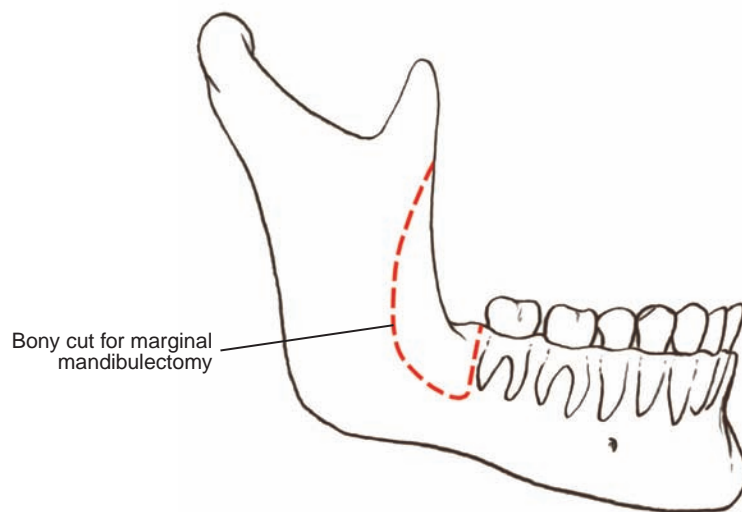


Figure 1.26

be resected. An oscillating saw is used to perform the osteotomies, first performing the vertical limbs and then the horizontal osteotomies. The horizontal limb of the osteotomy is angled slightly inferiorly as needed to remove more of the medial cortex of the mandible. In dentulous patients, the osteotomy site is made below the tooth roots. Care should be taken to ensure that the osteotomies are completely through the bone and that undue force is not placed on the bone to complete the osteotomies to avert possible fracture of the residual inferior cortex. At least 1 cm of inferior cortical bone should be preserved to maintain strength of the mandibular arch.

After the alveolar ridge osteotomies are performed and the bone is mobile, the soft tissue resection can proceed in an anterior to posterior and superficial to deep direction, maintaining a 1.5–2-cm margin of normal tissue. After the tumor is removed, it is oriented for the pathologist and frozen-section margins are obtained.

Closure of this type of defect usually can be performed with a combination of primary closure and skin grafting. Care is taken not to produce excess tethering of the tongue when approximating tongue mucosa to buccal mucosa, if it can be avoided.

Skin grafting over the alveolar ridge is frequently possible if radiation therapy has not been administered to the mandible and prevents tethering of the tongue. If greater exposure is needed, the rim mandibulectomy can be performed in conjunction with a lateral mandibulotomy.

For tumors requiring more exposure but not requiring segmental mandibular resection, a lateral mandibular osteotomy can be performed. The site of the proposed osteotomy is usually approximately at the level of the anterior mucosal margin of the resection. Prior to performing the osteotomy, the mandibular fixation plates are

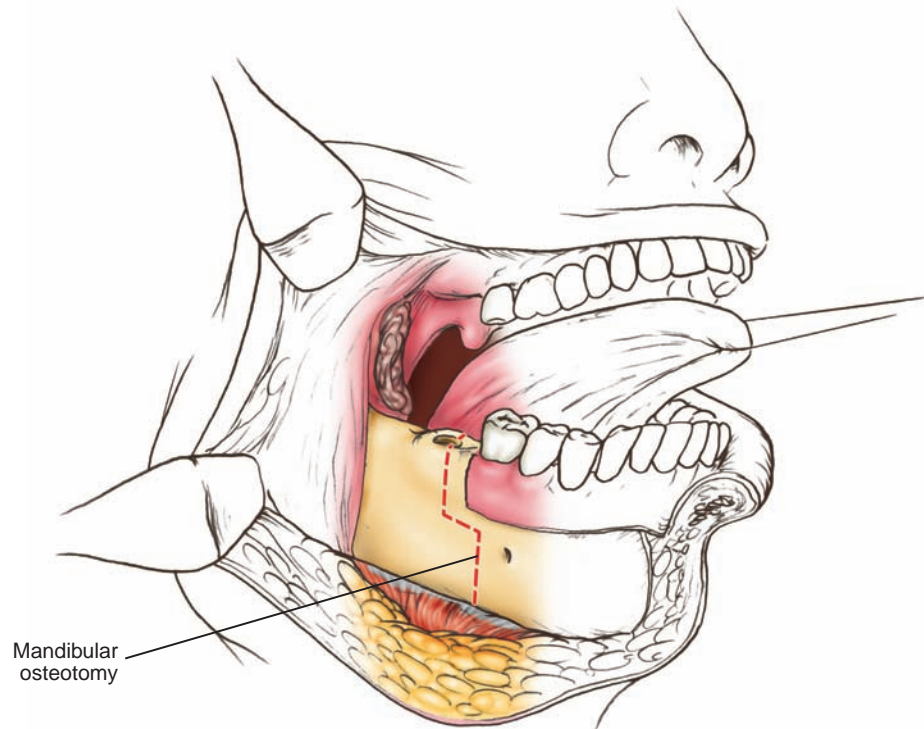


Figure 1.27

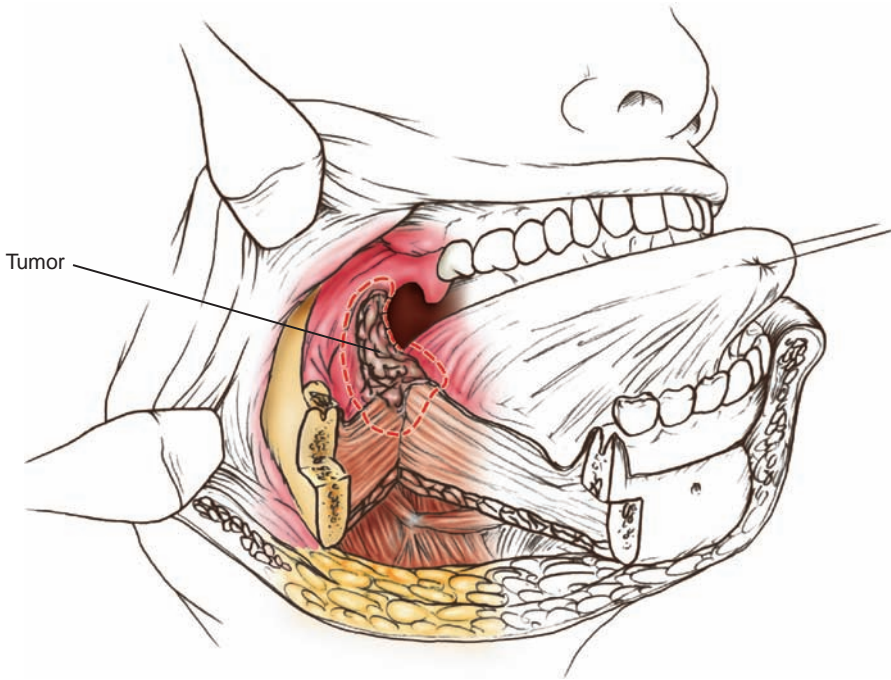


Figure 1.28

fitted, the holes drilled, and the screws placed. The screws and plate are then removed. The osteotomy is performed in a stair-step fashion as previously described.

Lateral distraction of the anterior and posterior mandibular segments allows exposure to the lingual gingiva, which is transected and the soft tissue resection performed as needed. This approach allows good access to the lateral posterior floor of mouth, posterior tongue and tongue base, tonsil, and soft palate. It also provides good access to the parapharyngeal space.

After soft tissue resection is completed, the defect is closed with either primary closure, split-thickness skin grafting, or a flap. Closure of the mandibulotomy involves replacement of the plates and screws. The lip-splitting excision is closed as previously described. The patient is given a soft diet for approximately 6 weeks postoperatively to allow for appropriate healing of the mandibulotomy.

For tonsil and other oropharyngeal tumors with mandibular invasion, a segmental mandibular resection should be performed. This is referred to as a composite resection. A lip-splitting incision is performed and a cheek flap elevation carried out as previously described.

Care should be taken in elevating the cheek flap so as not to make any mucosal incisions within 2 cm of the tumor. The degree of mandibular resection is determined based on the extent of bony invasion.

At least a 2-cm margin of noninvaded normal bone is resected on either side of the tumor. For tumors with deep bony invasion into the medullary space, the entire medullary canal from the mandibular foramen to the mental foramen should be resected, as the tumor may have spread through the medullary canal. The appropriate teeth are extracted to allow the osteotomy site to be performed through an extraction socket

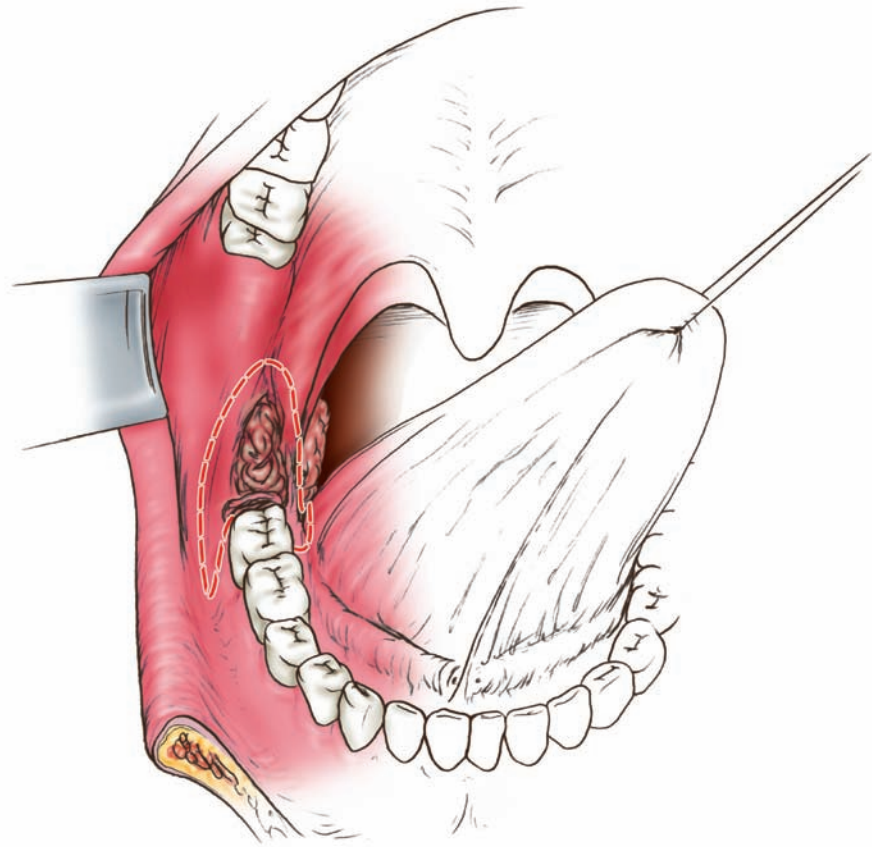


Figure 1.29

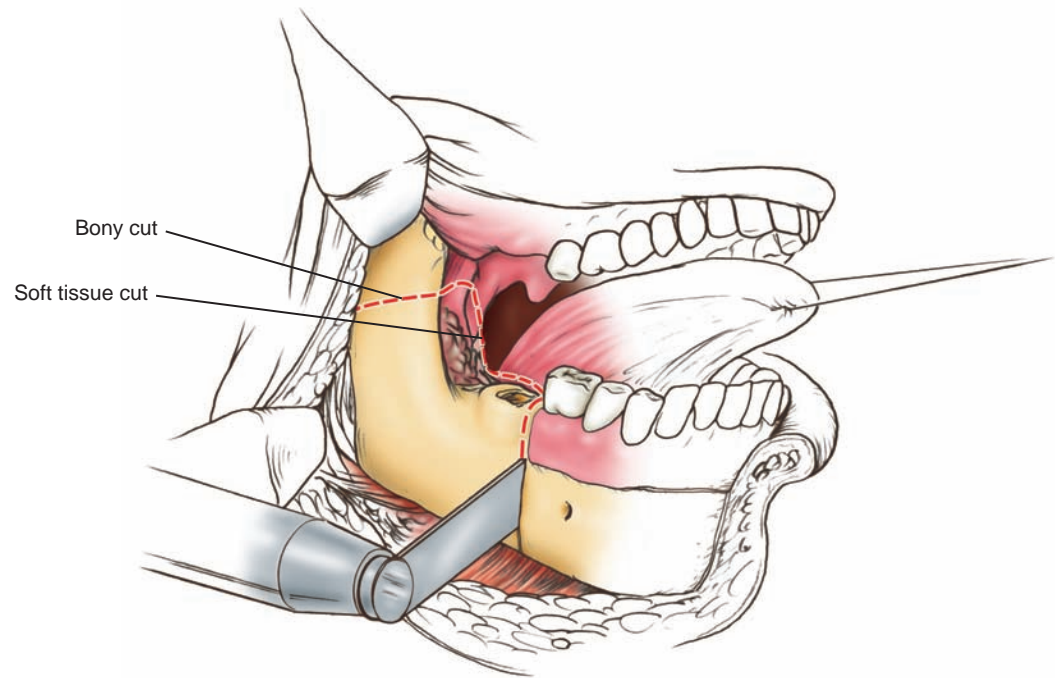


Figure 1.30

in the dentulous patient. Mucosal incisions are performed through the gingiva at the proposed osteotomy site. Elevation of the mucoperiosteum is performed only on the distal side of the proposed osteotomy site (on the mandible to remain). Mucoperiosteum should be minimally elevated on the portion of the mandible to be resected. An oscillating saw is used to perform the osteotomies. In segmental resections of the mandible, a stair-step incision is not necessary and a cut that is perpendicular to the long axis of that particular portion of the mandible is preferred. This usually involves a vertical cut through the body of the mandible and a horizontal cut thorough the ascending ramus. To prevent injury to the underlying soft tissues, a malleable retractor is placed on the underside of the mandible during the osteotomies to prevent the saw from penetrating the mucosa of the tongue or floor of mouth. This is especially important when performing the ascending ramus osteotomy, since deep penetration of the saw could cause inadvertent injury to the branches of the internal maxillary artery or the internal carotid artery.

After the osteotomies are completed, the anterior aspect of the transected mandible is distracted laterally to allow exposure to the medial soft tissues. The electrocautery is used to perform the deep tissue resections in an anterior to posterior direction. The final soft tissue cuts will involve resection of the medial pterygoid muscle from the medial aspect of the mandible. For patients who have trismus secondary to medial pterygoid muscle involvement, the pterygoid muscle should be resected as high as possible from the pterygoid plates.

Because of the close proximity of the carotid artery to the deep tissues of the tonsil, exposure of the carotid artery and protection with a malleable retractor is necessary to prevent injury, especially during the posterior mandibular cuts and transection

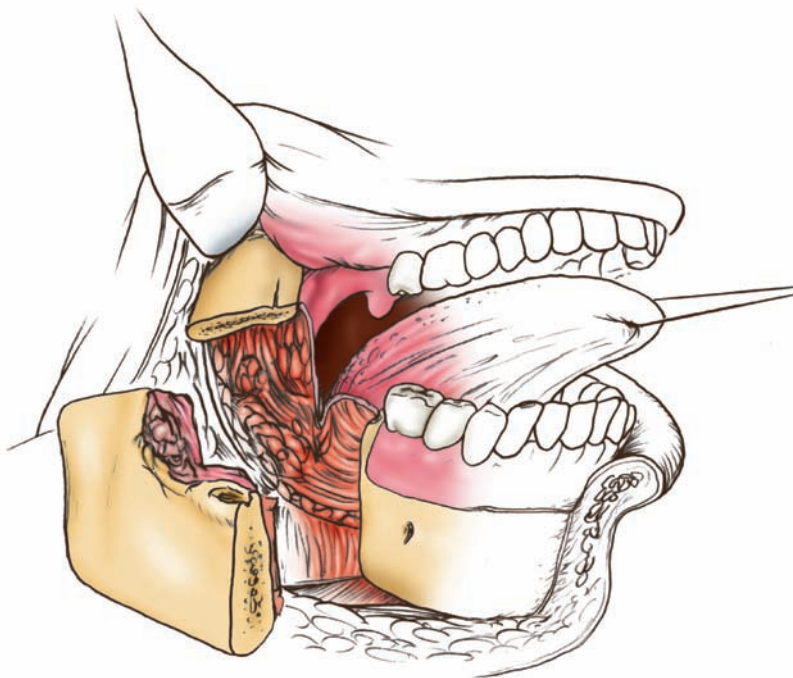


Figure 1.31

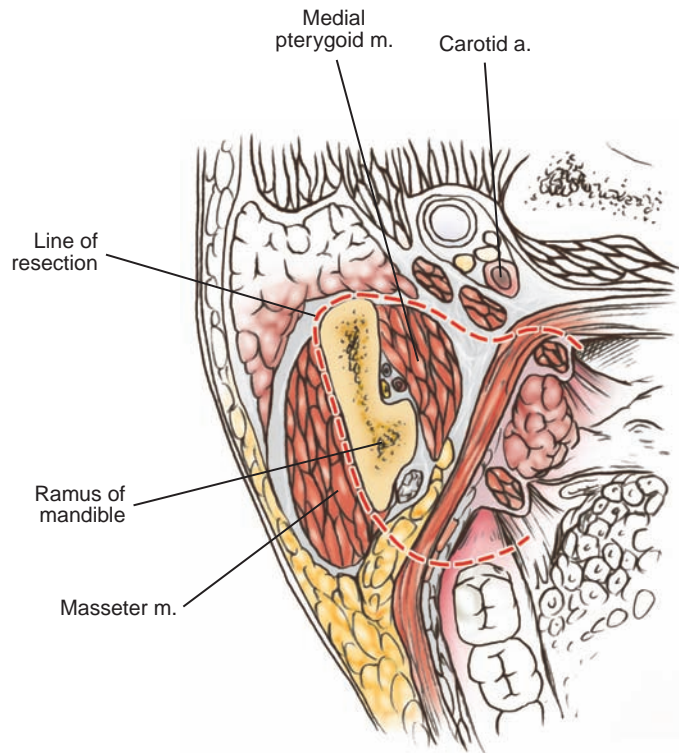


Figure 1.32

of the pterygoid musculature. After the tumor resection is completed, the tissues are oriented for the pathologist and frozen-section margins are obtained. Good hemostasis, especially in the area of the pterygoid muscles, is then obtained with cautery and suture ligation. Occasionally, dissolvable hemostatic packing is necessary to control persistent oozing from the pterygoid venous plexus.

Reconstruction of the defect, if mandibular reconstruction is not planned, can sometimes be performed by primary closure of the deep tissue and mucosa. Closure with a distant flap is usually necessary, especially if excessive tethering of the tongue occurs with primary closure.

A pectoralis major myocutaneous flap is the most frequently used form of closure. It provides bulk and epidermal closure, restoring contour to the lateral oral cavity and reducing tongue tethering. In most patients reconstitution of continuity of the mandibular arch is not necessary in lateral defects.

If reconstruction is planned, prior to mandibular resection a reconstruction plate is contoured to the lateral mandible, the holes are drilled, and screws are placed. At least three screws need to be placed on either side of the osteotomies. This reconstruction plate is then removed prior to performing the osteotomies.

After the tumor is resected, the mandibular plate is replaced and reconstruction is completed with a pectoralis major flap or a free osteocutaneous flap (i.e., fibula or iliac crest). Closure then proceeds as previously described.

Reconstruction of segmental anterior mandibular defects (e.g., after resection of advanced lip or anterior floor of mouth tumors) is always necessary to restore oral function and cosmesis. This is best accomplished with a free osteocutaneous flap,

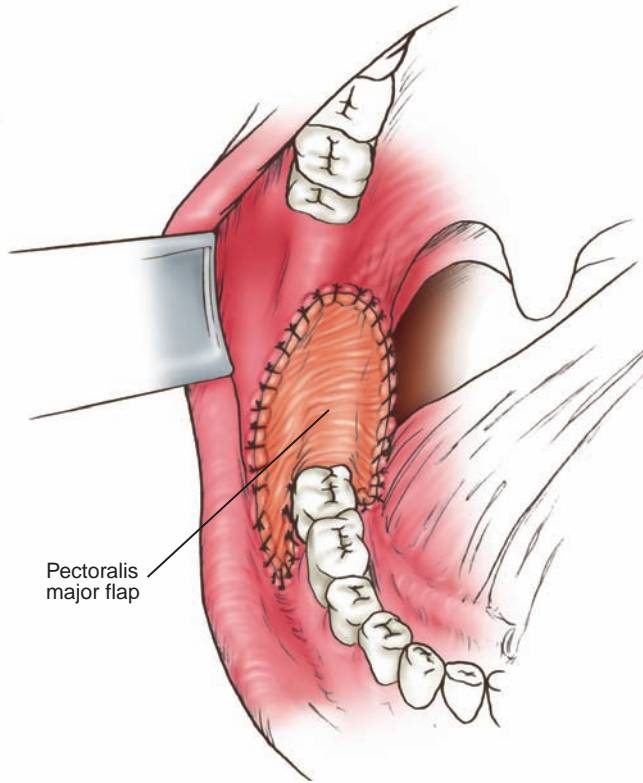


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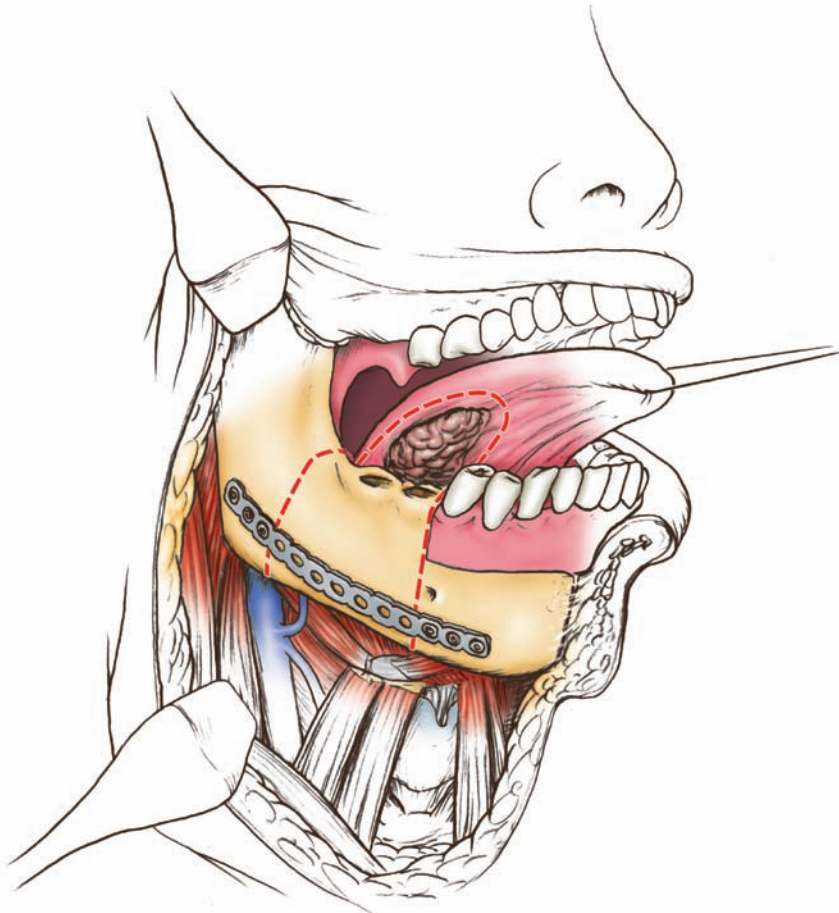


Figure 1.34

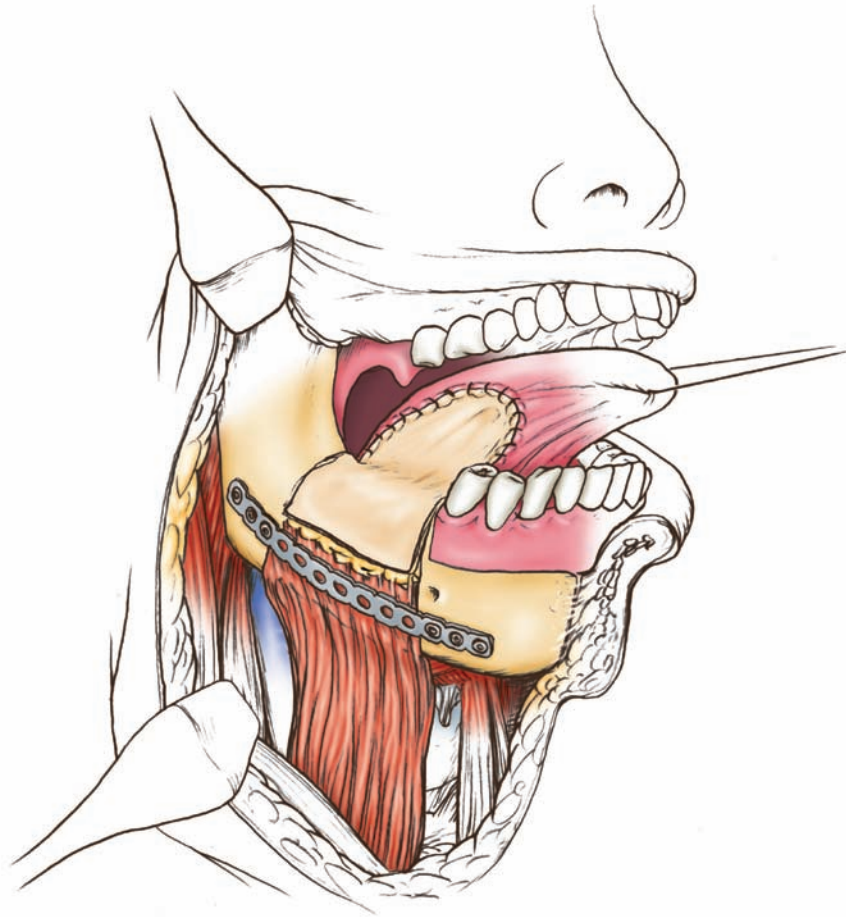


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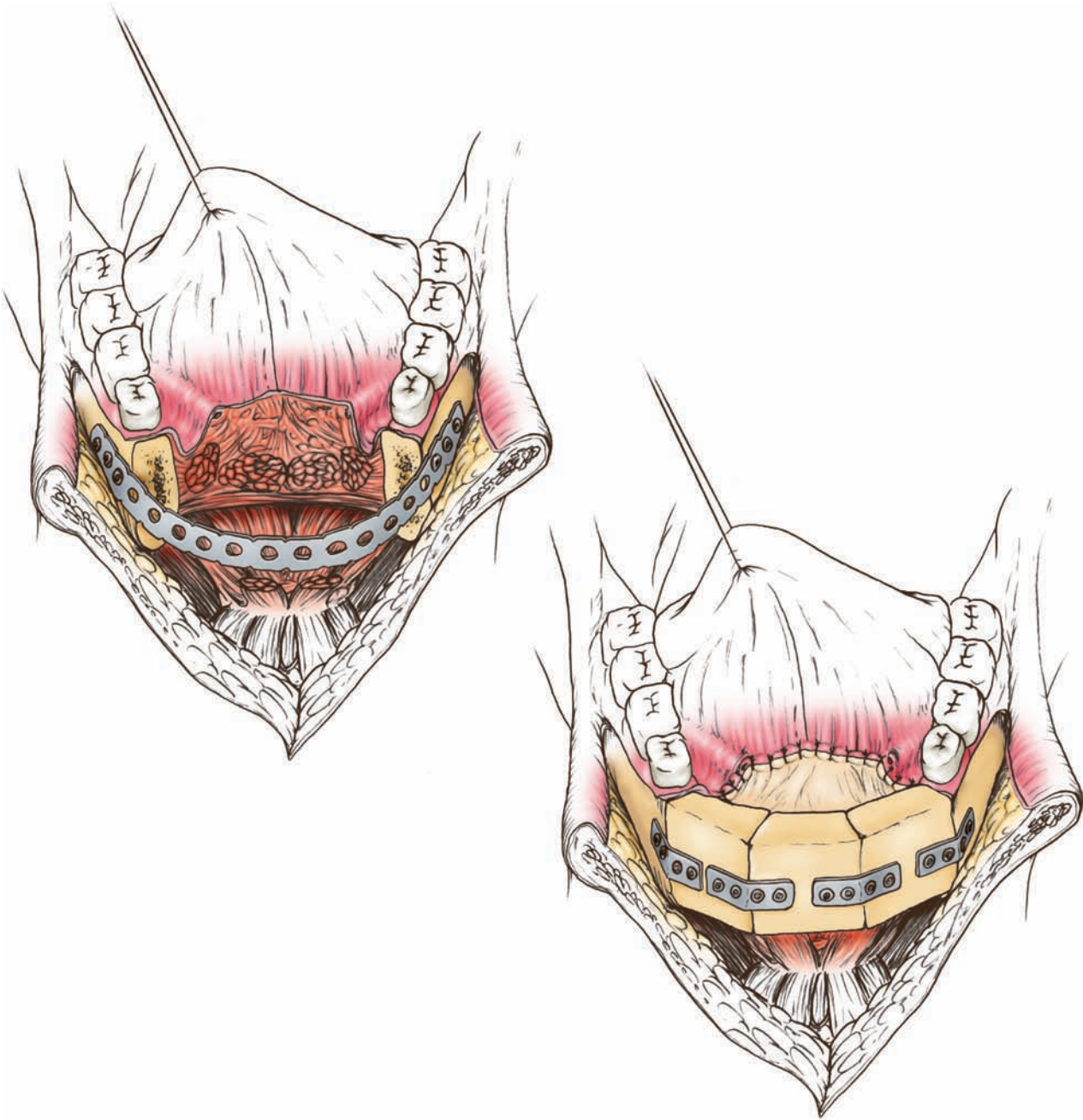
usually the fibula free flap, but the iliac crest is suitable when more soft tissue is needed. The skin is used to reconstruct the floor of mouth, the chin skin, or both.

Mandibular Swing Approach to Resection of Oropharyngeal Tumors

The mandibular swing procedure provides excellent exposure of the oral cavity and entire oropharynx along with the parapharyngeal space. It is indicated for posterior oral cavity and oropharyngeal tumors that do not require segmental mandibular resection. If segmental mandibular resection may be necessary, this approach is not used because subsequent segmental resection would be committed to include the entire hemimandible. A lateral mandibulotomy approach is best in this situation. The mandibular swing procedure also has the advantage of sparing the mental nerve.

The procedure begins with a tracheotomy and neck dissection (if necessary). The neck incision is continued superiorly into a lip-splitting incision. If a midline mandibulotomy is to be performed, no cheek flap elevation is performed. If a paramedian osteotomy is to be used, a cheek flap is elevated only to the level of the mental foramen preserving the mental nerve (a midline mandibulotomy is depicted).

A mandibular fixation plate is fitted to the osteotomy site, the holes are drilled and screws placed, and the plate is removed. The mandibulotomy is performed



through an extraction socket in dentulous patients, usually through a central incisor. After the mandibulotomy is performed, the ends of the mandible are distracted laterally, exposing the floor of mouth mucosa. An incision is made in the floor of mouth mucosa with the electrocautery from anterior to posterior, just medial to the lingual gingiva. A 1 cm cuff of floor of mouth mucosa should be preserved laterally for ease of closure at the end of the procedure. The submandibular duct orifice should be included with the mandibular segment. The deep incision is carried through the floor of mouth musculature, separating the muscular sling from the mandible. This allows significant distraction of the mandibular segments.

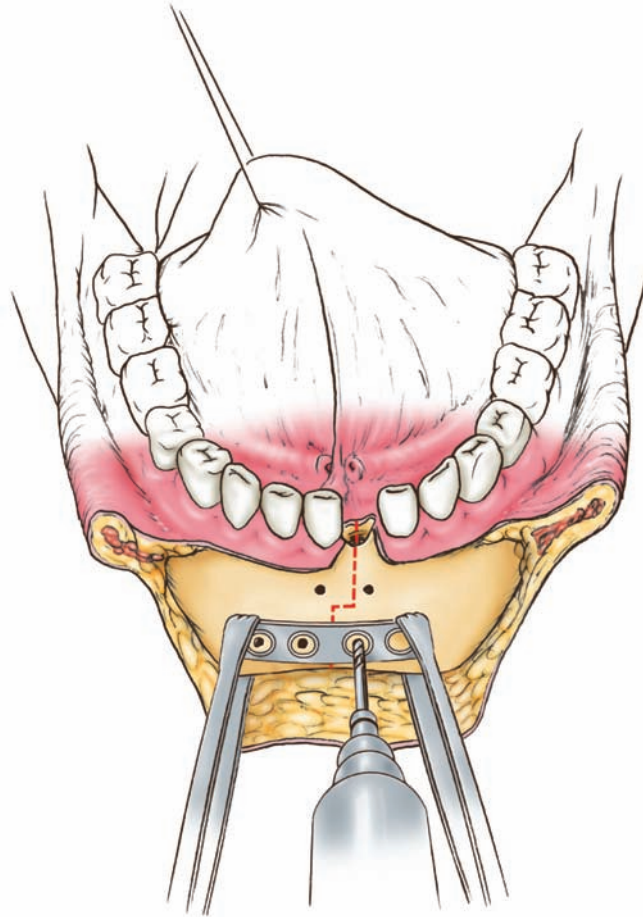


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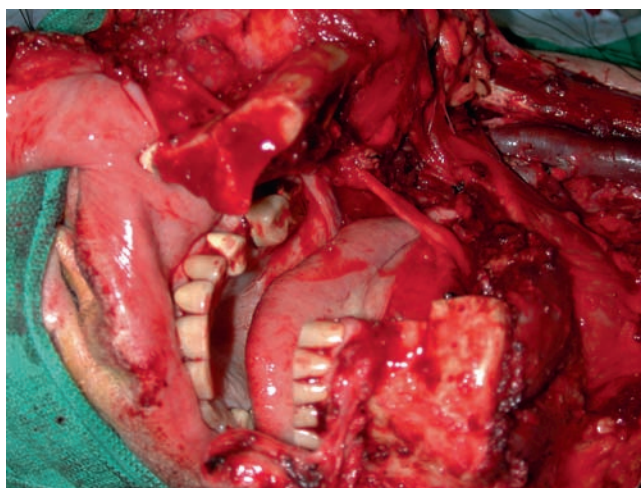


Figure 1.38

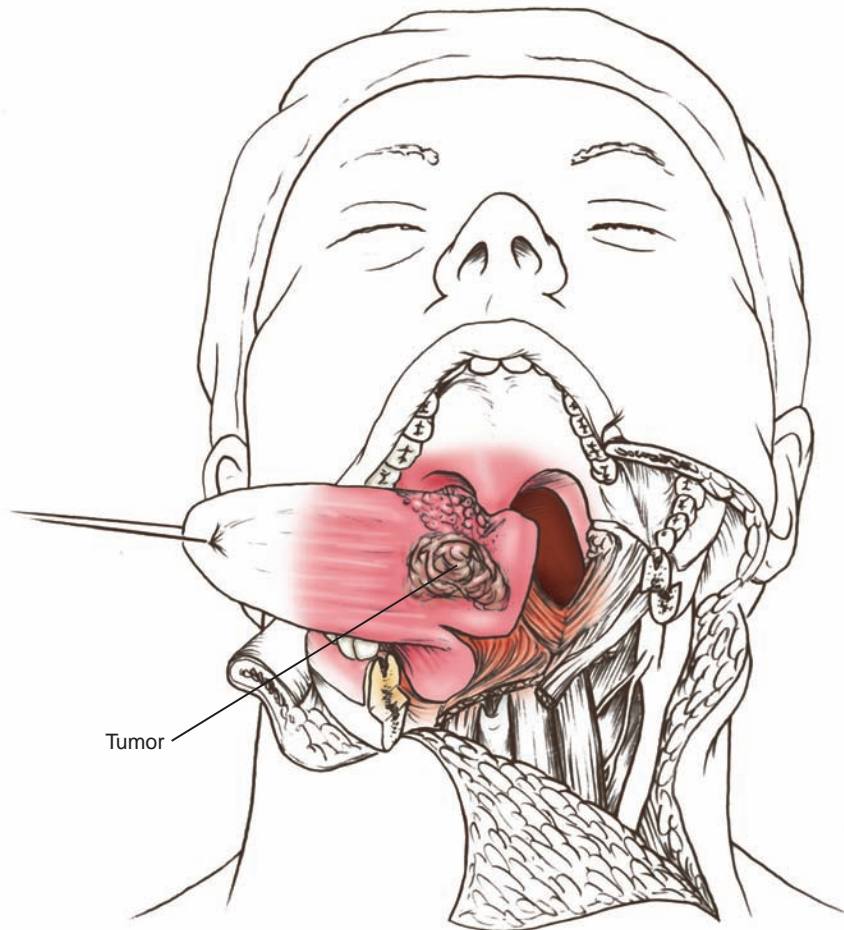


Figure 1.39

The lingual and hypoglossal nerves should be identified and preserved if possible. The mucosal incision can be carried superiorly along the anterior tonsillar pillar to include the tonsil or extended up onto the soft palate to access the superior parapharyngeal space.

The mucosal incision can also be carried posteriorly through the palatoglossal fold and down the lateral pharyngeal wall at its junction with the base of tongue to the level of the hyoid bone. This provides excellent exposure of the base of tongue and valleculae. The tumor is visualized and the Bovie used to resect it with a 2-cm margin of normal tissue. Frozen-section control of margins is performed.

If possible, primary closure of the tongue with interrupted 3-0 chromic or Vicryl sutures is preferred. Other options include a tongue setback procedure to move the oral tongue posteriorly or a pedicled myocutaneous flap or free flap.

For tumors involving the entire tongue or root of tongue, total glossectomy is indicated. Total glossectomy can be performed with the mandibular swing approach by making bilateral floor of mouth incisions extending all the way back to the hyoid bone. The infrahyoid musculature is then transected from the inferior surface of the hyoid bone to release the tongue from the supraglottic larynx.

Total Glossectomy

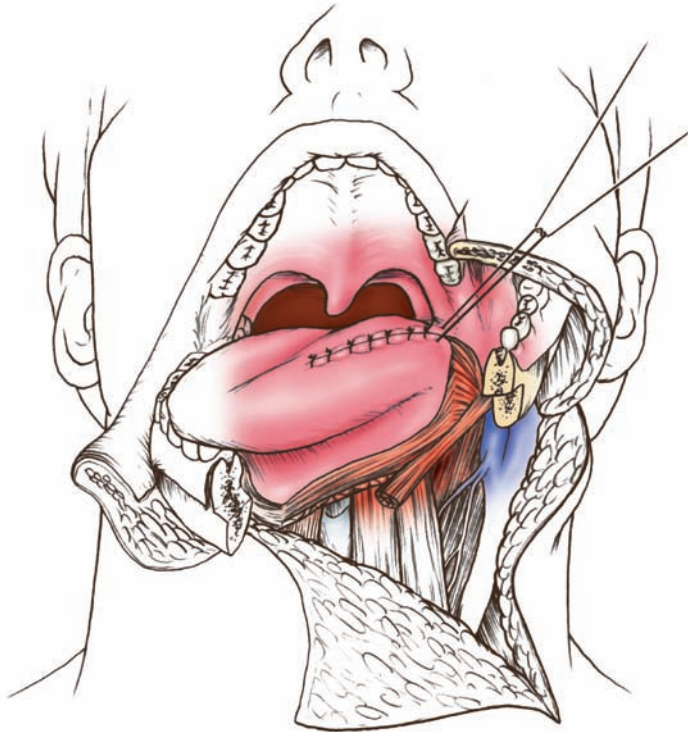


Figure 1.40

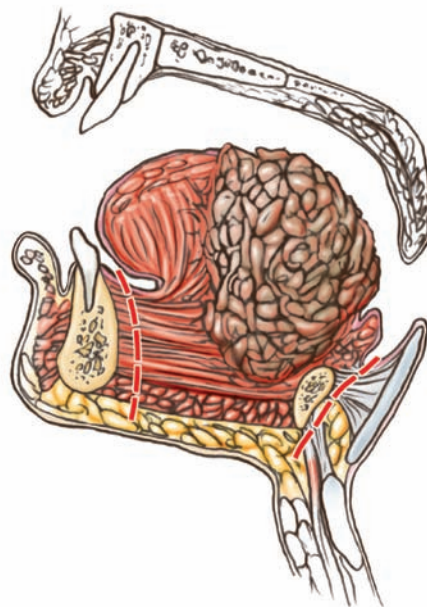


Figure 1.41

Reconstruction of total glossectomy defects requires large bulky flaps such as a pectoralis major myocutaneous flap, latissimus dorsi flap (pedicled or free), or rectus abdominis free flap to restore bulk. Other alternatives include a large sensate radial forearm or lateral arm free flap to restore sensation. The ultimate goal is to try to prevent aspiration while maintaining the larynx. Frequently after total glossectomy,

prolonged or permanent gastrostomy tube feedings are required. In patients who have recurrent aspiration after total glossectomy, a laryngeal closure procedure or total laryngectomy is indicated.

An alternative to total glossectomy with a lip-splitting incision is the combined intraoral and cervical approach. Bilateral floor of mouth incisions are performed and the tongue is pulled through the floor of mouth and the posterior resection performed transcervically. The exposure for this procedure is much more limited than with a midline mandibulotomy, and reconstruction is much more difficult.

The wound is closed with interrupted 3–0 Vicryl sutures to reapproximate the floor of mouth musculature and to close the mucosa with a watertight seal. The mandibulotomy and lip-splitting incisions are closed as previously described. The neck wounds are drained with closed suction drains.

It is important in resecting large tongue tumors (i.e., hemiglossectomy or subtotal glossectomy) to try to preserve the contralateral lingual artery and hypoglossal nerve to prevent complete loss of tongue function.

The lateral pharyngotomy approach is indicated for small (T1 or T2) tumors of the oropharynx, including the base of tongue, tonsil, and posterior pharyngeal wall. It averts the need for facial incisions and can be combined with a lateral mandibulotomy for further superior exposure. Inferior exposure can be extended to the level of the pyriform sinuses. The incision can also be extended anteriorly to allow complete oral tongue exposure.

Tracheotomy and selective or modified neck dissection are performed through standard incisions. After this, the lateral pharyngotomy is initiated.

The hypoglossal nerve is identified and followed anteriorly to its entrance into the floor of mouth lateral to the hyoglossus muscle. The hypoglossal nerve is freed circumferentially from its surrounding venous structures. The overlying posterior belly of the digastric and stylohyoid muscles is transected. The ansa hypoglossi branch of the hypoglossal nerve is transected. This allows the hypoglossal nerve to be retracted superiorly out of the field. The facial and lingual arteries are ligated at their origin from the external carotid artery. The superior laryngeal nerve is identified at the level

Lateral Pharyngotomy for Resection of Oropharyngeal Tumors

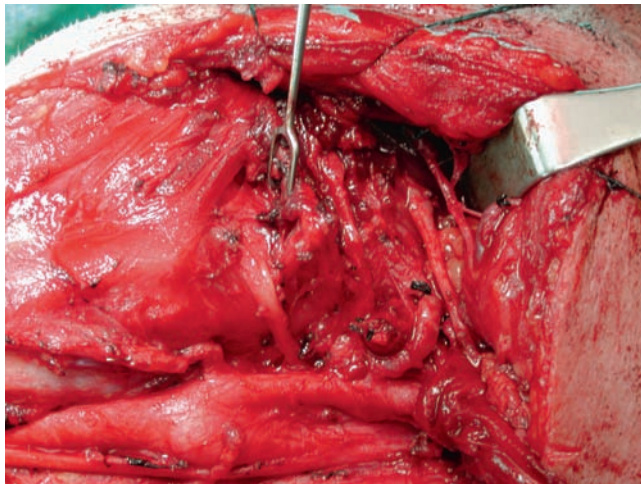


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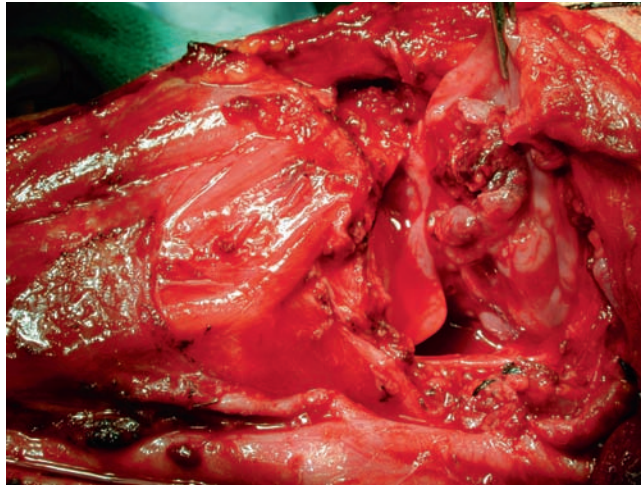


Figure 1.43

of the greater horn of the hyoid bone and mobilized along its course from the carotid sheath to its entrance through the thyrohyoid membrane. The hyoid bone may be freed from its attachments to the middle constrictor muscle and the greater horn or half of the hyoid bone removed.

A vertical incision is made through the middle constrictor muscle, exposing the mucosa. The mucosa is then incised in an area at least 1.5 cm from the tumor. Intraoral palpation with a finger in the oropharynx may assist in determining a safe area for the mucosal incision.

After the mucosa is opened, the tumor can be visualized with good headlight illumination through the pharyngotomy. Mucosal incisions are then carried out, leaving a margin of normal mucosa at least 1.5–2 cm around the tumor. In the case of a tongue base tumor, a vertical pharyngotomy is performed, exposing the base of tongue. The tumor is then excised under direct visualization. As mentioned, more anterior exposure can be obtained by incising the floor of mouth musculature and the mucosa along the gingivolingual sulcus or by performing a lateral mandibulotomy.

After the tumor is resected, frozen-section margins are evaluated. Good hemostasis is obtained. Closure of the defect depends on the extent of tissue loss.

When possible, primary closure is preferred, but for large defects flap closure is necessary.

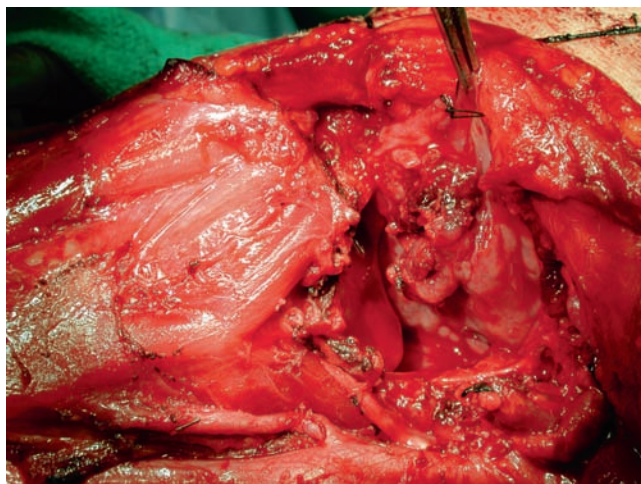


Figure 1.44

When primary closure is performed, the lateral pharyngeal wall mucosa is closed with interrupted 3–0 Vicryl sutures, with an attempt to evert the mucosal edges toward the pharyngeal lumen. The middle and superior constrictor muscles and the digastric and stylohyoid muscles are reapproximated with 3–0 Vicryl sutures. This reinforces the mucosal closure. The neck is drained with suction drains, which are kept away from the site of mucosal closure to prevent formation of a fistula. The neck is then closed as previously described.

Care is taken during the lateral pharyngotomy approach to avoid injury to the hypoglossal and superior laryngeal nerves, as injury to these structures can result in significant swallowing problems and aspiration postoperatively.

Anatomic Basis of Complications

- Because of the proximity of the carotid artery system and the internal jugular vein and its branches, there is the risk of significant bleeding. Repair or ligation of these vessels should be performed when necessary, and the internal carotid artery may require stenting or grafting. Airway obstruction can be the result of dislodgement of the endotracheal tube. Most major procedures on the oral cavity and oropharynx should include a tracheotomy. This allows bypassing the upper aerodigestive tract and minimizes the chance of airway obstruction.
- Airway obstruction can result secondary to soft tissue edema of the oral cavity or laryngeal or pharyngeal structures postoperatively, or as a result of compression of these structures due to hematoma or fluid collection. The likelihood of airway obstruction is essentially eliminated when a tracheotomy is performed as part of the surgical procedure. In those patients who do not undergo tracheotomy, oral cavity and oropharyngeal edema can sometimes be bypassed using a nasal or nasopharyngeal trumpet.
- Oral and pharyngeal dysfunction can result in significant postoperative problems in patients who have undergone upper aerodigestive tract surgery. This can be the result of cranial nerve injuries such as injury to the hypoglossal nerves, causing tongue weakness or paralysis; the glossopharyngeal nerve, causing pharyngeal hypesthesia; or the vagus nerve, causing poor pharyngeal phase of swallowing and vocal cord paralysis. In addition oral and pharyngeal tissue volume loss can significantly affect swallowing. Tethering of the tongue as a result of tight mucosal closure or tissue loss can also reduce swallowing efficiency. All of these factors can result in dysphagia, dysarthria, and possibly aspiration and subsequent aspiration pneumonia. Avoidance of postoperative oral feedings and use of a nasogastric or gastrostomy tube should be considered until the patient is able to safely swallow and protect the airway.
- Orocutaneous or pharyngocutaneous fistulas are tracts that extend from the mucosal surface to the skin. Multiple factors, including malnutrition and

underlying microvascular disease, in the head and neck cancer patient may predispose to the development of this problem. Other factors that may lead to fistula include mucosal closure under tension, incomplete mucosal closure, infection, and the presence of a foreign body or residual tumor. Also hypothyroidism increases the likelihood of fistula formation. Initial treatment for a fistula includes conservative treatments such as external and/or internal packing of the wound to allow granulation or placement of a compression dressing to prevent further drainage. The patient should not have anything by mouth until the fistula is healed.

- Mandibular complications may occur as a result of osteotomies or poor wound healing. Malocclusion can occur when a mandibular osteotomy site is not appropriately realigned. This can be minimized by accurate placement of mandibular fixation plates prior to performing an osteotomy to allow accurate reapproximation after the procedure has been completed. Nonunion or malunion of the mandible may occur as a result of inadequate bone contact or mobility at the reapproximated bone edges. Again, accurate realignment and fixation of the osteotomized bone will prevent this complication. Also full mucosal closure over the osteotomy site will minimize the chances of this complication. The patient should be maintained on a soft diet for approximately 6 weeks after mandibular osteotomies. Mandibular fracture may result if a partial rim or cortical mandibulectomy has been performed but an inadequate amount of bone remains to support the mandibular arch.
- Loss of a pedicled myocutaneous flap or free tissue flap can result. Avoiding compression of the vascular pedicle is extremely important in the postoperative period. Surveillance of the capillary refill and venous drainage of the flap is necessary to ensure early detection of flap complications.

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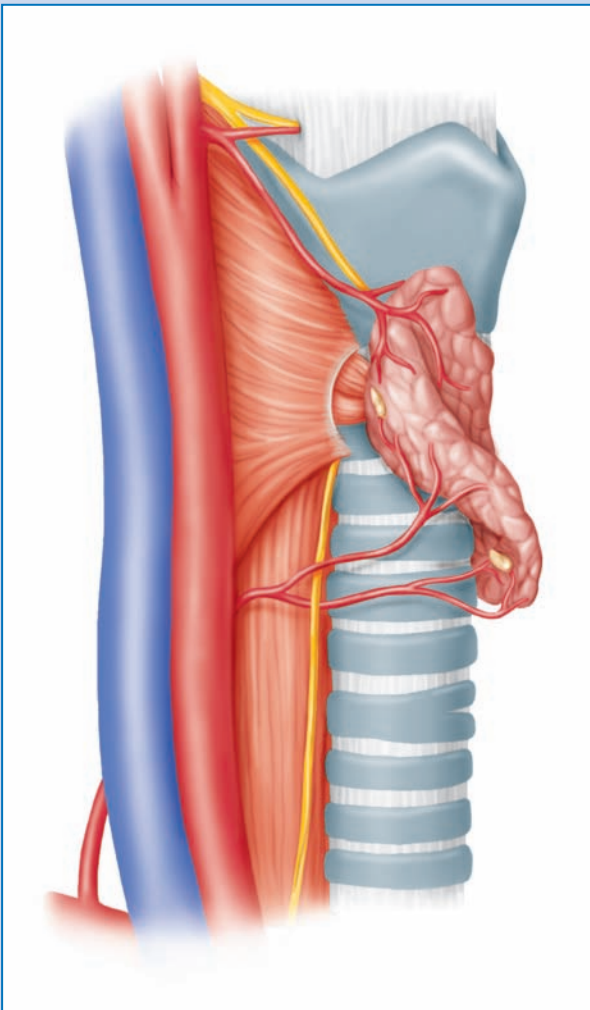
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Neck

Jyotirmay Sharma,
Mira Milas,
Collin J. Weber,
Grant W. Carlson



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Anterior Neck

Jyotirmay Sharma, Mira Milas, and Collin J. Weber

Because of the nature of the tumors involved, the neck is discussed in two sections. The section on the anterior neck describes primarily tumors of the thyroid and parathyroid glands. The section on the lateral neck describes the anatomy and procedures related to tumors of the salivary glands and the metastatic neoplasms involving the lymphatic vessels, the nerves, and vascular structures of the neck.

Introduction

Surgical resection remains the treatment of choice for most thyroid and parathyroid tumors. Goiters and thyroid nodules are problems of enormous magnitude, present in more than 7% of the world's population. Tracheal compression from goiter may respond only to thyroidectomy, and thyroid nodules may harbor carcinoma, occurring in approximately 15% of solitary thyroid nodules and 5% of multinodular goiters.

Thyroid cancer have an annual incidence of 90 per million (approximately 29,000 new cases of thyroid carcinoma occur each year in the United States). The overall mortality is low: four per million per year (approximately 1,000 deaths per year in the United States). However, thyroid carcinoma most often affects women in the prime of life, frequently before the age of 40, and the average 10-year mortality for follicular thyroid carcinoma is 25%. Thyroid carcinoma is the fastest growing malignancy in the United States. Total thyroidectomy is the mainstay of therapy for thyroid carcinoma. Patient survival is statistically better following bilateral thyroidectomy than after unilateral thyroidectomy. Application of total thyroidectomy for this disease requires the surgeon to have detailed knowledge of the anatomy of the thyroid and parathyroid glands and the recurrent and superior laryngeal nerves.

For the most part, goiter is a benign process, responsive to iodine repletion therapy. However, subtotal or total thyroidectomy is the conventional therapy for hyperthyroidism and symptomatic goiter, particularly for patients with ophthalmopathy, or when airway compromise is present. Thyroid lobectomy is generally reserved for benign thyroid nodules or other, appropriately selected clinical circumstances.

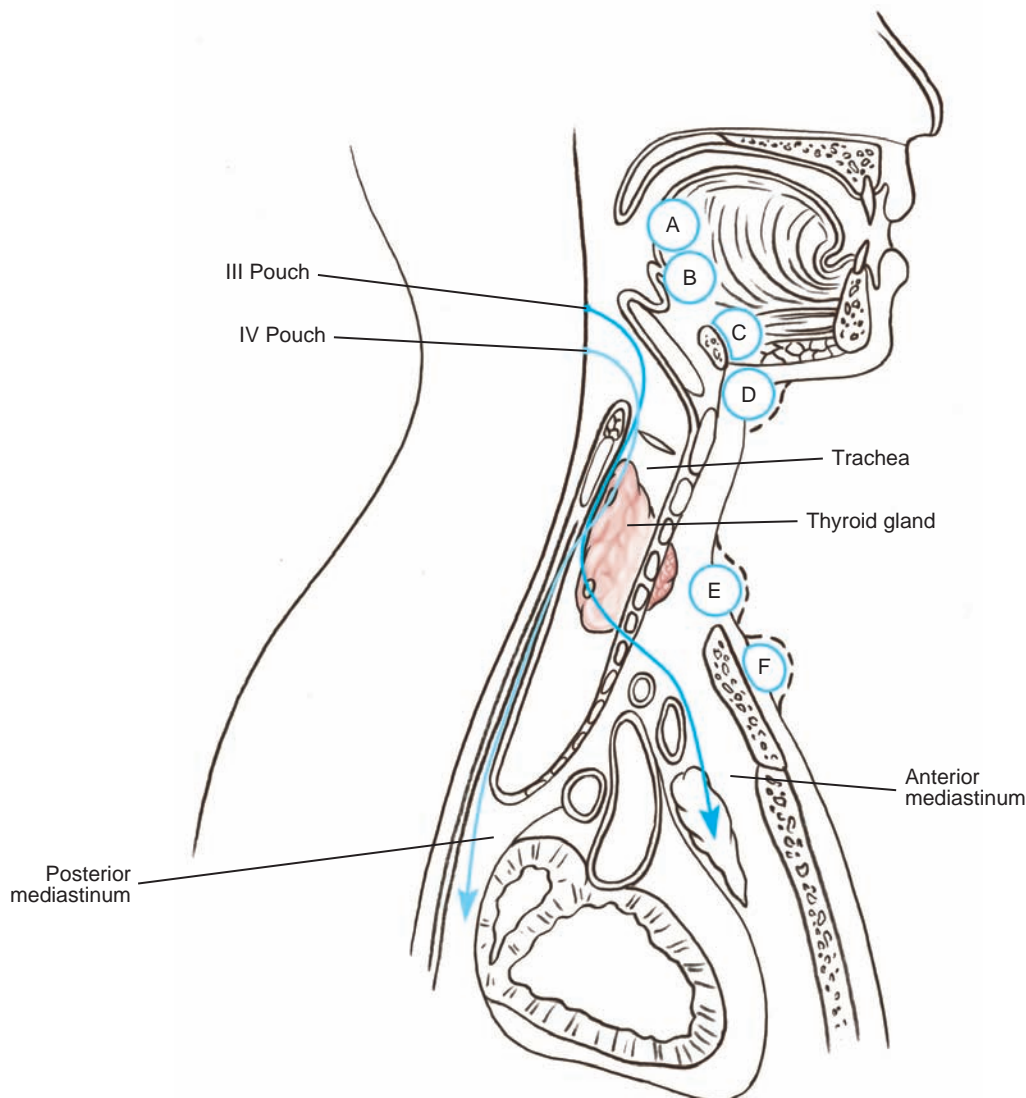
Hyperparathyroidism (due to solitary adenomas or hyperplasia involving multiple parathyroid glands) occurs in 1 in 500 women, and 1 in 2,000 men. The symptoms are multiple (renal stones and bone disease), and parathyroidectomy is the treatment of choice. More than 95% of patients can be cured with a single, well-planned neck exploration. However, success depends on the surgeon's knowledge of anatomic variations in the location and the number of parathyroid glands, and the locations of the laryngeal nerves.

Embryology of the Thyroid and Parathyroid Glands

It is essential that the surgeon treating thyroid and parathyroid diseases be familiar with their embryology. The thyroid gland originates from the midline of the pharyngeal anlage, the foramen cecum at the base of the tongue. A process of evagination takes place, and the thyroid divides into two lobes, connected by an isthmus, that migrate caudad to the normal paratracheal location.

The migratory tract of the thyroid, the thyroglossal duct, begins at the base of the tongue and runs adjacent to or through the hyoid bone. Normally, the epithelium of the thyroglossal duct atrophies and disappears. Occasionally it remains, and at any site along the duct, cysts, fistulas, or ectopic thyroid tissue may develop. Thyroglossal cysts may be located in front of the foramen cecum, at the foramen cecum, in the

Figure 2.1



suprahyoid area, in the infrahyoid area, in the area of the thyroid gland, or in the suprasternal area, and are almost always found in the midline of the upper neck.

Embryologically, the superior parathyroid glands migrate from the fourth branchial pouches, and the inferior glands migrate from the third branchial pouches with the thymus. Because of their embryonal motility, the inferior parathyroid glands have a more variable location than the superior glands. As illustrated, abnormal migration of the inferior parathyroids may cause them to descend into the anterior mediastinum, frequently within the thymus, and superior parathyroids often descend into the paraesophageal posterior mediastinum. Sometimes, though not very often, the inferior gland may not descend completely and reside near the upper pole of the thyroid, often with a remnant of undescended thymic tissue. Rarely, a parathyroid gland may be intrathyroidal (1%).

Surgical Anatomy

The skin of the anterior neck is innervated by the cervical plexus and has transverse skinfolds, which may be used as sites for an inconspicuous skin incision. Since there is little tension in the longitudinal axis of the neck, horizontal incisions are preferable in thyroid surgery.

The blood supply to the skin of the neck is abundant, and loss of skin from compromise of the circulation is rare. The amount of subcutaneous fat is variable and tends to be more prominent in the mid-region, between the platysma muscles. Unless the cervical plexus is damaged, there is rarely permanent loss of sensation in the upper flap following thyroidectomy.

The platysma muscle lies in the superficial fascia, anterolateral in the neck, and is innervated by the descending branch of the seventh nerve, which exits at the lower pole of the parotid gland near the posterior facial vein. There, it is associated with the mandibular branch of the facial nerve. If this descending branch is surgically sacrificed, the skin tone of the neck is impaired. If the mandibular branch is injured, the depressor muscle of the corner of the mouth cannot function, and the lateral lower lip will not elevate with smiling. If the platysma is transected in the submandibular region, a slight weakness of the lower lip may result, because the platysma muscle fibers blend with the depressor muscle. The so-called strap muscles include the sternohyoid, sternothyroid, and omohyoid muscles, all of which are innervated by the ansa hypoglossi nerve. The thyrohyoid muscle is innervated by the hypoglossi nerve.

The sternohyoid muscles are on either side of the midline and arise from the clavicle and the posterior manubrium. They run superiorly to insert into the lower border of the hyoid bone. The two bellies usually separate slightly at the sternal notch. The raphe may be displaced with one-sided thyroid enlargement, and the midline may be difficult to locate. The raphe are thus more easily identified at the hyoid or at the level of the thyroid notch, and also in some circumstances at the sternal notch, where

the fibers of the strap muscles diverge laterally and the midline fascia is wider and more easily appreciated. This muscle acts to depress the hyoid bone.

The sternothyroid muscles also arise from the posterior aspect of the manubrium and run superiorly over the lobes of the thyroid, deep to the sternohyoid, to insert into the lower border of the thyroid cartilage. Their action is to depress the larynx after deglutition.

The omohyoid muscle has an inferior and a superior belly and a common tendon on each side of the larynx and thyroid. The inferior belly arises from the upper border of the scapula and suprascapular ligament and crosses obliquely the lower posterior triangle of the neck deep into the sternomastoid. It ends in a common tendon with the superior belly. At this point, it crosses the carotid sheath attached to the deep cervical fascia. It continues superiorly as the superior belly alongside the sternohyoid, and inserts into the lateral aspect of the body of the hyoid bone. It stabilizes the hyoid bone in deglutition.

The thyrohyoid muscles arise just above the insertion of the sternothyroid on the thyroid cartilage and cover the ala and the thyrohyoid membrane to insert into the hyoid bone. These muscles may elevate the larynx or depress the hyoid, depending on the extent of fixation of the suprahyoid muscles.

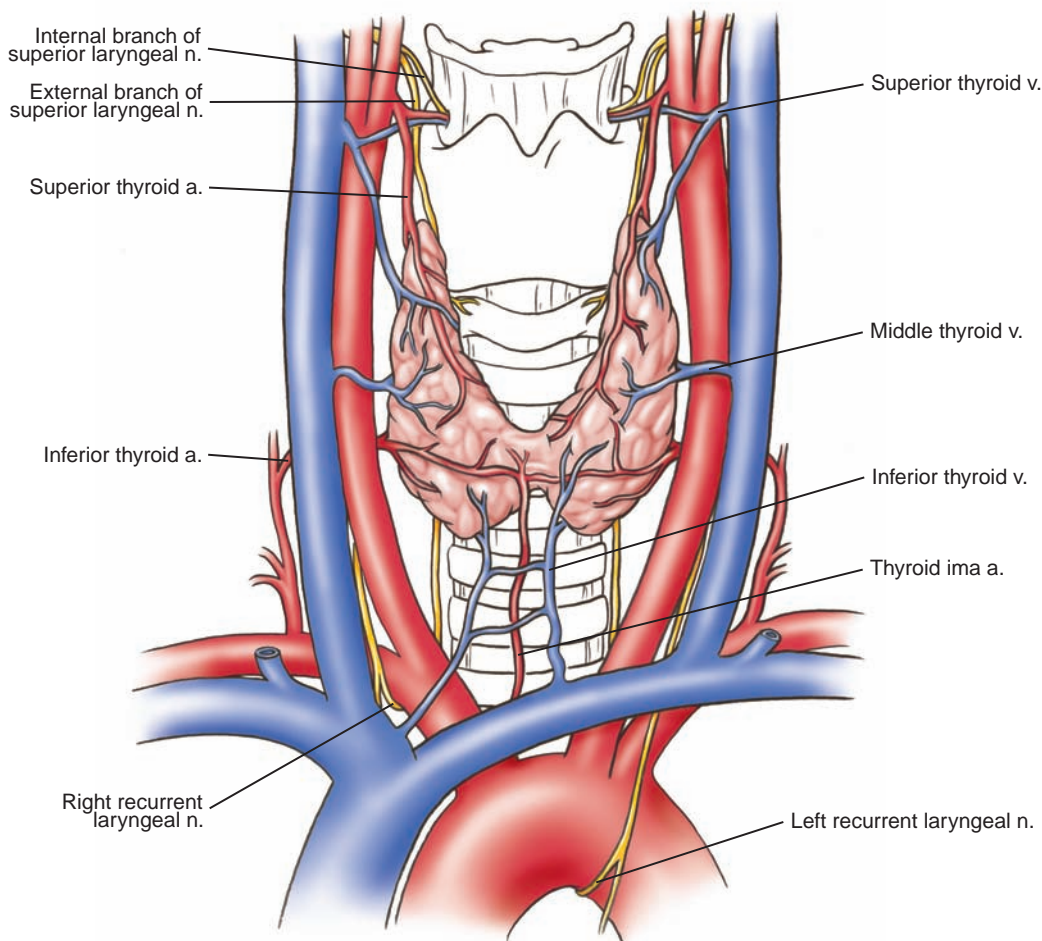


Figure 2.2

All strap muscles may be removed, divided, or denervated without serious changes in respiration, deglutition, or voice. Some surgeons routinely divide the strap muscles in all thyroidectomies to obtain adequate exposure of the gland and the superior pole vessels. This step is rarely necessary, except with extremely large, diffusely toxic glands, or huge nodular goiters with large substernal components.

Adequate exposure of the superior pole vessels can be obtained readily by dividing the medial aspect of the insertion of the sternothyroid muscle. In the event of direct involvement of the strap muscles with invasive cancer or thyroiditis, the sternothyroid muscle can be sacrificed. If total thyroidectomy follows an earlier partial thyroidectomy during which seeding by cancer cells had occurred, both sternohyoid and sternothyroid muscles can be sacrificed.

Thyroid

The normal thyroid gland usually appears as a small, flat, reddish tan, bilobed structure lying on either side of the larynx and trachea, with a flat band of similar tissue, the isthmus, crossing the first three tracheal rings just below the cricoid cartilage.

One lobe, usually the right, may be smaller than the other (7%) or may even be completely absent (1.7%). The isthmus is absent in about 10% of thyroid glands.

The thyroid gland normally extends from the level of the fifth cervical vertebra to that of the first thoracic vertebra. It may lie higher (lingual thyroid), but rarely lower.

Projecting superiorly from the isthmus may be a slender strip of thyroid tissue, the pyramidal lobe, to either side of or at the midline. This structure ascends toward the hyoid bone. In 50% of cases it is merely a residual fibrous tract. In pathologic conditions, such as Graves' disease or chronic thyroiditis, however, this lobe may become quite prominent. Cancer and benign nodules may develop in this or any other part of the thyroid.

Like many other organs, the thyroid gland has a connective tissue capsule continuous with the septa that makes up the stroma of the organ. This is the true capsule of the thyroid.

External to the true capsule is a more or less well-developed layer of fascia derived from the pretracheal fascia. This is the false capsule, the peri-thyroid sheath, or surgical capsule. Anteriorly and laterally this fascia is well-developed; posteriorly it is thin and loose, permitting enlargement of the thyroid gland posteriorly. Thickenings of the fascia fix the posterior aspect of each lobe to the cricoid cartilage. These thickenings are the ligaments of Berry.

The thyroid is intimately related to the trachea and larynx. Each lobe is pear-shaped, and the anterolateral aspect is covered by the sternothyroid muscle. The posterolateral aspect abuts the carotid sheath and its contents. Its superior deep surface abuts the inferior constrictor muscle. The recurrent laryngeal nerve is intimately adjacent to the middle-third of the gland and close to the ligament of Berry. The cricothyroid and thyrohyoid muscles separate the gland from the thyroid and cricoid

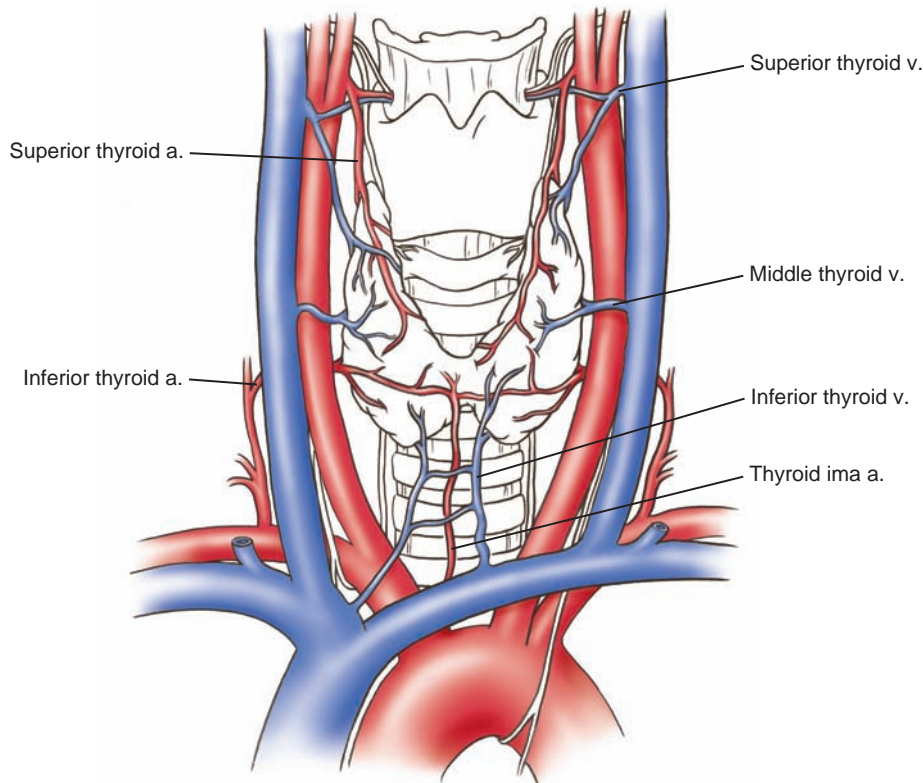


Figure 2.3

cartilages. At the anterolateral aspect of the cricoid cartilage is an intimate union with the gland through the suspensory ligament of Berry.

As normal variants, one lobe of the thyroid may be larger than the other, and the blood supply may vary accordingly. Also, the gland may vary in size with age or with demand such as pregnancy. In healthy infants, the thyroid may weigh 1.5–2 g; in the normal adult, it weighs between 15 and 25 g. The average length of each thyroid lobe longitudinally is 4–5 cm.

Blood Supply

The thyroid gland receives more blood per gram of tissue (5.5 mL/g/min) than do most other organs. One consequence is that hemostasis may be a major problem of thyroid surgery, especially in patients with toxic goiter. Two paired arteries, the superior and inferior thyroid arteries, and an inconstant midline vessel, the thyroid ima artery, supply the thyroid.

The superior thyroid artery arises from the external carotid artery just above, at, or just below the bifurcation of the common carotid artery, and it passes downward and anteriorly to reach the superior pole of the thyroid gland. In part of its course, the artery parallels the superior laryngeal nerve. The six superior thyroid branches

Arterial Supply

are the infrahyoid, the sternocleidomastoid, the superior laryngeal, the cricothyroid, the inferior pharyngeal constrictor branch, and finally the terminal branches of the superior thyroid artery, which supply the thyroid and occasionally the parathyroid glands. Usually the terminal branches further divide into two, an anterior and a posterior branch, and occasionally a so-called lateral branch. The anterior branch anastomoses with the contralateral artery; the posterior branch anastomoses with branches of the inferior thyroid artery. From the posterior branch, a small parathyroid artery may pass to the superior parathyroid gland.

The inferior thyroid artery usually arises from the thyrocervical trunk, but in about 15% of individuals it arises from the subclavian artery. The inferior thyroid artery ascends behind the carotid artery and the jugular vein, passing medially and posteriorly on the anterior surface of the longus coli muscle. After piercing the prevertebral fascia, the artery divides into two or more branches as it crosses the ascending recurrent laryngeal nerve. The nerve may pass anterior or posterior to the artery or between its branches. The main branch of the inferior thyroid artery usually enters the posterior aspect of the thyroid lobe at the midportion of the thyroid, rather than at the lower pole. This is in contrast to the superior thyroid artery, which as its name implies, does in fact enter the superior aspects of the thyroid lobe at the upper pole. The lowest branch of the artery sends a twig to the inferior and superior parathyroid glands and supplies the posterior surface of the thyroid gland. During thyroidectomy, ligation of the inferior thyroid artery should be distal to the terminal branches to the parathyroids to avoid ischemia of the parathyroid glands. Careful dissection of this artery and its branches is most important in total thyroidectomy or lobectomy, so that preservation of both the parathyroids and the recurrent nerves is assured. The upper branch supplies the posterior surface of the gland, usually anastomosing with a descending branch of the superior thyroid artery. On the right, the inferior thyroid artery is absent in about 2% of individuals; on the left, it is absent in about 5%. The artery is occasionally double.

The thyroidea ima artery is unpaired and inconstant. It arises from the brachiocephalic artery, the right common carotid artery, or the aortic arch. Its frequency has been reported at 1.5–12.2%. It may be as large as an inferior thyroid artery or be a mere twig. Its position anterior to the trachea makes its recognition important in tracheostomy.

Venous Drainage

Veins of the thyroid gland form a plexus of vessels lying in the substance and on the surface of the thyroid. The plexus is drained by three pairs of veins.

The superior thyroid vein accompanies the superior thyroid artery. Emerging from the superior pole of the thyroid, the vein passes superiorly and laterally across the omohyoid muscle and the common carotid artery to enter the internal jugular vein alone or with the common facial vein.

The middle thyroid vein arises on the lateral surface of the gland. It can be seen crossing the common carotid artery anteriorly to enter the internal jugular vein. This vein may be absent, and occasionally is double. The extra vein is inferior to the normal vein and has been called the “fourth” thyroid vein. The path of the middle

veins mimics the path of the inferior thyroid artery – both tend to have a course that is transverse in orientation and enters the thyroid at its midportion. However, the middle thyroid veins will be more superficial, while the inferior thyroid artery trunk may appear in a parallel path but deeper. The importance of these middle thyroid veins is their vulnerability to injury during thyroidectomy. These veins, even the smaller ones, also anchor the thyroid and impair mobilization of the thyroid medially until divided.

The inferior thyroid vein is the largest and the most variable of the thyroid veins; the right and left sides are usually asymmetric. The right vein leaves the lower border of the thyroid gland, usually off of the lower pole, passes anterior to the brachiocephalic artery, and enters the right brachiocephalic vein. The left vein crosses the trachea to enter the left brachiocephalic vein. In rare instances, the right vein crosses the trachea to enter the left brachiocephalic vein, sometimes forming a common trunk with the left vein. The common trunk is called the thyroid ima vein.

The thyroid veins may be found considerably engorged and dilated in the presence of intrathoracic goiter and may pose a difficult problem for the surgeon. Delivery of the goiter from the substernal area and thoracic inlet is required to relieve venous stasis and to prevent excessive bleeding. However, care must be taken to ensure that there are not untied, open, or torn veins, which may later result in hemorrhage or cause air embolus. This is best discovered by means of a Valsalva maneuver, performed by the anesthesiologist.

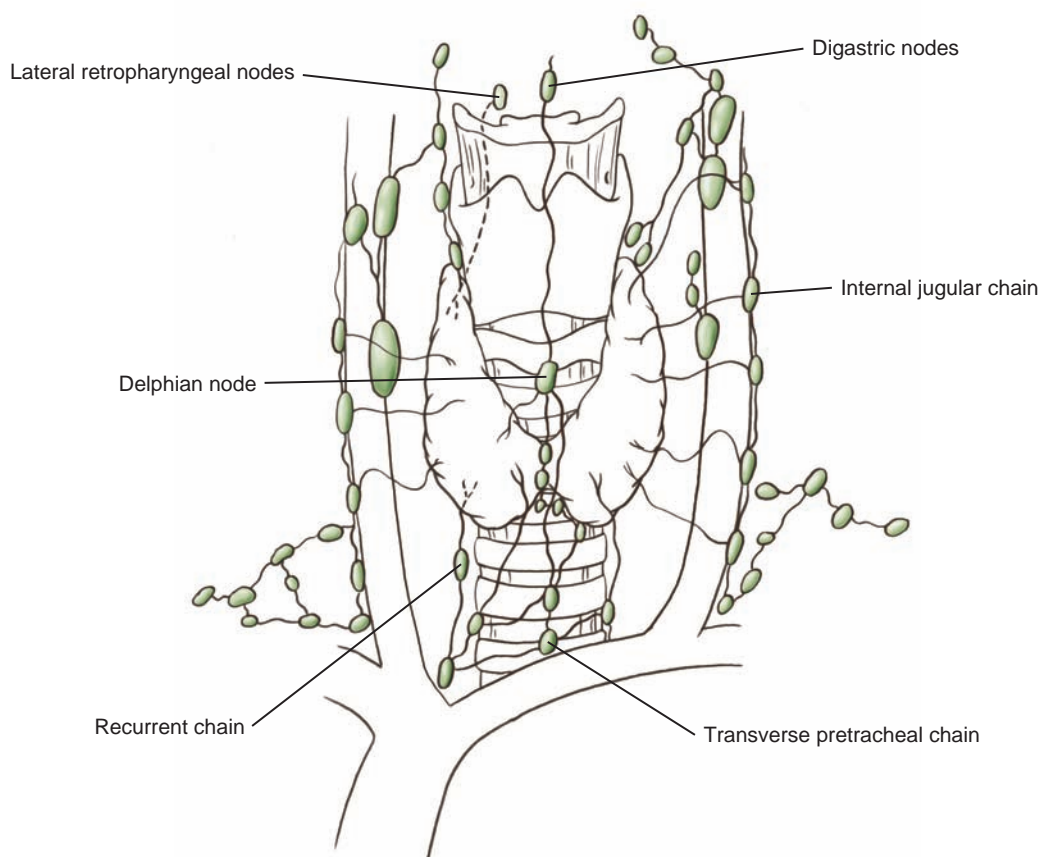


Figure 2.4

Inadvertent division of a large vein in the anterior neck may lead to fatal air embolism, since the neck is higher than the right atrium and there is negative venous pressure. Venous obstruction secondary to substernal goiter may make control of hemorrhage difficult until the goiter is delivered out of the neck and the venous obstruction is relieved. Imaging of a goiter using noncontrast CT scan or MRI may be helpful in determining the relationship of the substernal portion of the goiter to the brachiocephalic vein. If this vein is stretched over the goiter or displaced downward, knowing that this relationship exists may allow for careful selection of surgery technique and consideration of possible (though rare) sternotomy for large substernal goiters.

Transverse communicating veins may be seen between the inferior branches. There is great variation in the pattern found. This can be a significant problem, since it interferes with the accuracy of parathyroid tumor localization with selective venous sampling of parathyroid hormone.

Lymphatic Drainage

Knowledge of the anatomic considerations regarding the lymphatic drainage of the thyroid gland is of utmost importance to the surgeon operating for thyroid carcinoma. The thyroid is rich in intraglandular lymphatic capillaries, which encircle the thyroid follicles and are adjacent to parafollicular cells which secrete calcitonin. Tagged thyroglobulin can be identified in both the lymphatic and venous collecting vessels. This rich intraglandular lymphatic capillary network makes its way to a position below the capsule of the gland, where it gives rise to collecting trunks within the capsule. The collecting trunks are in close association with the capsular veins and follow them to the major sources of venous drainage. Occasionally, these lymphatic channels are visible upon inspection during thyroid surgery.

The number of collecting trunks depends on the configuration and blood supply of the gland. The chief efferent pathways are superior, lateral, and inferior and they follow the superior blood vessels, the inferior thyroid artery, the middle vein, and the inferior venous plexus.

The primary zones of lymphatic drainage are to the midline “Delphian,” tracheoesophageal, and superior mediastinal nodes. The nodes of the lateral neck (internal jugular, posterior triangle) constitute a zone of secondary drainage.

Several broad patterns of lymphatic drainage of the thyroid gland have been proposed. Three to six vessels arise from the superior margin of the isthmus and from the median margins of the lateral lobes. These vessels pass upward, anterior to the larynx, and end in the digastric lymph nodes. Some vessels may enter one or more prelaryngeal (Delphian) nodes just above the isthmus. Secondary drainage may be to upper jugular nodes on either side or to pretracheal nodes below the thyroid by a vessel passing from the Delphian nodes downward over the front of the thyroid. Several lymph vessels drain the lower part of the isthmus and the lower medial portions of the lateral lobe. They follow the inferior thyroid veins to end in the pretracheal and brachiocephalic nodes.

Lymphatic trunks arise from the lateral border of each lobe. Superiorly, they pass upward with the superior thyroid artery and vein; inferiorly they follow the inferior thyroid artery. Between these two groups, some vessels pass laterally, anteriorly, or

posteriorly to the carotid sheath to reach lymph nodes of the internal jugular chain. Occasionally such vessels drain into the right subclavian vein, the jugular vein, or the thoracic duct without passing through a lymph node. Posterior lymphatic vessels arise from the inferior and medial surfaces of the lateral lobes and drain into nodes along the recurrent laryngeal nerve (Level VI). Occasionally, a posterior ascending trunk from the upper part of the lobe reaches the retropharyngeal nodes.

The superior route of lymphatic flow drains the anterior and posterior portions of the upper third or more of each lobe as well as the medial portion adjacent to the isthmus. The collecting trunks cross in front of the cricoid cartilage and encompass and drain the pyramidal lobe when it is present. These superior collecting trunks follow the superior thyroid veins behind the insertion of the sternothyroid muscle and may pierce it in some instances. They continue to the subdiaphragmatic internal jugular nodes (middle jugular nodes). The posterior portion of the upper third of the lobe may also drain to the lower retropharyngeal nodes as well as to the midjugular nodes.

The inferior pathway drains the medial and posterior lower half of the lobe, the inferior pole, and the lower portion of the isthmus. The collecting trunks are numerous and go into the pretracheal, paratracheal, and recurrent laryngeal (Level VI) chain of nodes. The lymphatics may continue retrograde to the vicinity of the thymus, following the course of the innominate veins. The antero-superior mediastinal nodes are in communication with the lower thyroid lymphatic pathways and nodes.

The regional lymph nodes most likely to be involved with thyroid carcinoma (papillary or medullary) are the most immediate paraglandular nodes (i.e., those in the central or Level VI of the neck). When total thyroidectomy is done, these nodes should also be removed, namely those in the pretracheal, paratracheal, and recurrent laryngeal nerve chains.

Feind reported metastatic involvement of middle jugular lymph nodes in 85 of 111 specimens from patients with thyroid carcinoma. In 67 of these, lower jugular nodes were positive for disease. Submandibular and mediastinal nodes were rarely affected.

To check for cervical spread on the side of the obvious primary lesion, the middle internal jugular nodes should be inspected and biopsied, if found to be enlarged or abnormal to palpation. If these nodes are obviously involved, neck dissection should be done. If the lateral nodes prove positive in the final pathology report, neck dissection may be indicated. In Feind's series, in which only random sections or levels were taken of the specimens studied, about 40% had multifocal disease or intraglandular metastatic disease.

Based on these and recent data, it has been recommended that when papillary or follicular cancer is diagnosed, total thyroidectomy is warranted. Some authorities disagree with this approach and favor thyroid lobectomy, especially in the case of small primary thyroid tumors. However, the large summary reports by Bilimoria, Mazzaferri, and Hay et al. document enhanced long-term survival and lower local recurrence rates following bilateral, as opposed to unilateral, thyroidectomy for thyroid carcinoma.

Lymphatic Spread of Thyroid Carcinoma

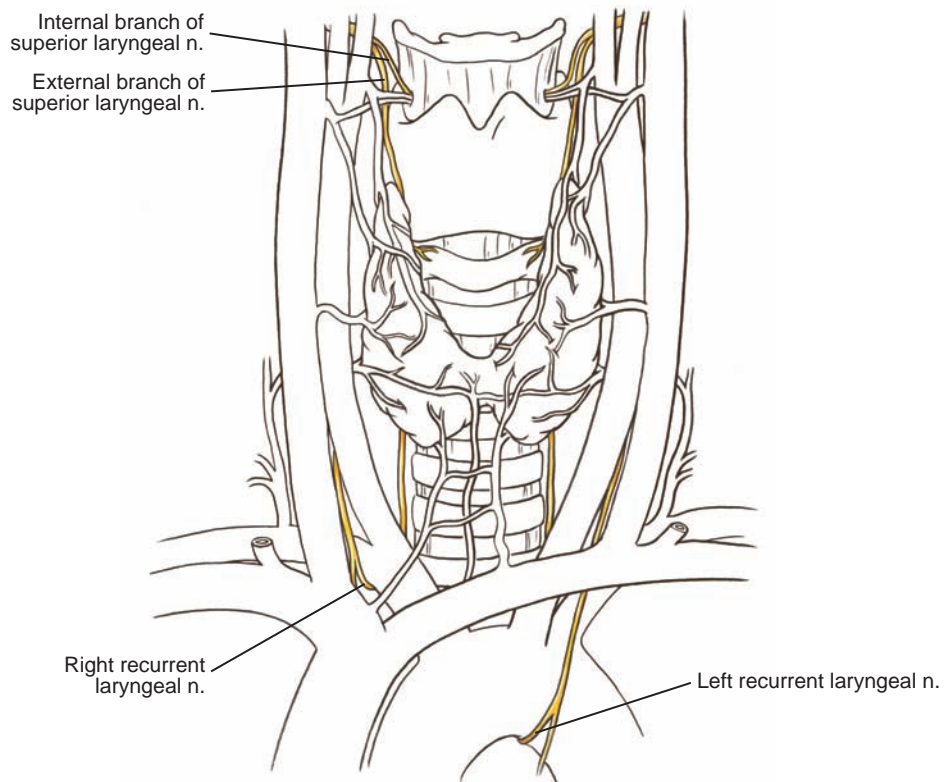
Nerve Supply

Recurrent Laryngeal Nerves

In intimate relation to the thyroid gland are the two recurrent laryngeal nerves. The right nerve branches from the vagus nerve as it crosses anterior to the right subclavian artery. The recurrent nerve loops around the artery from anterior to posterior and ascends in or near the tracheoesophageal groove, passing posterior to the right lobe of the thyroid gland to enter the larynx behind the cricothyroid articulation and the inferior cornu of the thyroid cartilage. The left recurrent nerve arises where the aorta crosses the vagus nerve. It loops under the aorta and ascends in the same manner as the right nerve.

The course of the recurrent laryngeal nerve relative, to the inferior thyroid artery may vary, increasing the likelihood of injury to the nerve during thyroid surgery. The recurrent laryngeal nerve crosses the inferior thyroid artery at the middle-third of the gland. For practical purposes, there are three major types of crossing. The nerve may cross anterior to, posterior to, or between the branches of the artery. Alternatively, it may exit directly from the carotid sheath, and course from lateral to medial, in a “nonrecurrent manner,” either above the inferior thyroid artery, or it may loop beneath the artery. No one pattern can be considered “normal”; the surgeon must be prepared for any configuration of artery and nerve. Over 20 different configurations have been described by Yalcin et.al.

Figure 2.5



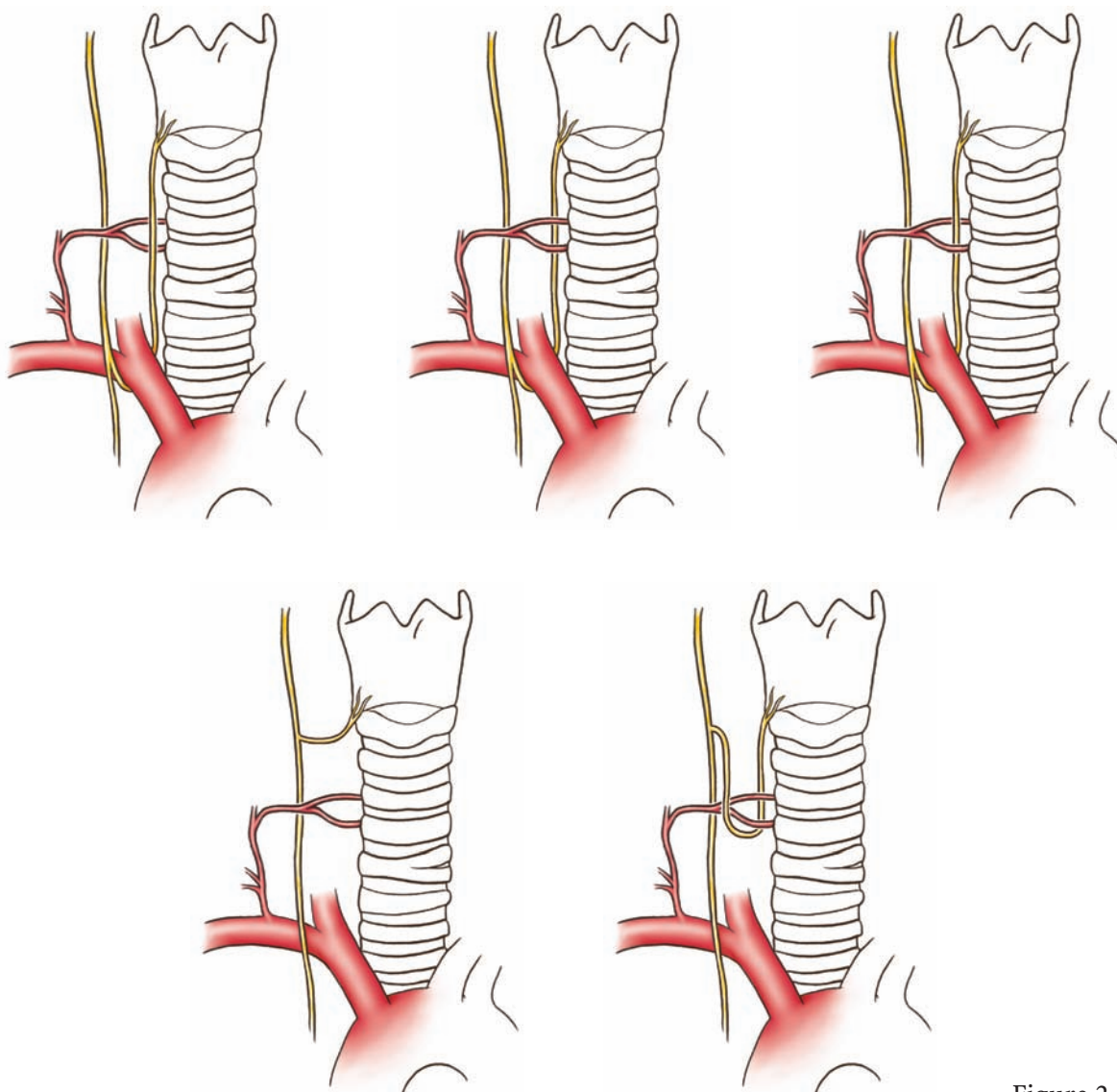


Figure 2.6

Most laryngeal nerves (approximately 80%) are located either posterior to or between the branches of the inferior thyroid artery. In Skandalakis' series, the right nerve was most frequently between arterial branches (48%); the left nerve was usually behind the artery (64%). Henry et al. found that the nonrecurrent nerve may pass directly to the larynx with no relation to the inferior thyroid artery or may loop around the artery (0.63% of patients). In these cases the right subclavian artery arises from the descending aorta and passes to the right behind the esophagus. This anomaly is asymptomatic, and the thyroid surgeon rarely will be aware of it prior to operation. Less common (0.04%) is a nonrecurrent left nerve in the presence of a right aortic arch and a retro-esophageal left subclavian artery.

In the lower-third of its course, the recurrent laryngeal nerve ascends behind the pretracheal fascia at a slight angle to the tracheoesophageal groove. In the middle-third of its course, the nerve may lie in the groove, medial to the suspensory ligament

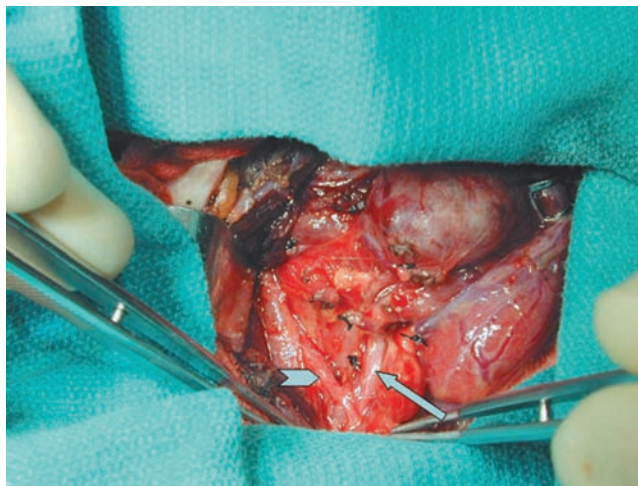


Figure 2.7

of the thyroid gland (ligament of Berry), within the ligament, or within the substance of the thyroid gland.

Skandalakis examined the course of the recurrent laryngeal nerve in 102 cadavers (204 sides). In about half of the specimens the nerve lay in the tracheoesophageal groove; in the other half the nerve was usually anterior to the groove (paratracheal), with a few situated more posterior (paraesophageal). Eight of 204 nerves lay within the thyroid gland. The nerve is safest and least vulnerable when it lies in the tracheoesophageal groove. It is the most vulnerable when it transverses the thyroid parenchyma or runs within the suspensory ligament of the thyroid. It must be identified and protected before the ligament is divided.

The recurrent laryngeal nerve fibers are both sensory and motor. They supply sensation to the trachea and subglottic region of the larynx. The motor branches innervate the abductor and adductor muscles of the larynx. Each recurrent nerve (thin arrow) in Figure 2.7 gives off sensory branches to the trachea, continues deep to the respective thyroid lobe, and passes either in front of or behind the inferior thyroid artery or its branches. Just above this, the nerve assumes a position very close to the thyroid and often bifurcates. The bifurcation is both motor and sensory. The sensory fibers may branch and communicate with the sensory branch of the superior laryngeal nerve to form the loop of Galen as shown by the thick arrow in Figure 2.7.

Close to the thyroid, a projection of thyroid tissue (tubercle of Zuckerkandl) overhangs the nerve. This lobulation may be very large in Graves' disease and, in some instances, actually projects behind the cricopharyngeus muscle. The nerve, in close association with the thyroid, pierces just below the inferior constrictor muscle to gain access to the muscles of the larynx.

Superior Laryngeal and Other Nerves

The superior laryngeal nerve arises from the inferior ganglion (nodosum) of the vagus nerve just outside the jugular foramen of the skull. The nerve passes inferiorly, medial to the carotid artery. At the level of the superior corner of the hyoid bone it divides into a large sensory internal laryngeal branch (to the mucous membrane of the pyriform fossa and the larynx above the cords) and a smaller (external laryngeal)

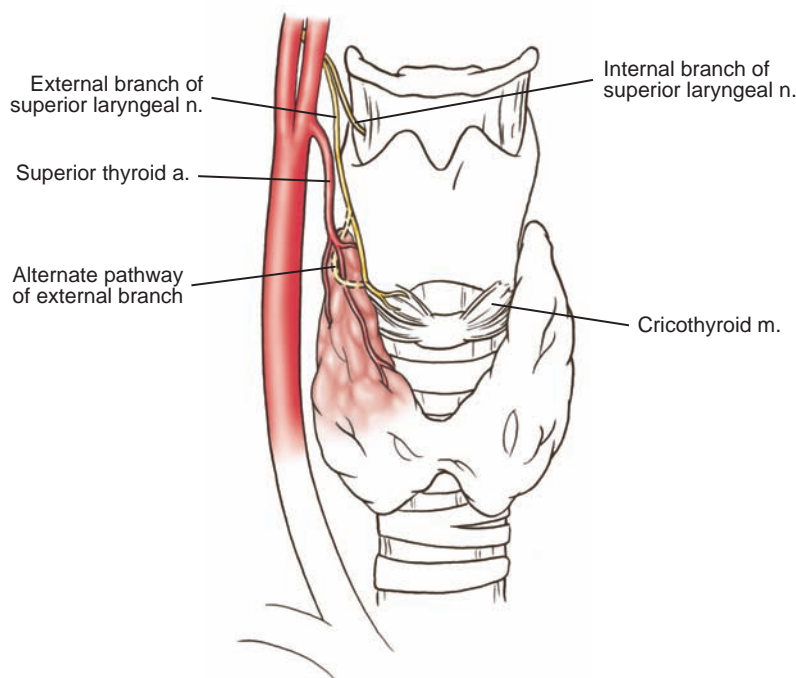


Figure 2.8

branch which descends medial to the superior thyroid artery and supplies motor function to the cricothyroid muscle. Injury to the external branch of the superior laryngeal nerve (“opera singer’s nerve”) causes early fatigue of the voice. The internal laryngeal branch is rarely identified by the surgeon, except where there is a greatly enlarged upper pole of the thyroid gland rising above the superior border of the thyroid cartilage. There is an intimate relationship between the external branch of the superior laryngeal nerve and the superior thyroid artery and the upper pole of the thyroid gland.

The cervical sympathetic chain lies deep to the common carotid artery between the prevertebral fascia and the carotid sheath. In the upper neck it continues deep to the internal carotid artery. The retropharyngeal lymphatic vessels are in communication with those of the anterior cervical chain and cross this trunk. These lymphatics and their lymph nodes may be involved in metastatic thyroid cancer. In advanced disease, the sympathetic chain may be directly invaded from these involved nodes, and eradication may result in a Horner’s syndrome. Rarely, Horner’s syndrome may result from compression by a large goiter or Graves’ disease.

The hypoglossal (twelfth cranial) nerve, a motor nerve to the tongue, emerges from the hypoglossal canal on the occipital base of the skull. It is in close contact with the ninth, tenth, and eleventh cranial nerves. It lies between the internal jugular vein and the internal carotid artery and descends to the lower border of the posterior belly of the digastric muscle, where it crosses both the internal and external carotid arteries. It then crosses anteriorly just deep to the anterior facial vein, follows the stylohyoid muscle to gain the submandibular triangle, and innervates the tongue muscles. The nerve is likely to be injured as it crosses the carotid arteries

and must be identified before the internal jugular vein is transected during neck dissection.

The descending branch of the hypoglossal nerve leaves the parent nerve at the crossing of the carotid arteries and descends on the surface of the internal and common carotid arteries. There it is joined by the descending cervical nerve (C2 and C3), which arises from the cervical plexus. This joining or nerve loop is termed the *ansa hypoglossi*, whose branches innervate the thyrohyoid muscle. Sacrifice of either the *ansa hypoglossi* or descending cervical nerve has no serious consequence.

In neck dissection, injury to the brachial plexus and phrenic nerve must be avoided. However, the cervical plexus may be sacrificed distal to the takeoff of the phrenic nerve at roots C3 and C4. The brachial plexus occupies the anteroinferior angle of the posterior triangle of the neck. In the neck, the plexus lies behind the inferior belly of the omohyoid muscle. It emerges posterior to the scalenus anticus and anterior to the scalenus medius. The upper trunk of the plexus is visible, and the nerve to the rhomboids is often easily seen. It is important that the prevertebral fascia not be violated. All the motor nerves given off lie in this fascia.

The phrenic nerve in the neck is also in the prevertebral fascia and descends from roots of C3 and C4 of the cervical plexus. The part of the cervical plexus arising from C1, C2, C3, and C4 may be sacrificed distal to the motor takeoffs or distal to prevertebral fascia, without serious consequences. The phrenic nerve remains in the prevertebral fascia of the scalenus anticus as it crosses from the lateral to the medial border of this muscle in its descent. On the left side, the nerve is in close association with the thoracic duct.

The spinal accessory (eleventh cranial) nerve emerges from the jugular foramen of the skull and gives off a branch to the inferior ganglion of the vagus, thereby providing motor branches to the pharynx and larynx. The spinal accessory nerve crosses the internal jugular vein and descends deep to the occipital artery and the posterior belly of the digastric muscle, where it reaches the deep surface of the sternocleidomastoid muscle. The nerve pierces the muscle, giving off a branch to the muscle, and emerges between the muscle's posterior border and the trapezius muscle, running inferiorly in the lateral aspect of the posterior triangle of the neck. The nerve finally enters and innervates the trapezius muscle.

Lymphatic collecting trunks accompany the nerve from the base of the skull. However, they are rarely involved by metastatic thyroid cancer. It is thus reasonable to save this nerve in a neck dissection. When the nerve is sacrificed during radical neck dissection for aggressive head and neck cancers, disability from the resultant shoulder drop is disfiguring and presents a physical and emotional handicap for the patient to overcome.

The descending branch of the seventh cranial nerve supplies the platysma muscle, but also gives off a mandibular branch as it leaves the lower pole of the parotid salivary gland. This branch goes to the depressor muscles of the lower lip. This small branch courses deep to the platysma muscle, usually close to the angle of the mandible at the lower border of the masseter muscle, and joins the facial vessels as they cross the mandible.

Exposure of the recurrent nerve during any procedure on the thyroid is a sound surgical principle and should be done wherever possible. If the nerve cannot be found readily, the surgeon must avoid the areas in which it may be hidden.

Visual identification, with avoidance of traction, compression, or stripping of the connective tissue, is wise. Complete anatomic dissection is not required. The recurrent laryngeal nerve forms the medial border of a triangle bounded superiorly by the inferior thyroid artery and laterally by the carotid artery. The nerve may be identified where it enters the larynx just posterior to the inferior cornu of the thyroid cartilage. If the nerve is not found, a nonrecurrent nerve should be suspected, especially on the right. With very large tumors the nerve can be displaced medially with thyroid growth on either side of the nerve. In the lower portion of its course the nerve may be palpated as a tight strand over the tracheal surface. There is more connective tissue between the nerve and the trachea on the right than on the left.

The external laryngeal branch, together with the superior thyroid vein and artery, passes under the sternothyroid muscles. The nerve then passes beneath the blood vessels into the lower part of the thyropharyngeal muscle to continue inferiorly and innervate the cricothyroid muscle. In most patients, there is a plane of dissection between the vessels and the nerve. In about 25% of individuals the nerve lies beneath the fascia together with the vessels and may pass between branches of the superior thyroid artery.

Exposure of Laryngeal Nerves

Parathyroid

The parathyroid glands are spherical or ovoid, somewhat flattened bodies varying in size from 4 to 6 mm in length and 3 to 4 mm in width and thickness. Each gland weighs approximately 40 mg or less. The two inferior glands usually are slightly heavier than the superior glands. The consistency is slightly softer than normal thyroid tissue. The normal parathyroid gland is yellowish brown, but may be more tan if the fat content is increased. When a parathyroid becomes adenomatous, it becomes more reddish, almost the color of liver.

Topography

The parathyroid glands usually are found on the dorsal surface of the thyroid gland. This posterior view of the neck demonstrates the relationship of the inferior thyroid arteries and recurrent laryngeal nerve to the parathyroid glands on the dorsal aspect of the thyroid. Superior parathyroid glands most commonly are located above the inferior thyroid artery at the junction of the middle- and upper-thirds of the posterior surface of the thyroid. Inferior parathyroid glands lie below the inferior thyroid artery on the posterolateral aspect of the inferior pole of the thyroid gland.

Parathyroid Number and Location

The normal parathyroid gland usually is underneath a thin film of opaque fascia, surrounded by fat globules that are lighter in color. Typically there are four parathyroid glands, but the number may vary from two to seven. Approximately 6% of all

Figure 2.9

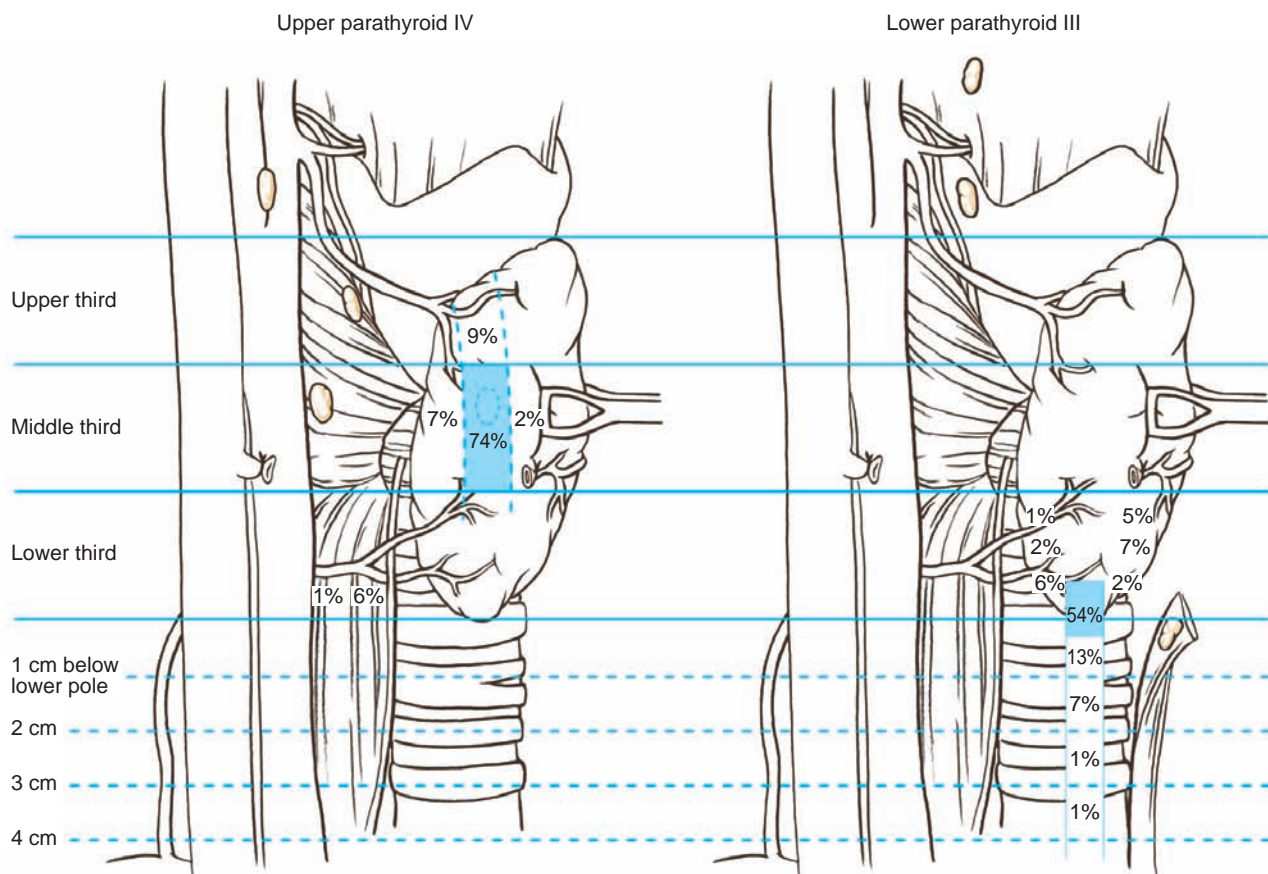
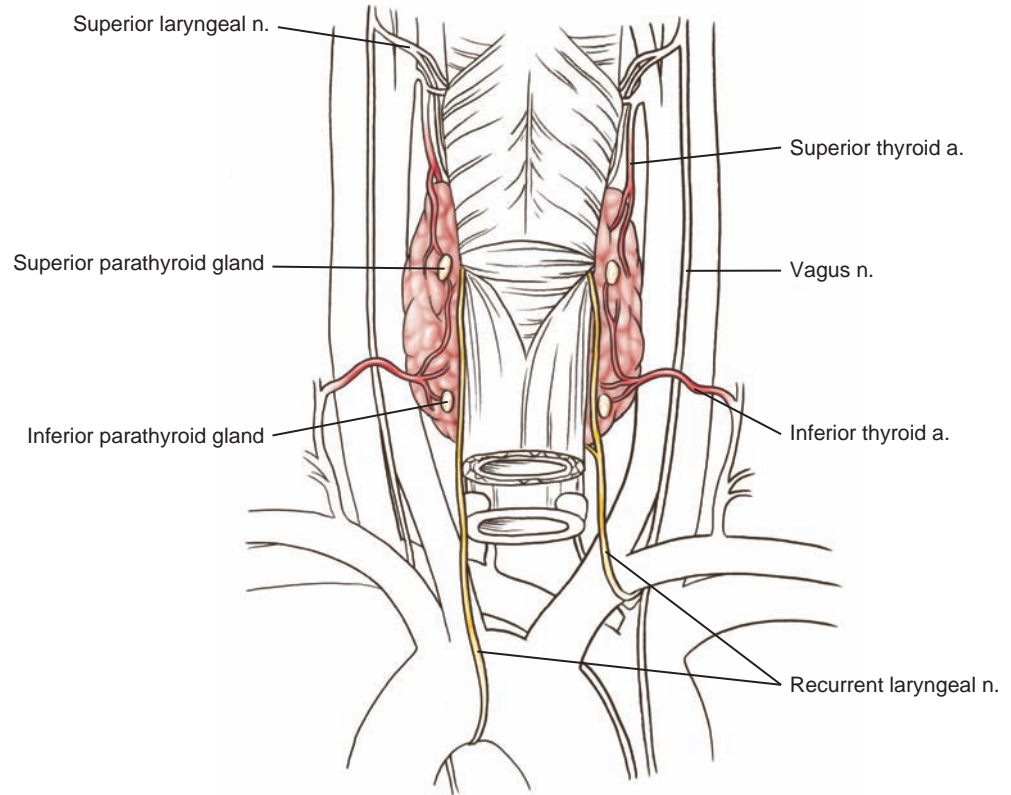


Figure 2.10

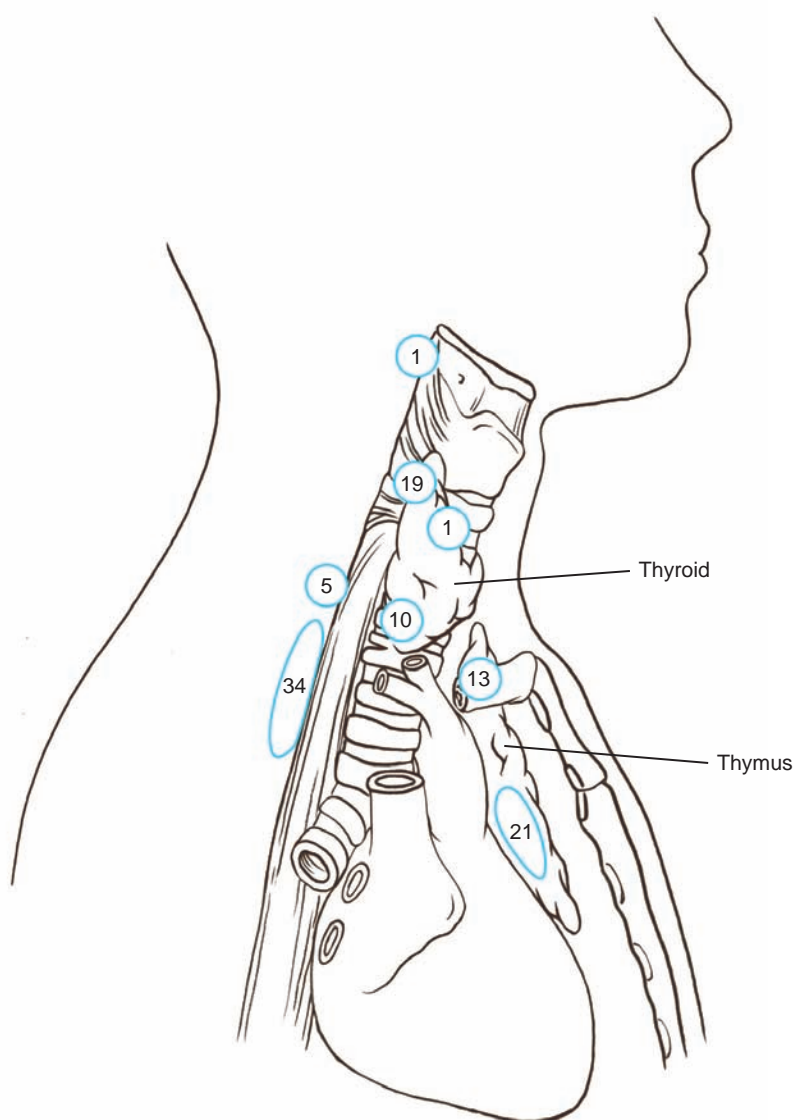
individuals have five parathyroid glands. These accessory parathyroids occupy somewhat unusual locations; for example, they may lie within the mediastinum. They are occasionally found within the substance of the thyroid, in 1% of cases.

Lateral views of the anatomic locations of upper and lower parathyroids, as dissected by Gilmour, are illustrated. Extreme locations are very rare, although glands have been found as high as the bifurcation of the carotid artery, posterior to the hyoid bone and as low as the mediastinum.

Illustrated is the location of 104 parathyroid tumors found at reoperation after failure to cure hyperparathyroidism at initial surgery, as described by Wang.

More than four or fewer than four parathyroid glands are not uncommon. For example, Gilmour reported that 6.1% of patients had only three parathyroids. Where fewer than four glands are found, the possibility of ectopic glands is hard to rule out. Two parathyroid glands may appear fused to one another. Such a pair can be differentiated from a bilobed gland by the presence of a cleavage plane between them.

Figure 2.11



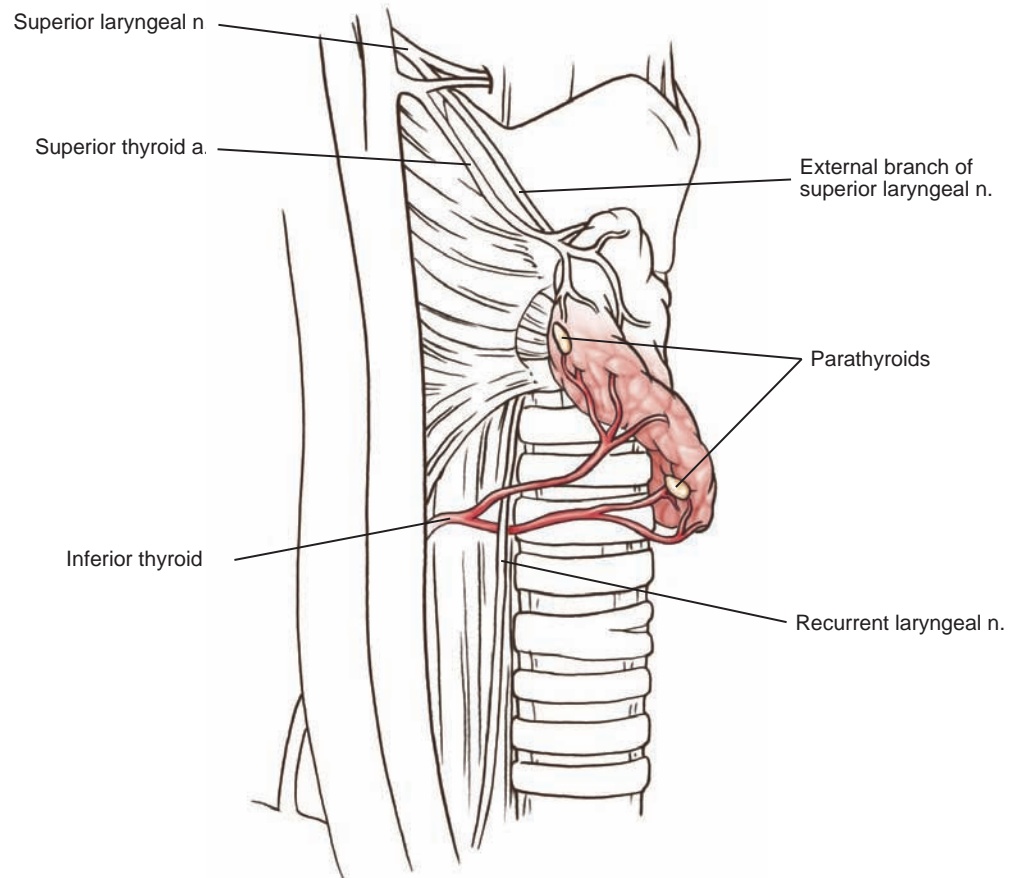


Figure 2.12

Blood Supply

The inferior thyroid artery is the major blood supply to all four parathyroid glands. Each gland receives an artery, which enters the hilus at a slight depression in the capsule. Occasionally, the superior thyroid artery supplies or adds additional blood vessels to the superior parathyroid glands.

The largest series (354 postmortem subjects) analyzing the parathyroid vascular supply is that of Aleryd, who found that both the superior and inferior parathyroids were usually supplied by the inferior thyroid artery, 86.1% on the right side and 76.8% on the left. In the majority of cases in which the inferior thyroid artery was absent, both the upper and lower parathyroids were supplied by the superior thyroid artery. When a parathyroid is enlarged, identifying a large vascular pedicle may be very helpful in locating the tumor. Rarely an inferior parathyroid adenoma may be intra-thymic and receive its blood supply from a branch of the internal mammary artery.

Surgical Applications

Thyroidectomy

The patient is placed in a semi-sitting (“lounge chair”) position. The head of the table is tilted upward approximately 30° to increase exposure and decrease venous engorgement. A rolled sheet is placed longitudinally between the shoulders to allow

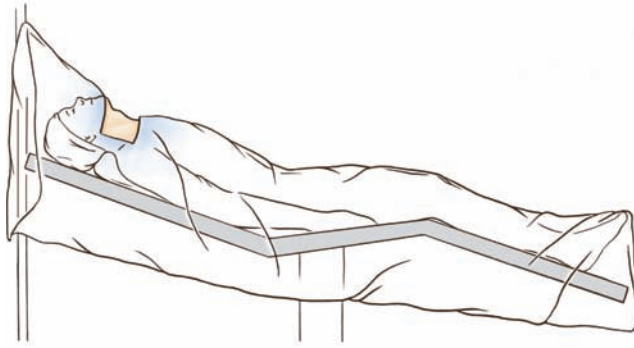


Figure 2.13

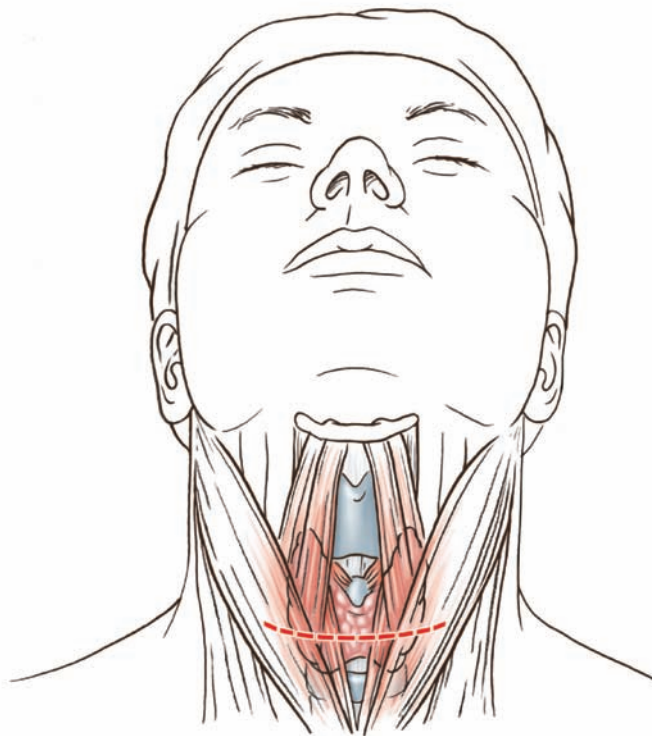


Figure 2.14

extension of the neck. Care should be taken in positioning the neck so as not to cause hyperextension of the cervical spine, which will result in severe postoperative pain. Surgical drapes should allow access so that the entire anterior aspect of the neck from the chin to the suprasternal notch is exposed.

The optimal incision for thyroidectomy must be long enough that the skin flap can be elevated for adequate exposure of the thyroid gland, yet cosmetically placed within a transverse skin crease, curving gently upward on both ends. The length of incision varies from 2 to 12 cm according to the technique used and the requirement of exposure is dependent on the underlying thyroid pathology. Current techniques also include videoscopic and other minimally invasive methods. The technique presented below aims to convey the key concepts of the standard thyroidectomy via a midline cervical approach.

Incision

The incision is made about 3 cm above the clavicles, and the scar will be about 1.5 cm above the clavicle in the upright position. It should not be straight, but curved

upward slightly. It should be symmetric, extending the same distance on each side from the midline, and should be curved equally on both sides so as not to be askew.

Elevation of the Skin Flap

The skin, subcutaneous fat, and platysma are elevated as one layer. The fascial plane between the posterior sheath of the platysma and the sternohyoid muscle is relatively avascular. After the skin incision has been completed, the platysma muscle is identified laterally and its fibers divided, exposing the fascia of the prethyroid muscles (the sternohyoid and the sternothyroid) underlying deep investing. The superficial veins are not elevated with the flap. Avoiding injury to the superficial veins prevents unnecessary bleeding.

By applying upward traction, the flap is raised above the thyroid notch by combined sharp and blunt dissection in a relatively avascular plane. This plane is identified by firm upward traction on the skin and counter-traction below on the midline tissues of the neck. One of the most important technical steps in the thyroidectomy is high elevation of the upper flap, which allows adequate anatomic exposure. Next, the inferior flap is developed to the level of the sternal notch, taking care to avoid injury to anterior jugular veins. A self-retaining retractor is placed in the wound.

Prethyroid Muscles (Sternohyoid and Sternothyroid)

Although rarely necessary, the prethyroid muscles may be divided in difficult cases (e.g., huge goiters) to obtain adequate exposure to perform thyroidectomy safely. If the muscles are severed high, preserving their innervation from the ascending branch of the ansa hypoglossi nerve, no disability results. Disfiguring atrophy of the prethyroid muscles, with sunken neck and prominent trachea, may result from dividing the prethyroid muscles and their innervation too low in the neck.

The medial borders of the sternohyoid and sternothyroid muscles are best identified in the midline low in the neck. The midline of the trachea above the suprasternal notch should be determined by palpation, and this area explored. The investing fascia is incised vertically. Often a small amount of free fatty tissue is a clue to the midline. It may be necessary to divide communicating anterior jugular veins crossing the midline. Both the sternohyoid and deeper sternothyroid muscles are freed from the anterolateral surfaces of the thyroid, using blunt and sharp dissection and electrocautery to avoid bleeding from small vessels present in this plane. At this point, the pretracheal space inferior to the thyroid isthmus should be inspected and any enlarged lymph nodes excised and sent for frozen-section.

Middle Thyroid Vein, Recurrent Nerve, and Parathyroid Glands

Identification

The strap muscles are retracted laterally, and the thyroid lobe is retracted medially with a gauze-covered index finger, a “peanut” dissector, or a Babcock clamp. This allows identification, ligation, and division of the middle thyroid vein. With the

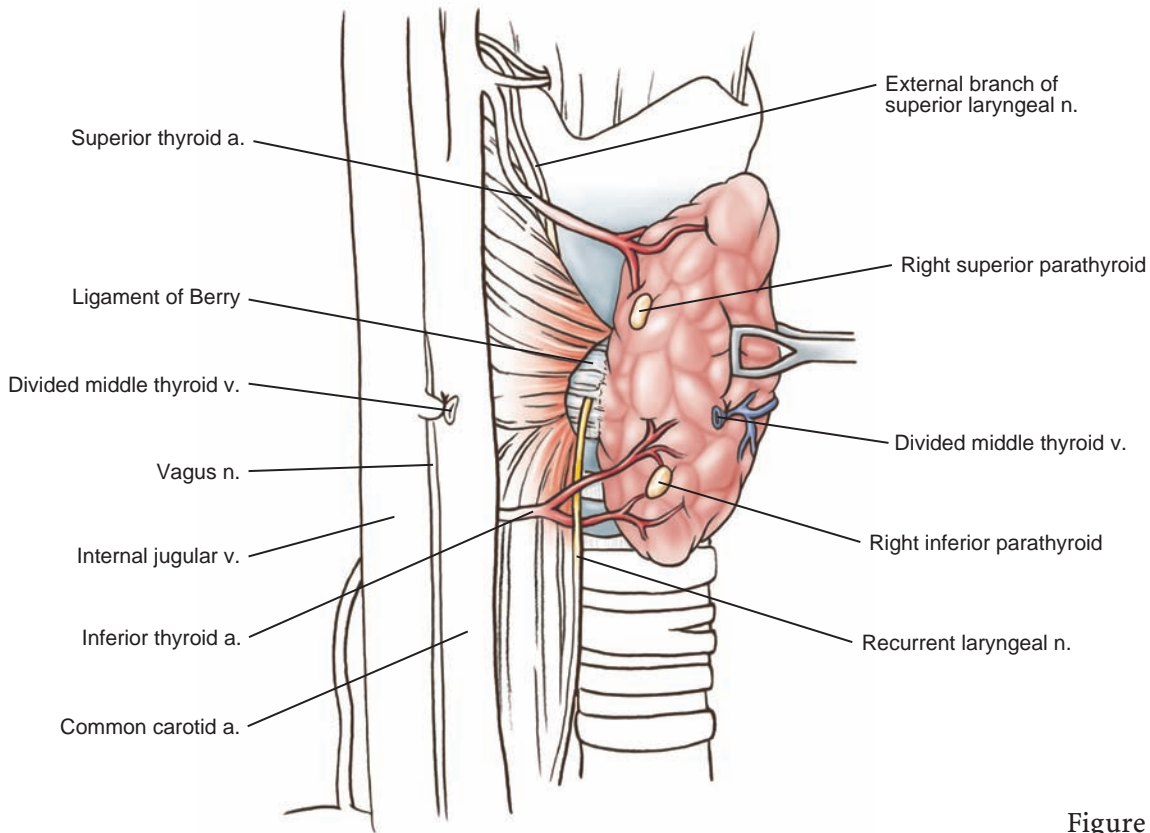


Figure 2.15

middle thyroid vein divided, the right thyroid lobe may be retracted further toward the left. Areolar planes adjacent to the thyroid, trachea, and esophagus are dissected gently, allowing exposure and identification of the inferior thyroid artery, the inferior and superior parathyroids, and the fascial attachments of the thyroid to the trachea (ligament of Berry). There may be two or more veins draining (and tethering) the lateral and inferior aspects of the thyroid lobe. It is important to dissect and divide these veins meticulously to avoid injury to the internal jugular vein or hemorrhage and discoloration of the operative field, which can make identification of the parathyroids and the recurrent laryngeal nerve more difficult. In cases involving large goiters, the internal jugular vein may be adherent to the capsule of the thyroid. Patience and careful retraction of the lobe are necessary to identify the location of the middle thyroid vein, and it may be necessary to divide multiple branches of the vein close to the capsule of the thyroid. Double ligation or suture-ligation of the middle thyroid vein is advisable. Current techniques also employ successful ligation using instruments such as the harmonic scalpel.

It is essential to identify the location and course of the recurrent laryngeal nerve. It should be sought and found prior to division of any major structures except the obviously blood-filled middle thyroid vein(s). The recurrent laryngeal nerve is a glistening, white, string-like structure emerging from the para-esophageal mediastinum and coursing cephalad in the tracheoesophageal groove, crossing either beneath or anterior to the transversely oriented inferior thyroid artery.

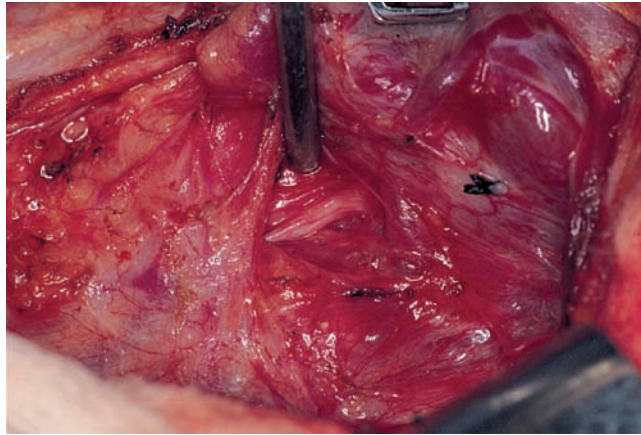


Figure 2.16

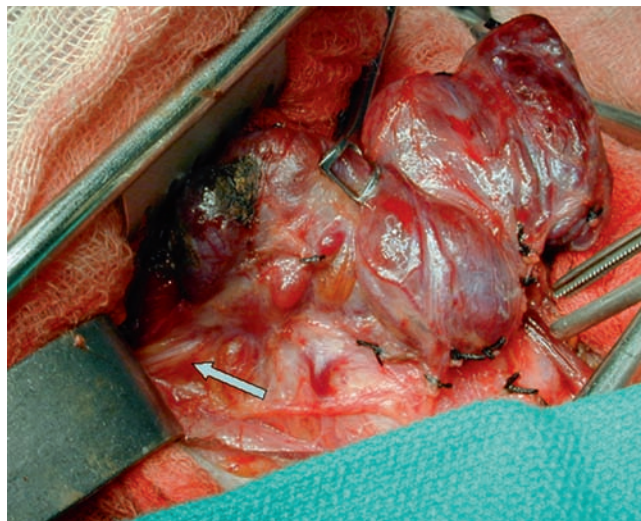


Figure 2.17

The left lobe of the thyroid is retracted anteriorly by surgical clamp; the patient's head is to the right. The left recurrent laryngeal nerve (arrow) courses from mediastinum (left side of photo) cephalad, to disappear beneath the cricothyroid membrane.

It is essential for the surgeon to be cognizant of the variations in anatomic location of the recurrent laryngeal nerve, especially its “nonrecurrence” (see arrow) when it exits directly from the carotid sheath and courses from lateral to medial to pierce the cricothyroid membrane. The right thyroid lobe is retracted anteriorly, surgical forceps points toward the trachea, and the patient's head is to the left. Following the RLN cephalad and caudad to be clear of its identification is a wise step and can facilitate identification of anatomical variants.

In most cases the recurrent laryngeal nerve is reliably and quickly identified as it crosses the inferior thyroid artery. Great care must be taken to avoid traction or cautery injuries to the nerve throughout the remainder of the procedure. Before clamping and cutting any structure, it is wise to ascertain its proximity to the nerve. It is best to keep the nerve in view at all times, since traction on the thyroid can distort its location markedly. A meticulous, bloodless dissection is advisable.

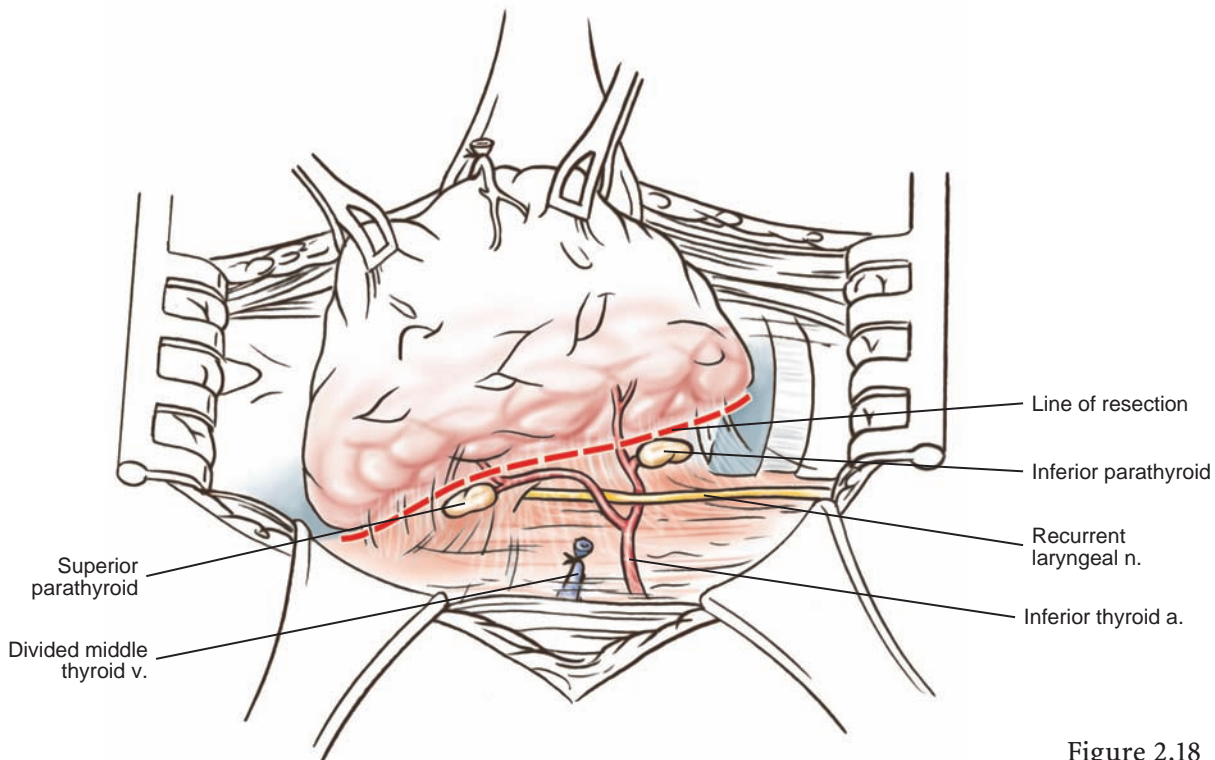


Figure 2.18

At this point in the procedure both parathyroids should be visualized, noting their blood supply and relationship to the thyroid capsule. It is usually possible to separate them from the surface of the thyroid and to divide branches of the inferior thyroid artery distal to the origin of its branches to the parathyroids, thus preserving them in situ in the neck. If it is not possible to maintain the viability of a parathyroid gland it should be excised, minced finely, and autografted to the ipsilateral sternocleidomastoid muscle.

Once these vital structures are identified, it is usually advantageous to dissect and divide the branches of the superior thyroid artery and vein. This allows much better mobilization of the lobe for the final pretracheal dissection. It is important to identify the external branch of the superior laryngeal nerve. Although it is usually higher and medial to the main trunk of the superior thyroid artery, considerable variation in its location has been documented. It may intertwine itself with branches of the artery. It is wise to divide the distal branches of the artery and vein individually to avoid nerve injury. Double ligatures of silk are advisable on this artery, tied in continuity prior to division, since it can retract cephalad if control is lost, causing hemorrhage and placing the nerve in jeopardy.

After the superior pole vessels are divided, the thyroid lobe may be retracted toward the opposite side, exposing the recurrent laryngeal nerve and parathyroid (see p. 80). It is important that, prior to division of the lateral and deepest branches of the superior pole vessels, the recurrent laryngeal nerve is fully exposed. A technique of identifying the recurrent laryngeal nerve near its insertion and also clearly

Division of Superior Vessels and Identification of External Branch of Superior Laryngeal Nerve

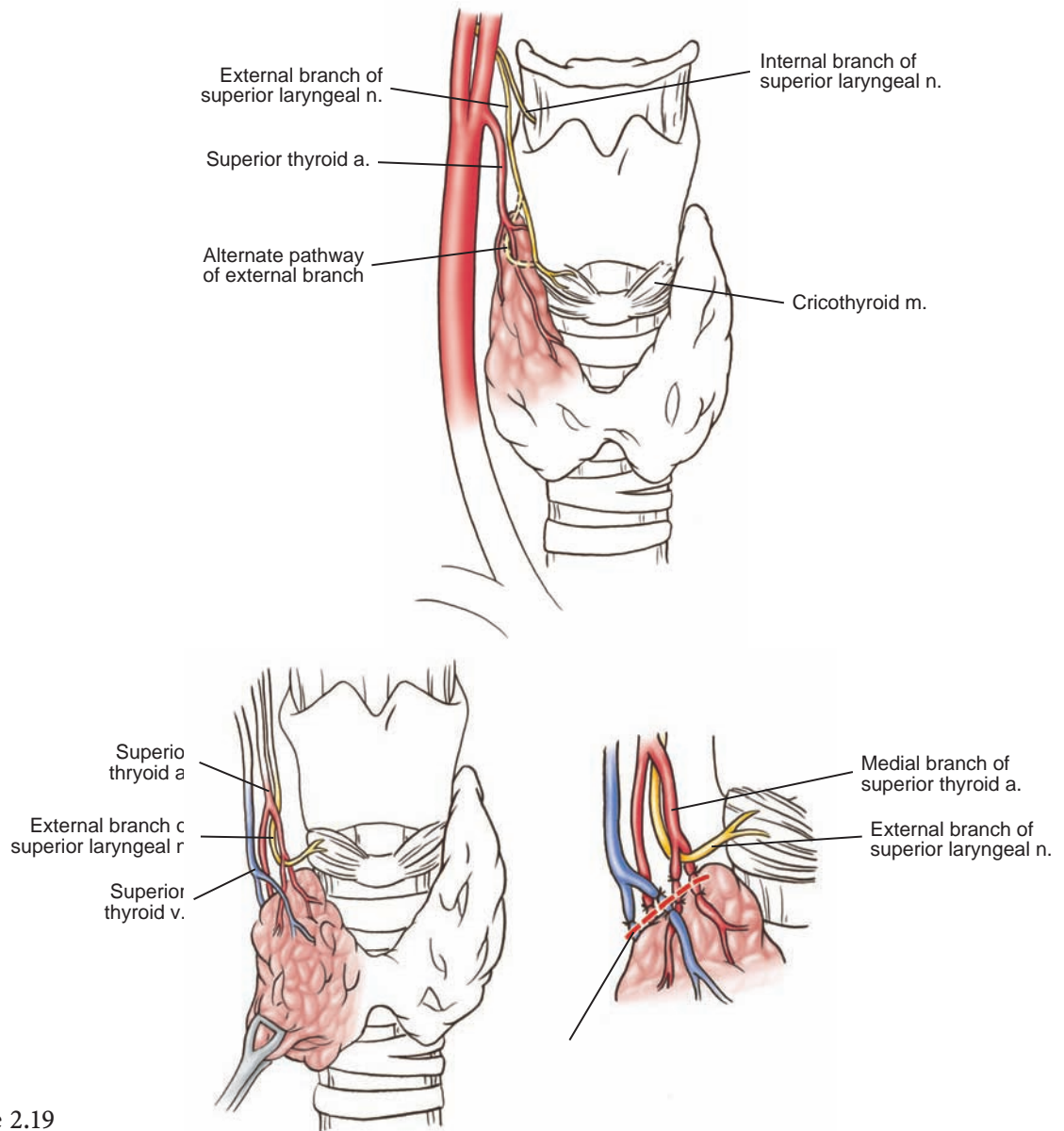


Figure 2.19

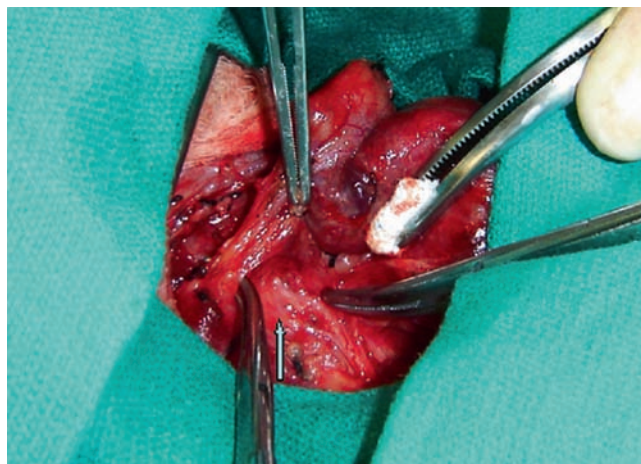


Figure 2.20

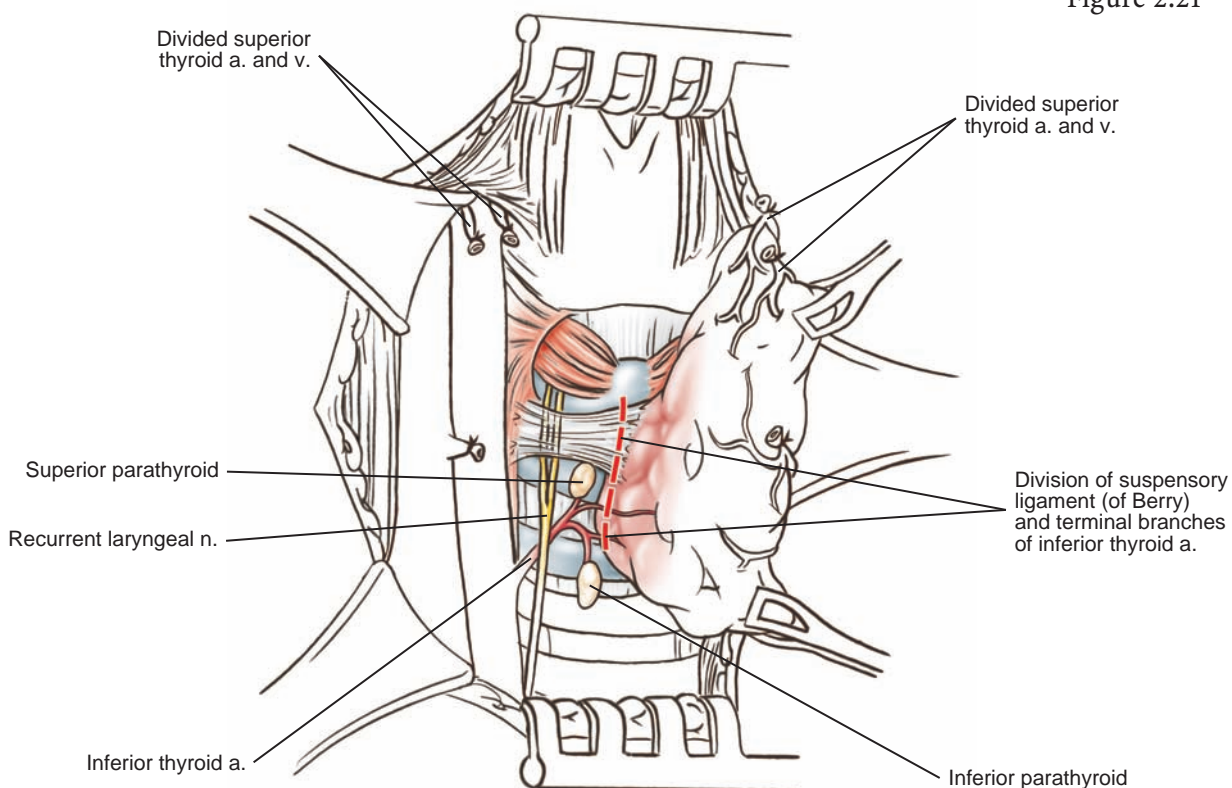
exposing the crossing vessels is to rotate the superior pole medially with an atraumatic clamp or forceps. This allows the surgeon to clearly observe the relationship between the nerve (arrow) and the vessel prior to its ligation, and keeps the recurrent nerve in direct view at all times during ligation and division of the vessels of the ligament of Berry.

The lobe is mobilized forward and medially, putting its posterior adventitial attachments on slight traction. Keeping the recurrent laryngeal nerve in view at all times to ensure that it is not being stretched, the thyroid is progressively mobilized upward by dividing its fascial attachments to the trachea and by dividing the distal secondary branches of the inferior thyroid artery near the surface of the thyroid. The parathyroid glands are gently dissected from the thyroid capsule, taking care to preserve their blood supply wherever possible. If a parathyroid gland is devascularized, it may be removed, minced finely into small (1 mm) pieces in sterile saline solution, and autotransplanted into a small intramuscular pocket in the sternocleidomastoid muscle with the aid of a 14-gauge angiocatheter and a 1-mL syringe.

As dissection progresses cephalad, portions of the tough ligament of Berry are dissected free from the tracheal surface, anteromedial to the path of the recurrent laryngeal nerve, and divided in continuity, keeping the nerve in view at all times. Guiding the dissecting instrument with the forefinger of the opposite hand will avoid trauma to the ligament and adjacent recurrent laryngeal nerve as the instrument

Division of the Ligament of Berry and Isthmus and Parathyroid Sparing

Figure 2.21



“pops through” the fibrous tissue of the ligament. It is important to ligate this ligamentous tissue, because it contains multiple small arterial and venous twigs that can retract beneath the path of the nerve, endangering the nerve as they are subsequently clamped and ligatured. Freeing of the ligament of Berry allows complete mobilization of the lobe toward the isthmus.

The isthmus is freed from its attachments to the trachea in the midline and divided after placement of circumferential suture-ligatures for hemostasis. Care must be exercised in separating the isthmus from the underlying pretracheal fascia to avoid injuring the trachea. At the upper aspect of the isthmus, the suspensory ligament is divided to complete the mobilization of the gland, and any pyramidal tissue is resected.

At this moment, in the thyroidectomy it is necessary to decide the amount of gland to resect. This is determined by the pathologic condition for which the thyroidectomy is being performed. In hyperthyroidism, usually about 90–95% of the gland is removed, leaving approximately 2–5 g. Concerns regarding persistence of hyperthyroidism or ophthalmopathy have led many surgeons to perform total thyroidectomy for this condition. With a diffuse hyperplastic gland, such as that found in Graves’ disease, it is better to err on the side of more complete removal, because surgically produced hypothyroidism is more easily controlled than persistent or recurrent hyperthyroidism. In toxic nodular and nontoxic nodular goiters, the risk for late recurrence (10–20 years) of the goiter has prompted total thyroidectomy in younger patients. In benign tumors, lobectomy to remove the tumor completely will suffice. In malignant tumors, total thyroidectomy is indicated in most cases. In general, isthmusectomy should accompany lobectomy, in order to leave behind a clear anterior tracheal surface that can facilitate subsequent reoperations if these become necessary.

In cases where papillary carcinoma is suspected but a definitive diagnosis is not established, it is wise to pass off the initial lobe for frozen-section. Controversy exists regarding the need for frozen-section in follicular neoplasms, although, occult carcinoma can be identified. If completion of a total thyroidectomy is indicated, the contralateral lobectomy is done precisely as described for the first lobectomy.

Subtotal Thyroidectomy

In some instances it is desirable to leave a thyroid remnant in situ. Subtotal thyroidectomy may be done as follows. After the thyroid lobe has been dissected in the usual manner and the recurrent laryngeal nerves and parathyroid glands have been identified, the resection margin is selected. Using a No. 2-0 or 3-0 silk suture on an atraumatic detachable needle, sutures are placed around the resection margin through the capsule and including 1–2 mm of underlying parenchyma. The suture is tied down onto the gland, occluding any capsular vessels. This is performed around the entire circumference of the lobe, with each suture spanning approximately a 3–5-mm length of capsule; normally 15–20 such sutures are required per lobe. Once all of the sutures have been placed, the capsule is sharply incised with a new blade, 1–2 mm above the suture line. The incision in the parenchyma is angled posteriorly to wedge out the thyroid tissue, leaving the capsule protruding 1–2 mm above the

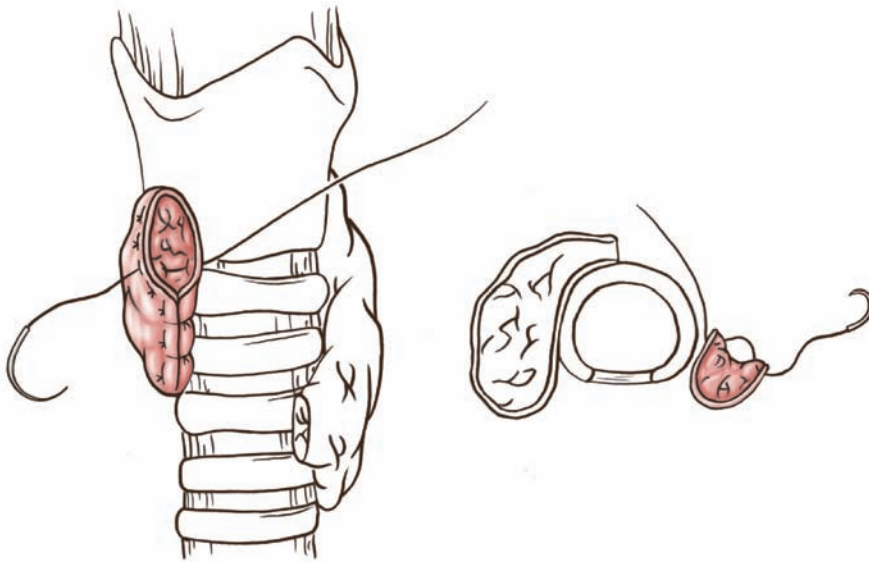


Figure 2.22

parenchyma. The cut ends of the capsule are then approximated using interrupted No. 3-0 silk to facilitate hemostasis and reestablish capsular continuity.

For closure of the thyroidectomy wound, the patient's head is slightly flexed to remove tension on the prethyroid muscles. The prethyroid muscles are approximated with mattress sutures. The platysma is reapproximated with absorbable sutures. This is important in that the platysmal closure takes tension off the subsequent finely sutured skin closure. Drains, if used, should be of the closed type (e.g., Hemovac) and are brought beyond the ends of the incision. Skin sutures of fine monofilament may be removed on the second postoperative day. Absorbable skin sutures are convenient, but may cause hypertrophic scars in some patients.

Closure of Wound

When the lymph nodes distributed along the lateral and posterior cervical region (Levels II-V) are clinically involved with thyroid carcinoma, a modified neck dissection is indicated. Because residual microscopic disease can be eradicated with subsequent radioactive iodine therapy, the disfigurement of a classic radical neck dissection is rarely warranted. The standard collar incision is extended laterally and upward along the posterior border of the sternocleidomastoid muscle. The space between the sternocleidomastoid and strap muscles is dissected. The sternal head of the sternocleidomastoid may be divided for exposure, but this is exceptionally rarely needed. The paraglandular, paratracheal, internal jugular, scalene, and posterior triangle nodes are easily accessible by reflecting the sternocleidomastoid muscle laterally. The spinal accessory nerve and the submandibular salivary gland should be preserved. Modified radical neck dissection can be performed through an extended transverse lower neck incision.

Modified Neck Dissection

The internal jugular nodes are dissected from the vein and removed along with surrounding fat. Node-bearing tissue from the posterior triangle is dissected in continuity with the jugular nodal specimen. It is rare to have either spinal accessory

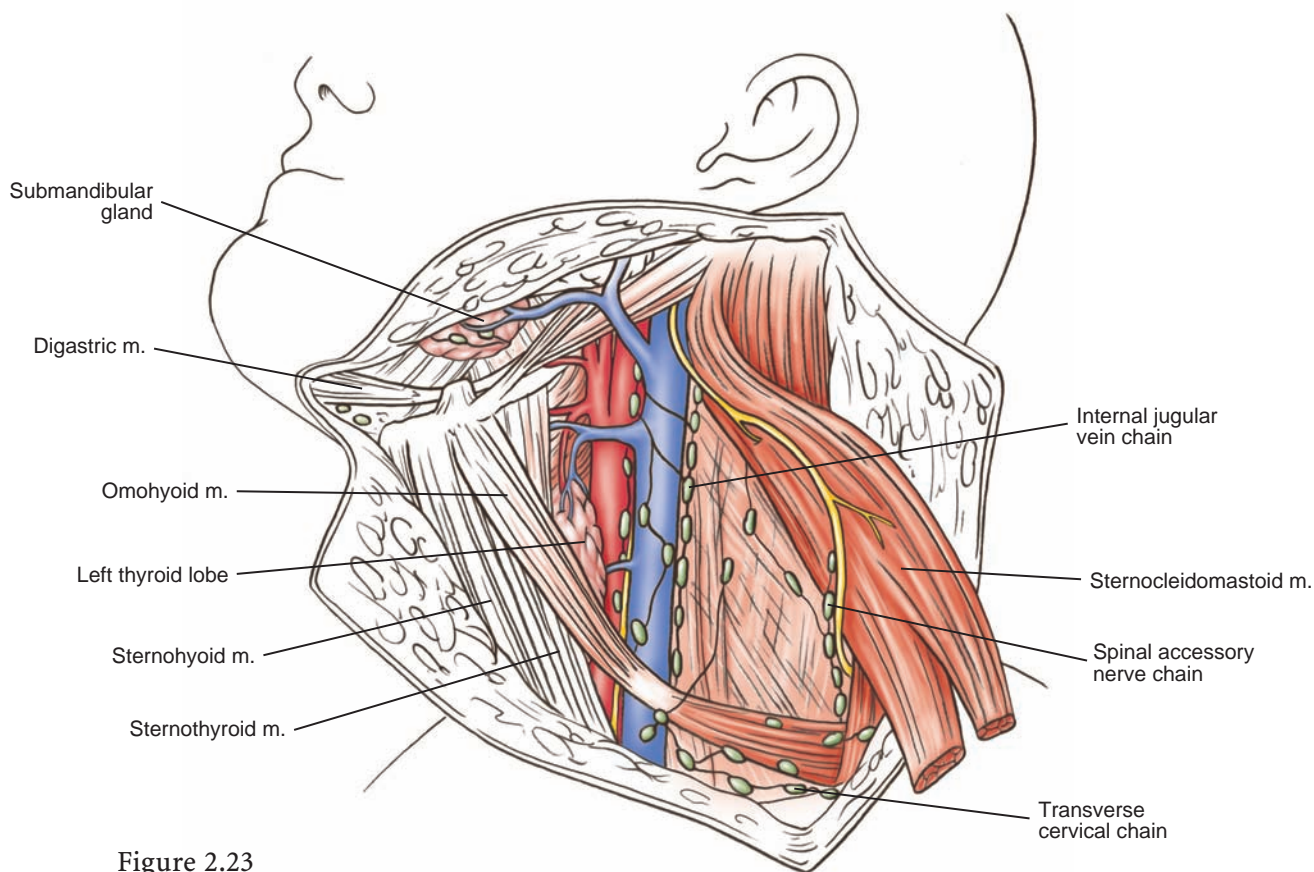


Figure 2.23

nerve or submandibular nodes involved with thyroid carcinoma. Cancer usually can be sharply peeled off these regions. This nerve and the submandibular compartment can thus be spared. The sternocleidomastoid muscle also is spared unless grossly involved or seeded with tumor from a previous neck node biopsy.

The goal is to preserve the spinal accessory nerve in all instances, if possible, because major disability from neck dissection relates to shoulder dysfunction resulting from its sacrifice. No increased incidence of recurrence within the neck area results from preservation of this all-important structure. When modifying standard radical neck dissection in patients with differentiated thyroid carcinoma, the structures preserved are, in order of descending cosmetic importance, the spinal accessory nerve, the submaxillary area, the jugular vein, and the sternocleidomastoid muscle. More complete neck dissection may be necessary in the case of medullary and undifferentiated carcinomas, however, since patients are generally older and have a greater tendency for local recurrence (for more information on this topic, see discussion of the lateral neck).

Central Neck Dissection

The central neck compartment or Level VI includes the Delphian, pretracheal, and paratracheal lymph nodes. Papillary, follicular, and medullary thyroid carcinomas often metastasize to the central neck and in some instances a prophylactic dissection of the central neck compartment is pursued. The boundaries include both carotid

arteries, the thyroid gland superiorly and the innominate vein inferiorly. The recurrent laryngeal nerves are dissected and skeletonized, but at a higher risk of injury. The inferior parathyroids are at a higher risk for devascularization and often need to be autografted. Types of lymphadenectomy include lymph-node sampling (“berry picking”), systematic neck dissection in patients with nodal involvement, and occasionally a prophylactic central neck dissection.

Most substernal goiters may be removed through the neck. Venous hemorrhage is more troublesome than arterial hemorrhage. Venous hemorrhage before delivery of a substernal goiter into the neck may be serious. The superficial and deep thyroid veins may be greatly enlarged and dilated secondary to the tourniquet effect of the goiter pressing on the superior thoracic strait. Extreme care must be exercised to avoid tearing these veins. The arterial supply to the substernal goiter arises in the neck, and it may be ligated before attempting mobilization of the goiter. After ligation of the inferior and superior thyroid arteries, a cleavage plane is sought between the capsule of the thyroid and the surrounding tissue. The trachea may be compressed and pushed to one side. The best cleavage plane is usually laterally and posteriorly. By finger dissection the goiter is freed from the pleura and the cellular tissue in the mediastinum and is delivered into the neck.

The thyroid surgeon should be familiar with a method of exposing the anterosuperior mediastinum. This may be necessary in order to remove a large substernal goiter or to perform anterosuperior mediastinal dissection in malignant disease. Seeking the assistance of a thoracic surgeon may be wise. A vertical incision is made from the midportion of the collar incision at the substernal notch in the midline downward to the level of the border of the fourth costal cartilage. The sternum is bared down to the periosteum. The undersurface of the sternum is freed by blunt dissection, and the sternum is divided using a sternal saw. Mediastinal tissues are further dissected from the undersurface of the sternum and the attached cartilages. The divided sternum is retracted laterally, and wide exposure to the anterior surface of the mediastinum is obtained. Beginning at the pericardium, the fascia with the lymph nodes, the fibroareolar tissue, the thymus, and the remaining thyroid remnants are dissected from the great vessels and the trachea. The recurrent laryngeal nerves must be constantly in view. In this fashion the trans-sternal dissection can be combined with thyroidectomy and neck dissection.

Resection of Substernal Goiter

Parathyroidectomy

In 97% of patients, hyperparathyroidism can be cured with a single, well-planned neck exploration. However, surgical treatment sometimes is difficult because of the minute size of the parathyroid glands, their varied location, and types of disease. Comprehensive knowledge of parathyroid embryology, pathology, and surgical

Indications and Pathology

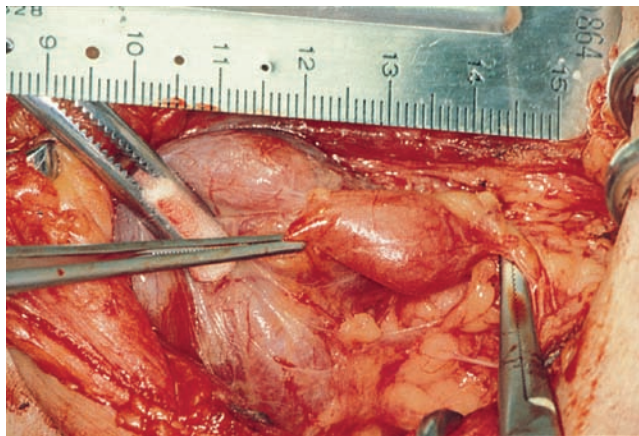
anatomy is essential if the treatment is to be successful. The surgeon's goal should be to identify all parathyroid glands in the neck and remove only the enlarged glands responsible for parathyroid hyperfunction. Confirmation of the location and histology of normal parathyroids by frozen-section biopsy is optional, but provides valuable information in patients with multiglandular disease and helps enormously in guiding repeat operations for those patients in whom initial neck exploration does not result in cure.

In approximately 70–80% of the cases reported, primary hyperparathyroidism is caused by a solitary parathyroid adenoma. Approximately 20–30% of patients with primary hyperparathyroidism have multiglandular disease either as hyperplasia or double adenomas. Double adenomas can occur in 2–15% of patients with a nonrandom distribution that affects primarily superior parathyroids. Occasionally, a patient may have both an adenoma and hyperplasia. About 1% of patients with primary hyperparathyroidism have parathyroid carcinoma.

Approximately 5% of renal failure patients undergo parathyroidectomy for secondary hyperparathyroidism, with a decrease to 3% after a successful renal transplant. The most common cause of secondary hyperparathyroidism is chronic renal failure. Parathyroidectomy is indicated when severe sHPT is unresponsive to medical therapy. Coronary and peripheral artery calcifications and calciphylaxis are two complications that contribute to a high mortality in patients with secondary hyperparathyroidism. A few patients progress to develop hypercalcemia and tertiary hyperparathyroidism. Usually all parathyroid glands are hyperplastic and large. Both diffuse and nodular hyperplasia, are found in enlarged parathyroid glands, with nodular hyperplasia being found predominantly in larger glands.

The average adenoma is 1–3 cm in diameter; however, they can be much larger. Adenomas are encapsulated and are slightly firmer than the surrounding tissue. Their capsule is reddish brown and their cut surface is yellowish brown. Illustrated is a right lower parathyroid adenoma. Surgical clamps are on vascular pedicles of the adenoma, sponge forceps retract the right thyroid lobe anteriorly and cephalad, and the patient's head is to the left.

Figure 2.24



The hyperplastic gland is usually irregular, but can simulate an adenoma, and the size varies from slightly larger than normal to 3–4 cm in diameter. All four glands may be the same size or they may vary in size, and one gland may be enlarged while the other three glands are nearly normal in size, making it difficult to distinguish grossly between an adenoma and hyperplasia. Normal parathyroids may become atrophic in the presence of an adenoma (“suppressed glands”), and thus appear as fatty tissue, although this is rare.

Histologically, the normal parathyroid gland is made up of sheets of epithelial cells separated by sinusoids and fat. There are three cell types: chief cells, which show scanty cytoplasm and large deeply staining nuclei; water-clear cells, distinguished by their vacuolated cytoplasm and small eccentric nuclei; and oxyphil cells, which have granules in their cytoplasm that stain deep red with acid dyes. A normal parathyroid gland is composed predominately of chief cells with scattered water-clear and oxyphil cells throughout the gland. There are fat cells between sheets of parathyroid cells. The percentage of fat cells vs. chief cells increases with age, from 10% in childhood to approximately 50% in adulthood.

Adenomas and hyperplastic glands are usually composed predominately of chief cells. Water-clear cell hyperplasia and adenomas rarely occur. Even rarer is the occasional oxyphil adenoma. Histologically, chief cell adenomas are composed of closely packed small cells that resemble the cells of a normal parathyroid except they are more tightly packed and there is little or no fat seen. To confirm the diagnosis of adenoma, the pathologist must find a capsule and an associated fragment of normal parathyroid tissue that is being compressed by the adenoma.

Hyperplastic parathyroids are composed of chief cells plus varying amounts (5–30%) of fat. Carcinoma of the parathyroid is usually larger than an adenoma, with firm to hard consistency. Histologically, it is usually made up of closely packed chief cells. The diagnosis of a malignancy cannot be made on the histologic features of the cells; there must be evidence of invasion of adjacent structures or distant metastasis.

The initial steps in parathyroidectomy are identical to those for thyroidectomy. The patient’s neck is comfortably hyperextended by placing a folded sheet longitudinally between the shoulders to give good exposure of the operative field. The head of the table is tilted upward approximately 30° to increase exposure and decrease venous engorgement. In recent years, multiple operative techniques for parathyroid surgery have emerged. Like the length of a thyroidectomy incision, the length for parathyroidectomy incision depends on the technique used and can be as small as 2 cm. The length of incision should be appropriately matched to the disease process and to the experience of the surgeon.

Operative Techniques

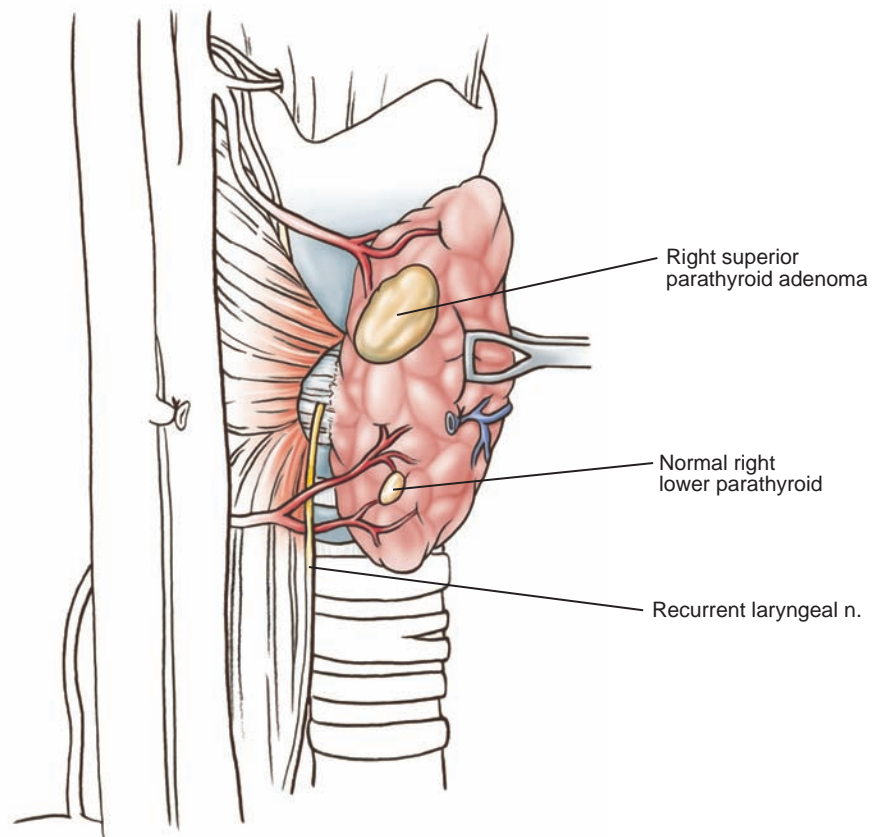
Bilateral Neck Exploration (Traditional)

A transverse incision is made 3 cm above the clavicles in or parallel to a crease in the neck. The scar will be 1.5 cm above the clavicles when the neck is in normal position. Lower incisions over the clavicle and sternum are more likely to develop

hypertrophic scars and keloids, since the skin is somewhat tethered to these structures, and therefore the incision is put under transverse tension with motion of the neck. The incision is extended through the skin, subcutaneous tissue, and platysma muscle, and is continued to the lateral border of the sternocleidomastoid muscle on each side. The skin flaps are dissected along the avascular plane between the platysma and the investing layer of deep cervical fascia, as described for thyroidectomy. The upper flap is dissected to the level of the superior thyroid notch and the lower flap to the manubrium, exposing the suprasternal notch. The wound edges are draped, and a self-retaining retractor is applied to facilitate good exposure. The strap muscles and sternohyoid and sternothyroid muscles are separated in the midline in the avascular plane, up to the superior thyroid notch of the thyroid cartilage and extending inferiorly to the jugular notch of the manubrium. It is unnecessary to divide the anterior jugular veins unless they communicate across the midline. The sternothyroid muscle is then dissected free from the thyroid lobe to expose the thyroid and the superior mediastinal tissue. It is rarely necessary to divide the strap muscles during parathyroid exploration. The middle thyroid vein is identified, ligated, and divided. The thyroid lobe then can be retracted medially and anteriorly.

The area bordered medially by the lateral surface of the thyroid gland and laterally by the carotid sheath is now dissected. Gentle anteromedial traction on the thyroid lobe with the use of a “peanut” dissector or Babcock clamp tends to tense up the

Figure 2.25



structures, making their identification easier. This gives a clear view of the posterior aspect of the thyroid gland. It is seldom necessary to ligate the superior pole vessels of the thyroid gland; however, when it is required for good exposure, mobilization should be done carefully to prevent injury to the external branch of the superior laryngeal nerve.

After adequate exposure has been obtained, the inferior thyroid artery and recurrent laryngeal nerve are identified in the lower portion of the neck, usually in the groove between the trachea and the esophagus, although enlarged parathyroids can “displace” the nerve laterally and also can be intimately associated with the recurrent laryngeal nerve. In about two-thirds of cases, the nerve runs posterior to the inferior thyroid artery, but it may be anterior to or between branches of the artery. The nerve enters the larynx under cover of the anterior constrictor muscle of the pharynx. The superior parathyroid glands are normally above the inferior thyroid artery, and the inferior parathyroid glands are below the inferior thyroid artery.

The superior parathyroid gland is in its normal position in approximately 75% of cases, posterior to the thyroid lobe at the level of the upper- and middle-thirds of the thyroid gland. It usually hangs from the thyroid gland or lies near or is closely attached to the dorsal surface of the thyroid gland. The superior parathyroid gland usually is found lateral and dorsal to the recurrent laryngeal nerve as it enters the larynx under cover of the inferior constrictor of the pharynx.

The normal parathyroid gland has a yellow-brown color slightly darker than fat and is rarely larger than $6 \times 3 \times 3$ mm. Surgical forceps hold fat near this left lower parathyroid, and a surgical clamp retracts the left thyroid lobe anteriorly; the patient's head is to the right. Parathyroid tissue can be confused with fat, lymph nodes, thyroid, and thymus. Frozen-section biopsy of parathyroids is thus done principally for confirmation of parathyroid tissue, and not to distinguish adenoma from hyperplasia.

The superior parathyroid gland is usually covered or surrounded by fat and a thin capsule or opaque fascia. On gentle palpation of the suspected gland, one can see a small “body” moving beneath the fat capsule. The entire parathyroid gland should not be dissected free from the surrounding fat and capsule because of the danger of interfering with its blood supply. A tiny biopsy may be done to confirm diagnosis,

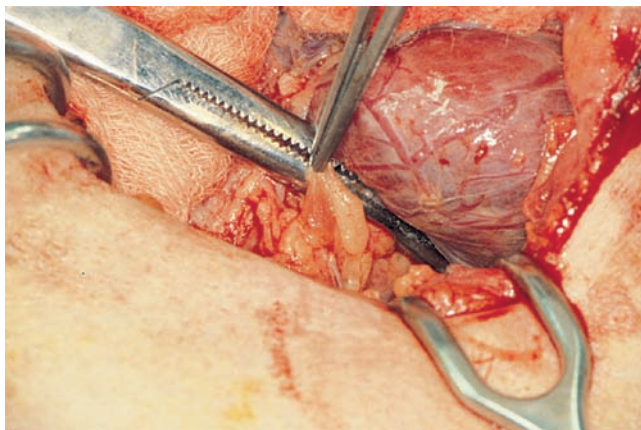


Figure 2.26

using microsurgical technique, opposite its feeding artery. Two gross findings are helpful in identifying parathyroid tissue at the time of biopsy. Parathyroid tissue is quite vascular, and on biopsy a “blush” or diffuse bleeding is seen from the cut surface; fat does not exhibit such a blush. The gland holds its shape or body following biopsy; this does not occur if the tissue is fat.

The lower parathyroid gland is more difficult to identify than the superior gland. It is in its normal position in approximately 50% of individuals. The lower parathyroid gland is normally located on the posterolateral aspect of the inferior pole of the thyroid gland, below the inferior thyroid artery (see p. 83). Sometimes it may be in a fatty appendage distal to the lower pole of thyroid. The inferior parathyroid gland is usually surrounded by fat and a thin capsule. On gentle palpation of the suspect gland, it may be seen moving within the fat and capsule. A small area of the parathyroid tissue is exposed by gentle dissection of the fat and capsule distal to its blood supply. The surgeon should expose only enough of the gland for identification and determination of size and for biopsy. The mass of parathyroid may be estimated in situ by taking its measurements in three dimensions and multiplying the volume by 0.6, which yields the volume of a prolate ellipsoid. The volume in cubic millimeters is approximately equal to the mass in milligrams. While the normal parathyroid is rarely larger than 40 mg, most surgeons will not resect parathyroids which are calculated to be less than 80 mg.

All four parathyroid glands should be identified before removing any parathyroid tissue. Generally the parathyroid glands can be identified by gross appearance. However, many surgeons prefer to biopsy each gland to confirm identification of the four parathyroid glands and to establish the histologic picture of each gland.

Minimally Invasive Parathyroid Surgery (MIPS)

Many synonymous terms are used for MIPS including limited, focused, unilateral, and radioguided parathyroidectomy. Preoperative localization studies such as the ^{99}Tc -Sestamibi (Mibi) scan and ultrasound are done routinely in many centers and can help to select for patients with single-gland pathology prior to performing a limited neck exploration.

The technique described here uses a smaller transverse incision in the lateral neck which can be extended across midline for a traditional approach to parathyroidectomy if necessary. The incision is extended through the skin, subcutaneous tissue, and platysma muscle. Subplatysmal flaps are often not necessary and external jugular veins are spared and used for cannulation for intraoperative parathyroid hormone measurements (IOPTH). The dissection plane is between the sternocleidomastoid muscle and the strap muscles. The internal jugular vein and carotid artery are encountered at the lateral extent of exposed tissue. The middle thyroid vein is identified, ligated, and divided. The thyroid lobe can be rotated medially with a Babcock clamp and the recurrent laryngeal nerve and inferior thyroid artery are identified. The superior and inferior parathyroid glands can then be identified as described in the previous section. The parathyroid tumor is then resected and IOPTH is measured at 5 and 10 min

post resection. If IOPTH falls to normal, the operation is halted; otherwise the incision is extended and the contralateral neck is explored.

With the use of IOPTH and parathyroid localization, a less extensive dissection can be performed with equivalent results in approximately 50–60% of patients. In the remaining 40% of patients, the preoperative localization studies are inconclusive or IOPTH dynamics identifies multi-gland pathology. With addition of IOPTH, our criteria for classification of abnormal parathyroid glands not only include size, histology and morphology but also function. IOPTH allows us to determine if the localized tumor is the only functioning tumor in the patient. In our series, IOPTH remained elevated in 22% patients after a limited neck exploration and after conversion to a bilateral neck exploration another tumor was identified in all patients.

If an adenoma is found and the other glands are histologically normal, the adenoma is removed. The adenoma is frequently tucked down under the lateral lobe of the thyroid in a space beside the esophagus. It may be just slightly posterior, in the groove between the esophagus and the trachea or thyroid cartilage. With careful dissection, a normal rim of parathyroid tissue can often be identified grossly inside the capsule of the adenoma. This may be labeled with a suture and brought to the attention of the pathologist so that it can be identified histologically.

If the parathyroid glands are hyperplastic, three and three-fourths are removed, leaving a vascularized remnant of one gland which approximates the size of two normal parathyroids; and the fragments which are equivalent of 8–10 normal glands are

Extent of Parathyroidectomy

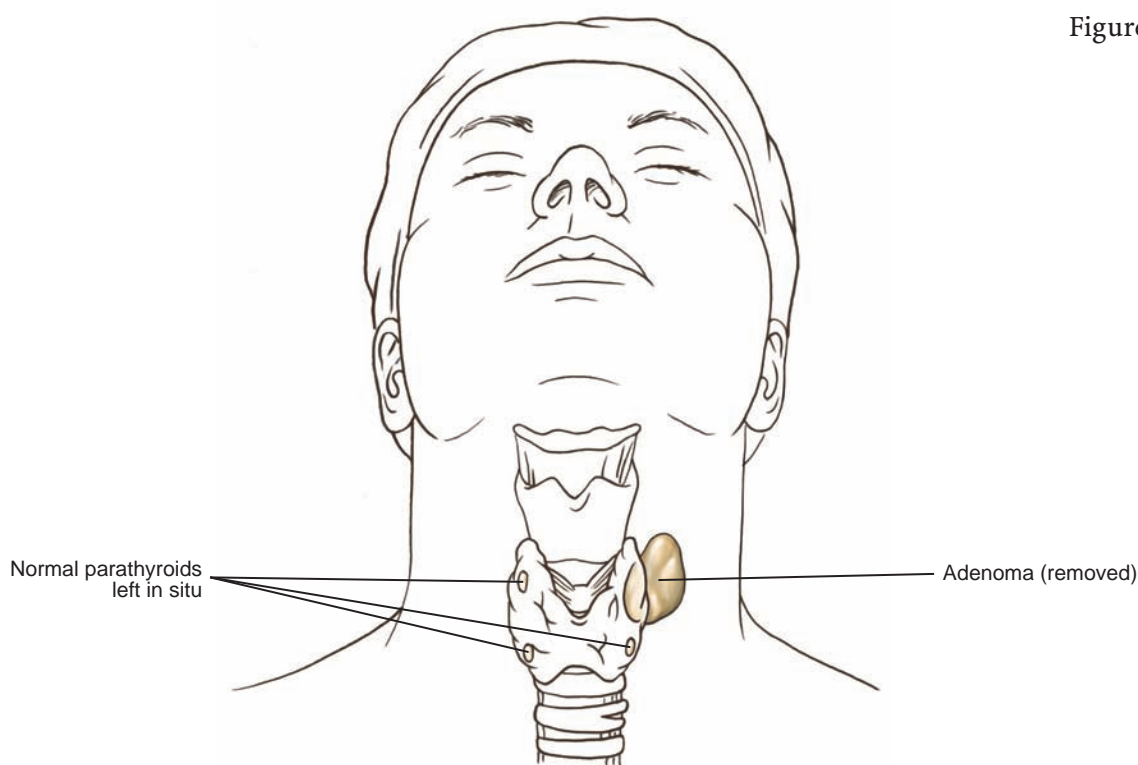


Figure 2.27

cryo-preserved. The in situ gland remnant may be marked with a permanent suture for future identification. Alternately, all parathyroids may be removed from the neck, and the equivalent of 1–2 normal parathyroids may be minced into 1–2 mm fragments and autografted into either the sterno-cleidomastoid or nondominant forearm muscle. Autografted fragments should not be prepared from nodular parathyroids but from the more uniform parathyroids. In this instance, additional fragments may be cryopreserved as a safeguard in case the autografted tissue is insufficient. Total parathyroidectomy and autotransplantation has the advantage that recurrent parathyroid hyperfunction may be treated by partial autograft excision under local anesthesia. However, some autografts fail to function, particularly in marginally nourished patients receiving dialysis. In these patients a vascularized parathyroid remnant often functions better, and patients may be discharged sooner. Furthermore, in our experience, vascularized remnant regrowth is distinctly uncommon if the size of the remnant is small (the equivalent of 1–2 normal parathyroids in mass, approximately 80 mg).

If carcinoma of the parathyroid is found, en bloc excision of the primary tumor and metastases is the treatment of choice. This usually includes an ipsilateral thyroid lobectomy and a central neck lymph-node dissection. An ipsilateral modified radical neck dissection may also be necessary in the presence of significant local lymphatic invasion.

After hemostasis has been accomplished, a small closed suction drain may be left on each side of the neck and brought out through a separate site. The strap muscles

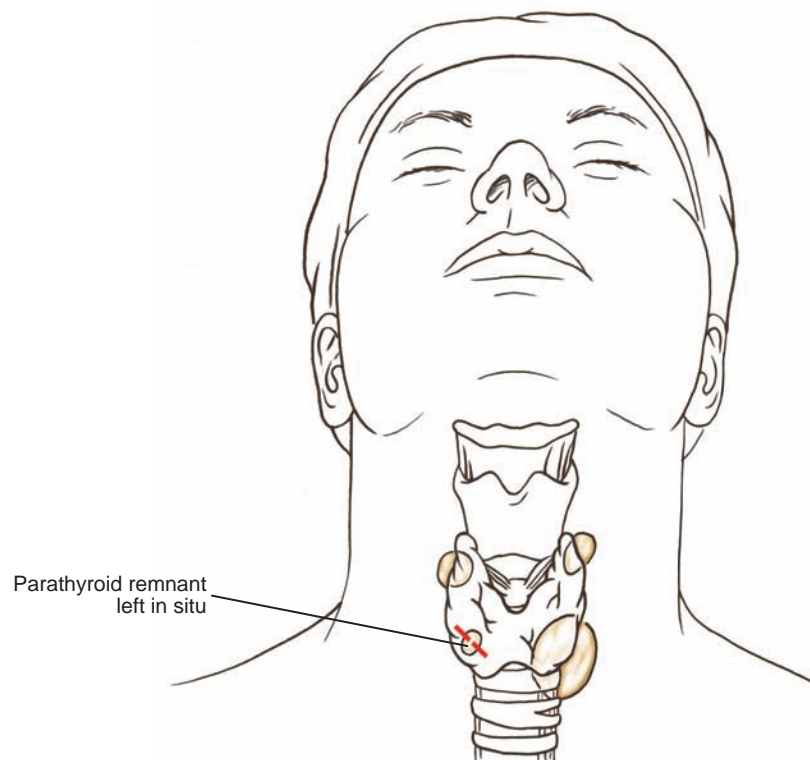


Figure 2.28

are approximated in the midline with interrupted 4–0 silk sutures. The platysma is sutured with interrupted 4–0 white absorbable suture and the skin edges approximated with interrupted mattress sutures. The drains are removed in 24h. The skin sutures are removed on the second day.

The location of the inferior glands varies because of their embryologic motility. Abnormally located parathyroid glands may be found from the level of the angle of the jaw to the carina. Frequently missing superior parathyroid adenomas are found in the tracheoesophageal groove and the area posterior to the esophagus. The abnormal gland may be found lying below or lateral to the cervical vertebral bodies. The area along the carotid sheath should also be palpated and exposed. The capsule on the dorsal aspect of the thyroid gland should be inspected carefully. A branch of the inferior thyroid artery, which may appear larger than expected or redundant, may lead the surgeon to the missing parathyroid gland. If the gland still is not found, transcervical thymectomy should be performed. By gentle traction with clamps, the thymus can be withdrawn from the mediastinum into the cervical incision. Ectopic parathyroid glands should be searched for superior to the thyroid gland, to a level at the angle of the jaw near the submaxillary gland. If the missing parathyroid gland still is not found after an extensive search such as described, the thyroid lobe on the appropriate side should be removed because an intrathyroidal parathyroid adenoma may be present in 1% of patients.

If a hyperfunctioning parathyroid cannot be found during initial surgery, exploration of the mediastinum should be delayed. A careful operative record should be made for future reference, with a detailed description of the location of the normal parathyroids which have been found. By deduction, the parathyroid not found is the missing adenoma. The hyperfunctioning parathyroid tissue may have been removed in the tissue or thyroid submitted for histologic study, or the blood supply to the hyperfunctioning parathyroid tissue may have been interrupted during the course of dissection. If significant hypercalcemia persists, the patient should be reevaluated. High-resolution, real-time sonography; magnetic resonance imaging; and computed tomography may be helpful. However, the single most reliable localization test currently is technetium-sestamibi scanning. Approximately 2% of parathyroid tumors are found within the mediastinum or the thymus or in the aortopulmonary window or precarinal spaces. The aortopulmonary window can be dissected via sternotomy. The precarinal space is best approached via right thoracotomy.

Abnormal Parathyroid Tumor Locations

Anatomic Basis of Complications

- Nerves at risk during thyroidectomy and parathyroidectomy include the recurrent laryngeal nerves, the external branches of the superior laryngeal nerves, and the cervical sympathetic nerve trunks. In a series of 217 thyroid operations,

Nerve Injuries

Holt et al. found nine laryngeal nerve injuries, four of them permanent. In the same series there were three injuries to superior laryngeal nerves; one was permanent.

- Most recurrent laryngeal nerve injuries occur “just below that point to where the nerve passed under the lower fibers of the inferior constrictor muscle to become intralaryngeal.” The usual cause is a hemostatic stitch. Another source of injury is mass ligation of the vessels of the lower pole of the thyroid. Such ligation may include a recurrent nerve which is more anterior than usual. The nerve should be identified before ligating the inferior thyroid vein.
- Sites of possible nerve injury in thyroidectomy are as follows:
 1. External branch of the superior laryngeal nerve during ligation of the superior thyroid vascular pedicle.
 2. Recurrent laryngeal nerve as it traverses the ligament of Berry during total lobectomy. The recurrent nerve usually courses posterior to the “adherent zone” (ligament of Berry); however, in 25% of cases it passes through it. The nerve traverses the thyroid itself at this level in 10% of patients. By retraction on the lobe, the recurrent nerve can be pulled forward into the operative field and be injured. In addition, traction can injure the nerve.
 3. Recurrent laryngeal nerve during ligation of the inferior thyroid artery. It is important to ligate branches of the artery while keeping the nerve under direct vision.
 4. Recurrent laryngeal nerve during ligation of the inferior thyroid veins. The nerve is anterolateral to the trachea in about 10% of cases and may be caught and divided during ligation of the veins.
 5. Nonrecurrent nerve during ligation of the inferior thyroid artery. A nonrecurrent nerve may be mistaken for the inferior thyroid artery and ligated, because it takes a parallel horizontal course from the cervical vagus to the larynx. Fortunately, this anatomic variant is rare.
 6. Cervical sympathetic trunk during ligation of the inferior thyroid artery. If the inferior thyroid artery is ligated too far lateral, the cervical sympathetic trunk may be caught in the tie.
- Specific causes of recurrent nerve injury have been detailed by Chang. Separation of the inferior thyroid artery from the recurrent laryngeal nerve requires care. Where the nerve passes between branches of the artery, the individual branches must be ligated and divided separately.
- Injury to the recurrent laryngeal nerve usually is complete. The vocal cord then takes up a paramedian position. When only one side is involved, the airway is adequate. However, the voice may be hoarse until one cord compensates by adducting over to the opposite cord. If the external branch of the superior laryngeal nerve is also injured, the cord becomes flaccid as well as paralyzed. This may cause noisy breathing on both inspiration and expiration.
- The recurrent laryngeal nerve carries both adductor and abductor fibers. The abductor fibers are more superficial and more vulnerable to injury. The abductors

may be preferentially damaged by traction, cautery, and other procedures. Such incomplete bilateral damage to the recurrent laryngeal nerves is more dangerous and more potentially life-threatening than is bilateral complete injury, since damage to abductor fibers results in unopposed function of adductor fibers, which draw the cords toward the midline, narrowing the glottic opening to a slit and resulting in severe respiratory distress, which may necessitate emergent tracheostomy.

- Injury to the external branch of the superior laryngeal nerve results in dysfunction of the cricothyroid muscle, with ensuing hoarseness. The voice is usually “breathy” and aspiration of liquids is a frequent complication. Bilateral damage to both external branches results in flaccid vocal cords and extreme weakness of the voice on phonation. The superior thyroid artery should not be clamped above the upper pole of the thyroid because the external laryngeal nerve may be injured. The branches of the artery should be divided individually.
- Postoperative hoarseness is not always the result of operative injury to laryngeal nerves. One percent to 2% of patients have a paralyzed vocal cord prior to thyroid resection. Based on several large series, it is recommended that the patient be informed that, despite all precautions, there is a possibility (1–2%) of some vocal disability following thyroidectomy or parathyroidectomy.
- A sympathetic ganglion may be confused with a lymph node and removed when the surgeon operates for metastatic papillary carcinoma of the thyroid. Injury to the cervical sympathetic nerve results in Horner’s syndrome (constriction of the pupil, ptosis of the upper eyelid, apparent enophthalmus, and dilation of retinal vessels).

- With total thyroidectomy, transient hypocalcemia may occur in 5–10% of patients. The incidence of permanent hypoparathyroidism is less than 1% in patients operated on by experienced surgeons, especially with preservation or autotransplantation of resected tissue from a normal parathyroid gland. The surgeon performing thyroidectomy should be familiar with the technique of parathyroid fragment autografting. It is important to recognize arterial or venous compromise to a parathyroid and autograft its fragments rather than assuming that it is viable in situ. With careful dissection, most normal parathyroids can be spared in situ; but in 5–10% of thyroidectomies at least one parathyroid will require autografting, usually because its arterial supply is intimate to the thyroid capsule. If a parathyroid is not found during thyroidectomy, the surface of the resected thyroid specimen should be inspected.

Hypoparathyroidism

- Thyroid arteries must be ligated carefully with double or suture ligature of the superior and inferior thyroid arteries. The superior thyroid artery tends to retract. The middle thyroid vein is short and easily torn and, if divided accidentally, will retract, making hemostasis difficult. With too much traction of the thyroid gland, the vein becomes flattened and bloodless, making it difficult to

Vascular Injuries and Hemorrhage

recognize. The tear is often at the junction of the middle thyroid vein with the jugular vein. The thoracic duct is rarely injured in thyroidectomy, although it may be injured during neck dissection. The duct may be ligated with impunity.

Organ Injuries

- The pleurae are injured rarely, except in cases such as a huge goiter extending into the mediastinum. Both anteriorly and posteriorly, the two pleurae approach the midline and hence each other. Intrathoracic goiter may descend into the anterior or posterior mediastinum, bringing the thyroid gland close to the pleurae.
- The trachea and esophagus may be injured in the presence of thyroiditis, calcified adenoma, or malignancy. The true capsule of the thyroid, the pretracheal fascia, the trachea, and the esophagus may be fixed to one another, and vigorous attempts at separation may perforate the trachea. Tracheal perforation may require immediate tracheostomy but usually can be repaired primarily with absorbable suture, after advancing the cuff of endotracheal tube below the perforation.

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Lateral Neck

Grant W. Carlson

Introduction

The vast majority of solitary, nonthyroidal neck masses in adults represent metastatic cancer from a primary lesion located above the clavicle. Squamous cell carcinoma accounts for the vast majority of these neoplasms. Benign tumors and infectious causes comprise the majority of neck masses seen in children.

Tumors of the salivary glands and carotid body are infrequent causes of neck masses. Lymphoma commonly presents in the head and neck and is the most common tumor of childhood.

A complete head and neck examination can locate the primary cancer in over 90% of cases that present as a neck mass. The diagnosis can usually be made by fine-needle aspiration cytology. Equivocal results or insufficient tissue may necessitate open biopsy. Computed tomography (CT) or magnetic resonance imaging (MRI) can improve the sensitivity of physical examination of the neck and parotid glands, and guide treatment planning.

Surgical Anatomy

Fasciae of Neck

Knowledge of the fascial layers of the neck is mandatory to extirpate cancer and treat infections of the head and neck. The fascia surrounds muscles, vessels, and viscera to form defined surgical planes and fascial envelopes. Metastatic squamous cell cancer of the head and neck follows predictable patterns, and the fascial planes enable resection with preservation of many vital structures.

The superficial fascia of the neck is composed of the platysma muscle, loose connective tissue, fat, and small unnamed nerves and blood vessels. The platysma is a voluntary muscle and is innervated by the cervical branch of the facial nerve. The muscle may be included in elevating skin flaps to improve vascularity. Superficial lymphatic channels lie above the muscle, and removal would require skin excision.

The cutaneous nerves of the neck and the external and anterior jugular veins lie between the platysma and the deep cervical fascia. The deep cervical fascia consists of areolar tissue that supports the muscles, vessels, and viscera of the neck. In certain areas, it forms well-defined fibrous sheets called the investing layer, the pretracheal layer, and the prevertebral layer. The investing layer of the deep cervical fascia arises from the ligament nuchae and the spines of the cervical vertebrae and courses forward

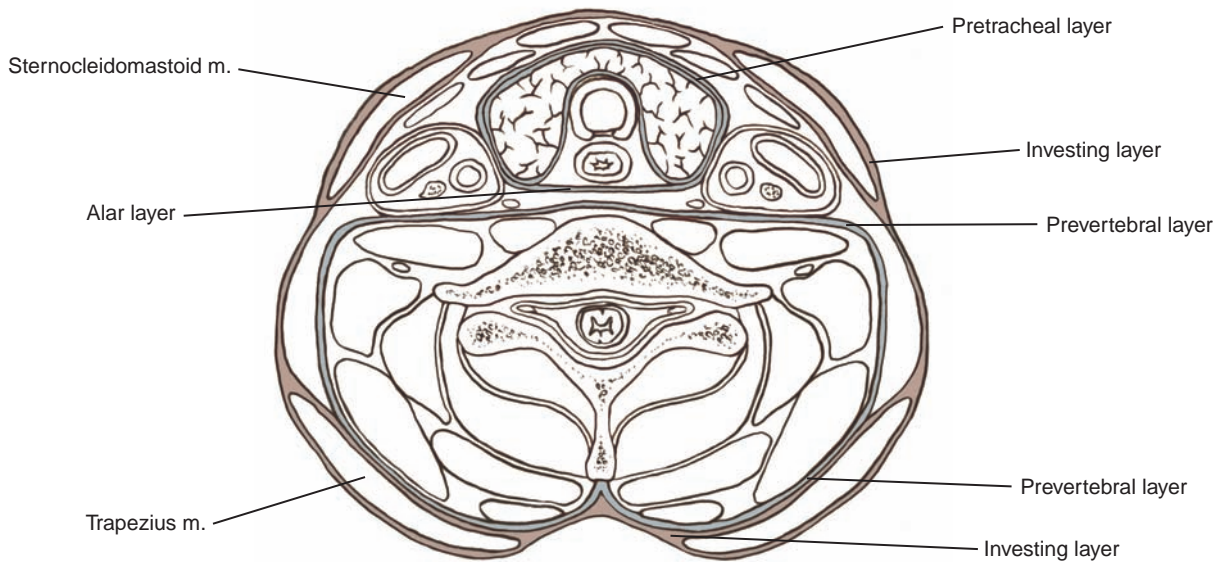


Figure 2.29

to completely surround the neck. It is attached to the external occipital protuberance, mastoid process, and zygoma. The investing layer envelops the trapezius and sternocleidomastoid muscles and the parotid and submaxillary glands. At the anterior border of the sternocleidomastoid muscle, it contributes to the anterolateral wall of the carotid sheath and continues as a single layer to the midline. The pretracheal layer splits into an anterior portion that envelops the sternohyoid and sternothyroid muscles and a posterior layer that envelops the thyroid gland, forming the false capsule of the gland. Below, it extends into the thorax and blends with the fibrous pericardium. Laterally, it blends with the carotid sheath and with the investing layer beneath the sternocleidomastoid muscle. The carotid sheath contains the common and internal carotid arteries, the internal jugular vein, and vagus nerve. The nerve lies between and beneath the vessels. The deep cervical group of lymph nodes is found along the internal jugular vein, within the sheath. Removal of the nodes can be facilitated by removal of the internal jugular vein, as described in a classic radical neck dissection. With careful fascial dissection, the nodes can be removed without vein sacrifice in a modified neck dissection. The prevertebral or deep layer encircles the muscles attached to the vertebral column: splenius capitis, levator scapulae, and the anterior, middle, and posterior scalene muscles. The deep cervical lymphatic channels are embedded in the loose connective tissue between the investing and deep layers of the deep cervical fascia.

The sternocleidomastoid muscle divides the neck into two large triangles: anterior and posterior. It is attached to the lateral surface of the mastoid and the superior nuchal line of the occipital bone. Inferiorly, it divides into two heads inserting into the clavicle and the sternum. At the anterior margin of the sternocleidomastoid muscle, the thickened fascia attaches to the angle of the mandible, forming an angular band called Charpy's band. This band must be released to expose the tail of the parotid

Triangles of the Neck

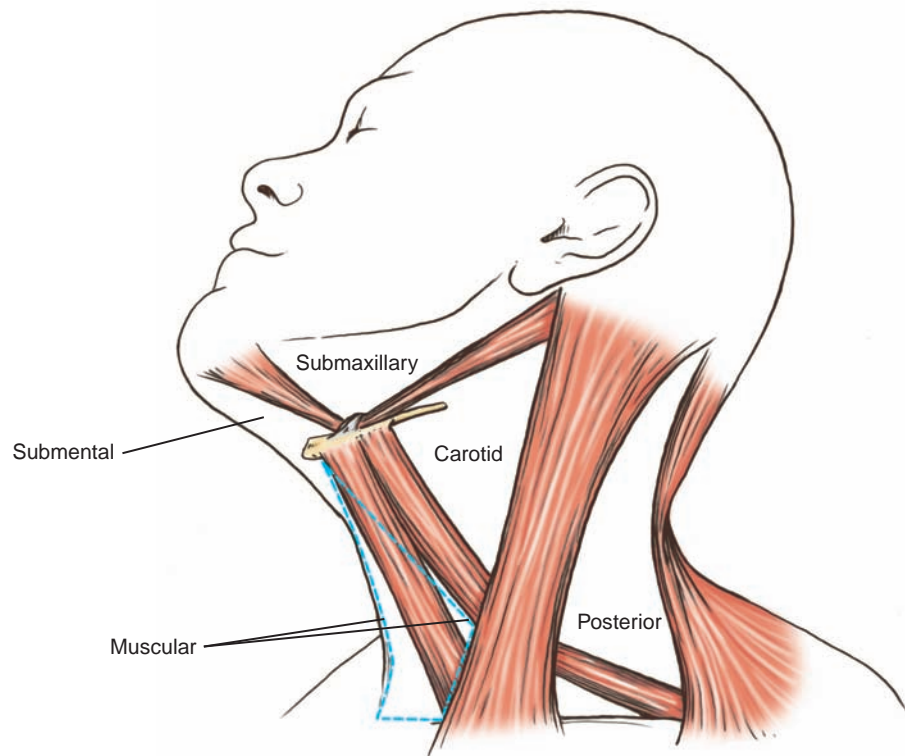


Figure 2.30

and carotid vessels. The anterior triangle is formed by the anterior edge of the sternocleidomastoid muscle, the midline of the neck from the manubrium to the symphysis of the mandible, and the inferior margin of the mandible. It is composed of four smaller triangles: submental, submaxillary, carotid, and muscular. The submental triangle is bounded laterally by the anterior belly of the digastric muscle, inferiorly by the hyoid bone, and medially by the midline of the neck. The floor is composed of the mylohyoid muscle. Within the triangle is the terminal portion of the submental artery and a few submental lymph nodes. These nodes drain the anterior part of the tongue, the floor of the mouth, and the gingiva.

The submaxillary triangle is formed by the anterior and posterior bellies of the digastric muscles and the inferior border of the mandible. This area includes the most complicated anatomy in the neck and has clinical importance in the treatment of tumors of the submandibular gland as well as metastatic disease from the anterior tongue and the floor of the mouth. The roof is formed by the skin and the platysma muscle. The floor is composed largely of the mylohyoid muscle and a small amount by the hyoglossus muscle and the middle constrictor of the pharynx.

The carotid triangle is formed by the anterior border of the sternocleidomastoid muscle, inferiorly by the superior belly of the omohyoid muscle, and superiorly by the greater cornu of the hyoid bone and the posterior belly of the digastric muscle. The floor is formed anteriorly by the thyrohyoid muscle and posteriorly by the middle and inferior constrictors of the pharynx. Passing superficially within the triangle are tributaries of the common facial vein, the greater auricular nerve, and the cervical

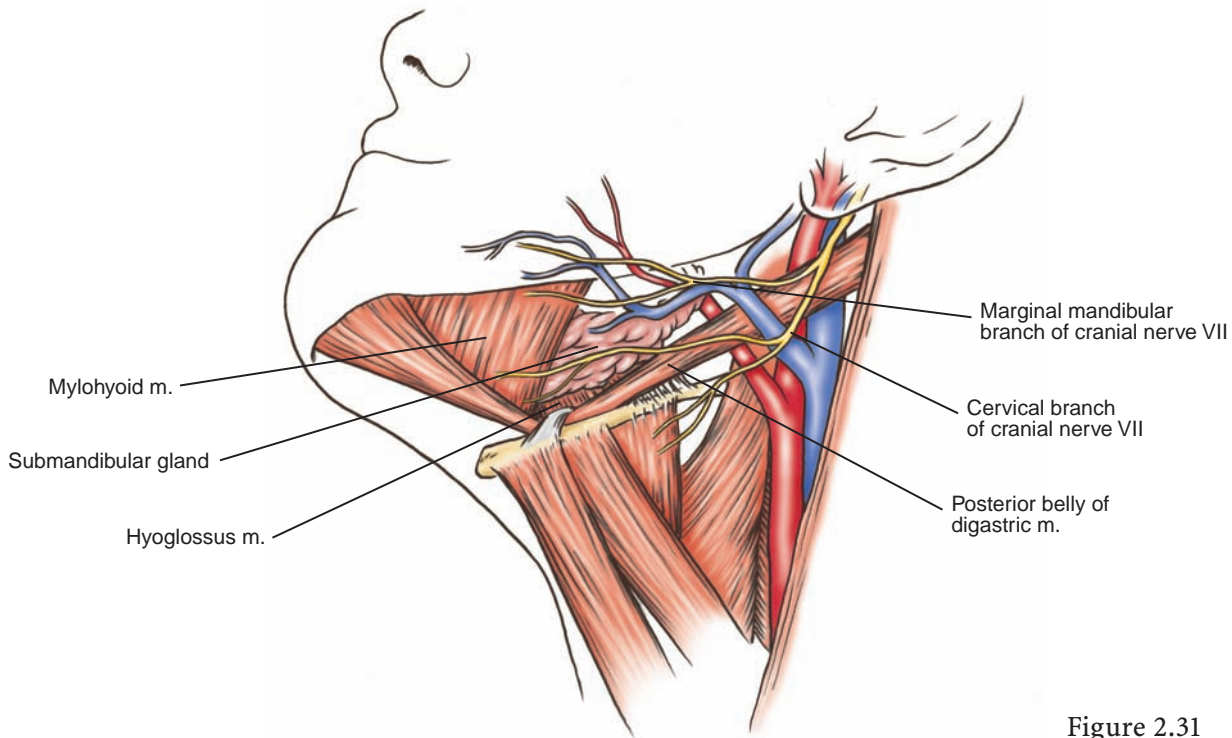


Figure 2.31

branch of the facial nerve. The superior thyroid, occipital, and ascending pharyngeal branches of the external carotid artery arise within the triangle.

The muscular triangle lies below the hyoid bone. It is formed anteriorly by the midline of the neck, superiorly by the superior belly of the omohyoid muscle, and inferiorly by the anterior border of the sternocleidomastoid muscle. The floor is composed of the sternohyoid and the sternothyroid muscles. Beneath the floor lie the thyroid gland, larynx, trachea, and esophagus. The anterior jugular veins course beneath the platysma muscle on either side of the midline. Just above the suprasternal notch, the veins unite, then pass laterally beneath the sternocleidomastoid muscle to drain into the external jugular vein.

The sternocleidomastoid and trapezius muscles attach on a continuous line, extending from the external occipital protuberance along the superior nuchal line to the mastoid process. The proximity of the attachments forms the apex of the posterior triangle. The anterior and posterior boundaries are these two muscles, and the base is the middle-third of the clavicle. The floor is formed by the splenius capitis, levator scapulae, and scalenus medius muscles, covered by prevertebral fascia. The roof is formed by the overlying skin; the platysma muscle is present only in the anterior part. Its absence makes it difficult to develop skin flaps in the posterior neck. The triangle contains the third part of the subclavian artery and the transverse cervical, suprascapular, and occipital arteries. The external jugular vein courses obliquely through the triangle to drain into the subclavian vein. Difficulty arises in dissection of the most inferior portion of the triangle, where troublesome bleeding may be encountered. The inferior belly of the omohyoid muscle serves as an important

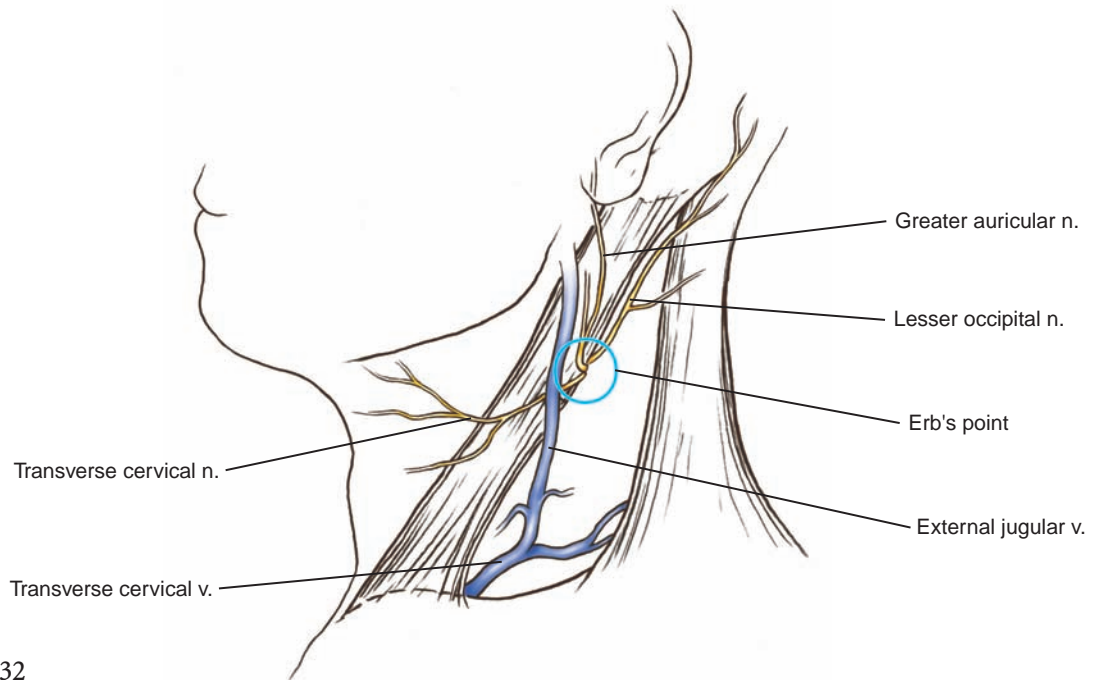


Figure 2.32

landmark. No important structure other than the external jugular vein is found until the muscle is divided. The spinal accessory nerve is the most important structure in the posterior triangle. It exits the jugular foramen, crossing ventral to the internal jugular vein and deep into the posterior belly of the digastric muscle. It goes deep into the sternocleidomastoid muscle and divides within the muscle to supply it, and then continues through the lateral neck on the levator scapulae muscle to innervate the trapezius muscle.

The nerve can be identified as it enters the deep surface of the sternocleidomastoid muscle approximately 4 cm below the mastoid. It can also be found at Erb's point just superior to where the greater auricular nerve surfaces from behind the sternocleidomastoid muscle. The nerve enters the deep surface of the trapezius approximately two fingerbreadths superior to the clavicle.

Submaxillary Gland

The submaxillary gland and associated lymph nodes fill the triangle overlapping the digastric muscles and extending upward deep into the mandible. Differentiating gland from lymph nodes can be difficult. The gland sends a prolongation of tissue with the submaxillary Wharton's duct under the mylohyoid muscle. The duct opens into the mouth on the side of the frenulum of the tongue. Superficial to the gland, the facial vein crosses the submaxillary triangle to reach the anterior border of the mandible. The facial artery enters the triangle under the posterior belly of the digastric and stylohyoid muscles. It ascends to emerge above or through the upper border of the gland. The marginal mandibular branch of the facial nerve courses through the triangle beneath the platysma muscle. It is the only important structure above

the digastric muscle in a submaxillary dissection. The course of the nerve is variable and frequently has multiple branches. Dingman and Grabb found the nerve to be above the anterior ramus of the mandible in 81% of their cadaver dissections. In my experience, the nerve loops below the mandible to a varying degree in most patients. Skandalakis et al. reported that in 50% of cases the mandibular branch was above the mandibular border and therefore outside the submaxillary triangle. It courses over the facial vessels as it travels upward to supply the depressor anguli oris and the depressor labii inferioris muscles. To prevent injury during neck dissection, the facial vessels are divided below the nerve and used to retract the nerve above the mandible. Lymph nodes are present about the vessels, and the nerve may need to be sacrificed to facilitate removal. Injury to the nerve can result in facial asymmetry, occasionally with drooling. The hypoglossal nerve descends between the internal jugular vein and the internal carotid artery, giving branches to the thyrohyoid and geniohyoid muscles, and supplies the superior limb of the ansa cervicalis, which supplies the infrahyoid strap muscles. It enters the triangle deep to the posterior belly of the digastric muscles. It lies on the surface of the hyoglossus muscle and courses deep to the mylohyoid muscle to supply motor function to the tongue. The lingual nerve, a branch of the mandibular nerve, is found under the border of the mandible on the hyoglossus muscle above the hypoglossal nerve. It is attached to the submaxillary gland by the submaxillary ganglion and courses deep to the mylohyoid muscle to provide sensation to the anterior tongue and floor of mouth.

One-third of the lymph nodes in the body are concentrated in the head and neck region. Detailed knowledge of the cervical lymphatic channels is necessary to diagnose and treat cancer of the head and neck. The superficial lymphatics course in the subcutaneous tissue intimately associated with the skin and superficial fascia. They perforate the superficial layer of the deep cervical fascia to communicate with the deep cervical nodes. These superficial nodes are frequently involved in cervical metastases, especially during the late stages, but are of little significance from the surgical standpoint. Superficial lymphatic nodes involved with cancer cannot be removed without resection of large areas of skin, and their involvement implies a dismal prognosis.

At the junction of the head and neck are groups of nodes named for their location: occipital, retroauricular, parotid, submandibular, submental, and retro-pharyngeal nodes. These groups of nodes form a cervical ring and are the first-echelon drainage for the scalp, the face, and the mucous membrane of the upper aerodigestive tract. Involvement of a particular nodal group provides a clue to the location of the primary lesion.

The lymph nodes in the posterior cervical triangle course along the spinal accessory nerve. The upper nodes in this group are in the anterior neck, where there is a coalescence of nodes from both the upper jugular and spinal accessory groups. These nodes drain the nose and upper extent of the aerodigestive tract. The spinal accessory nodes are infrequently involved in metastases from the oral cavity, but preservation may be impossible because of proximity to the anterior jugular chain. Small nodes course along the transverse cervical vessels, communicating with both the spinal accessory and jugular chains. They receive drainage from the skin of the lateral neck and chest. The nodes in this group are more frequently involved by metastatic

Cervical Lymph Nodes

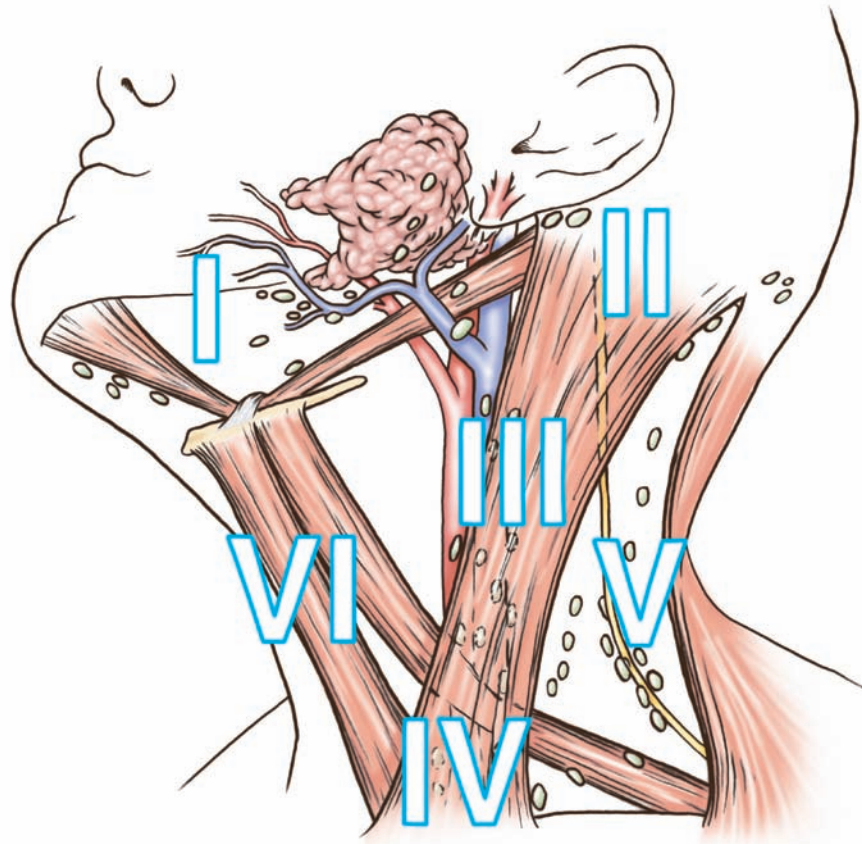


Figure 2.33

carcinoma from below the clavicle (breast, lung, kidney, stomach, lower gastrointestinal tract) than from the neck itself.

The lymphatics of the anterior triangle course along the internal jugular vein. They are embedded in the fascia of the carotid sheath, and the majority lies on the anterolateral aspect of the vein. The jugulodigastric nodes are in the upper neck, below the posterior belly of the digastric muscle and behind the angle of the mandible. This is an important surgical area and is a frequent site of cervical metastases. The spinal accessory nerve must frequently be sacrificed to adequately remove metastatic nodes in this area. The middle jugular nodes are found where the omohyoid muscle crosses the carotid sheath. These drain the middle part of the aerodigestive tract and thyroid. The inferior nodes are below the omohyoid and drain the thyroid, esophagus, and trachea.

A system of levels for describing the location of lymph nodes in the neck was developed by the Memorial Sloan-Kettering group and provides standardization that is useful to accurately compare studies of cervical nodal disease.

Level I

Submental Group. Nodal tissue between the anterior belly of the digastric muscles and above the hyoid bone. *Submandibular Group.* Nodal tissue in the triangular

area bounded by the anterior and posterior bellies of the digastric muscle and the inferior border of the mandible.

Level II

Upper Jugular Group. Nodal tissue around upper portion of the internal jugular vein and the upper spinal accessory nerve. It extends from the skull base to the bifurcation of the carotid artery or the hyoid bone. The posterior limit is the posterior border of the sternocleidomastoid muscle and the anterior border is the lateral border of the sternohyoid muscle.

Level III

Middle Jugular Group. Nodal tissue around the middle-third of the internal jugular vein, from the inferior border of level II to the omohyoid muscle. The anterior and posterior borders are the same as for level II.

Level IV

Lower Jugular Group. Nodal tissue around the inferior-third of the internal jugular vein, from the inferior border of level III to the clavicle. The anterior and posterior borders are the same as for levels II and III.

Level V

Posterior Triangle Group. Nodal tissue around the lower portion of the spinal accessory nerve and along the transverse cervical vessels. It is bounded by the triangle formed by the clavicle, posterior border of the sternocleidomastoid muscle, and anterior border of the trapezius muscle.

Level VI

Anterior Compartment Group. Lymph nodes around the midline visceral structures of the neck, extending from the level of the hyoid bone superiorly to the suprasternal notch inferiorly. The lateral border is the medial border of the carotid sheath. Included are the perithyroidal and paratracheal lymph nodes, and nodes along the recurrent laryngeal nerves.

The carotid sheath is a filmy fascial covering surrounding the carotid artery and internal jugular vein. The vast majority of the venous outflow from the head and neck courses through the internal jugular vein, the external jugular vein, and the anterior jugular vein. The internal jugular vein empties and fills during the inspiratory–expiratory cycle. Once divided at its lower end, it becomes distended with blood, which can make further dissection difficult. For this reason, some surgeons prefer to ligate the upper portion of the vein first. The internal jugular vein has no posterior branches. Dissection carried out from behind the sternocleidomastoid muscle moving forward can effectively exploit this.

Blood Supply

The internal jugular vein begins at the jugular foramen in the skull as a continuation of the sigmoid sinus. It descends through the neck to unite with the subclavian vein behind the medial head of the clavicle to form the brachiocephalic vein. The facial vein is a main tributary of the internal jugular vein. It courses over the submandibular gland to drain the face. It must be divided to expose the carotid bifurcation. The external jugular vein begins behind the angle of the mandible by the union of the posterior auricular and retromandibular veins. It descends obliquely across the sternocleidomastoid muscle parallel to the greater auricular nerve. It enters the subclavian vein just above the clavicle in the posterior triangle.

The arterial supply to the extracranial head and neck is derived predominantly from the external carotid artery. The level of carotid bifurcation is variable but is most commonly at the angle of the mandible.

Nerve Supply

The anterior and lateral neck areas are innervated by the anterior rami of cervical nerves C2–C4. The greater auricular nerve runs obliquely with the external jugular vein, across the sternocleidomastoid muscle to supply sensation to the skin of the external ear. The transverse cutaneous nerve passes across the midportion of the sternocleidomastoid muscle to provide sensation to the anterior and lateral portions of the neck.

The vagus nerve exits the jugular foramen at the skull base. It lies between the carotid artery and the internal jugular vein in the carotid sheath. The spinal accessory nerve also exits the jugular foramen. It usually courses over the internal jugular vein to enter the sternocleidomastoid muscle, which it innervates. It exits posteriorly behind the sternocleidomastoid muscle at Erb's point to innervate the trapezius muscle. The hypoglossal nerve exits the skull at the hypoglossal foramen. It descends between the internal carotid artery and the internal jugular vein beneath the digastric muscles. It enters the oral cavity after passing under the mylohyoid muscle.

Surgical Applications

The primary role of lymph-node dissection in head and neck cancer is to achieve locoregional control. Radical neck dissection, systematic removal of the cervical lymph nodes, was first described by Crile in 1906. The procedure removes all the lymph-node-bearing tissue from the midline of the neck to the anterior border of the trapezius muscle and from the horizontal ramus of the mandible to the clavicle (levels I–V). The classic operation, popularized by Martin, includes removal of the sternocleidomastoid muscle, internal jugular vein, and spinal accessory nerve. The upper portion of the nerve exits the jugular foramen in close proximity to the internal jugular vein. Dissection of the nerve in this portion violates the anterior fascial compartment. The nerve then passes through the fascial envelope of the posterior triangle to innervate the trapezius muscle. Martin stressed that the nerve must be sacrificed to adequately extirpate the cervical lymphatics. Metastases to the posterior triangle are relatively infrequent unless levels I to IV nodes are involved.

Sacrifice of the spinal accessory nerve is extremely debilitating. Nahum described in 1961 the shoulder syndrome of pain, scapular displacement, and shoulder droop. Trapezius muscle paralysis limits abduction and support of the shoulder. Several studies have demonstrated successful grafting of the resected nerve with a portion of greater auricular nerve. Modifications of the radical neck dissection have been developed to preserve the spinal accessory nerve in early stage neck disease when level V metastases are infrequent.

The recurrence rate for tumor in the neck after radical neck dissection has been reported at 10–70%. Historically, the lack of control attributed to radical neck dissection was related to lack of control of the tumor primary site. One has to look at the older data regarding recurrence after radical neck dissection to avoid the effect of combined treatment with radiation therapy. Strong found that tumor recurrence in the neck was 71% if multiple levels of nodes were involved initially. The problem with the study was that in 25% of cases the primary tumor was not controlled.

Schneider et al. found recurrence rates of 11% for N1 disease and 19% for N2 disease when the primary tumor was controlled. As reported by DeSanto et al., recurrence rates in dissected necks at 2 years after radical neck dissection were 7.5% for N0 disease, 20.2% for N1 disease, and 37.4% for N2 disease. These results indicate that the efficacy of radical neck dissection decreases as the severity of disease in the neck increases.

Modified neck dissection, or functional neck dissection, preserves one or more of the nonlymphatic structures sacrificed in radical neck dissection. Removal of levels I to V nodes with preservation of the spinal accessory nerve, sternocleidomastoid muscle, and internal jugular vein was suggested by Bocca et al. The theoretical advantages of modified neck dissection are as follows:

- Preservation of neck and shoulder girdle function
- Better cosmetic contour of the neck
- Protection of the internal carotid artery
- Ability to perform bilateral procedures
- Use as an elective operation in clinical N0 disease

Preservation of the spinal accessory nerve is an attempt to reduce the shoulder morbidity seen with a radical neck dissection. It is usually followed by a temporary, reversible phase of dysfunction resulting from traction or devascularization of the nerve. Preservation of the sternocleidomastoid muscle may improve the cosmetic contour of the neck and protect the carotid artery. Despite the increase in morbidity, a radical neck dissection is preferred in cases with extensive extracapsular nodal disease and regional failure after neo-adjuvant chemoradiation or therapeutic radiation.

Sentinel lymph-node mapping and biopsy has been widely accepted as a staging modality in the management of head and neck melanoma. The procedure is being studied to supplant elective lymph node neck dissection in the management of early head and neck squamous cell carcinoma.

Bilateral cervical lymph-node metastases are not an infrequent occurrence. Bilateral radical neck dissection usually is performed as a staged procedure over several

weeks. Loss of both internal jugular veins may alter cerebral and facial circulation, although Crile thought the vertebral venous system would provide adequate collateral circulation. The perceived risks of bilateral jugular vein loss include death, brain damage, blindness, and permanent facial distortion. Beahrs reported a series of bilateral radical neck dissections and found a low complication rate.

Radical Neck Dissection

Sequence of Dissection

The classic description of the radical neck dissection begins with the division of the sternocleidomastoid muscle and internal jugular vein at the base of the neck. The operation then proceeds in a cephalad direction. This is technically easy, but involves sacrifice of the spinal accessory nerve without assessment of the upper neck; it can be difficult to ligate the upper end of the internal jugular vein. It also fails to take advantage of the fact that the major vessels of the neck have no posterior branches except the occipital artery arising under the posterior belly of the digastric muscle. Resectability of the nodal metastases cannot be assessed until the neck dissection is almost completed.

Beginning in the submandibular triangle and proceeding laterally and inferiorly has several advantages. The majority of nodal metastases are in the upper part of the neck, which allows early assessment of operability. This sequence allows assessment of the spinal accessory nerve's relationship to nodal metastases for possible nerve preservation. This operation is an attack on the tumor and not on the neck.

Surgical Exposure and Incisions

Many incisions have been described for use during a neck dissection. Each represents a compromise between exposure of the operative field and the need to provide soft tissue coverage for vital structures left in the neck. A superiorly based subplatysmal apron flap provides good surgical exposure and adequate soft tissue coverage of the major vessels. A vertical extension along the anterior border of the trapezius muscle can provide additional exposure to the posterior triangle. The incision can be incorporated into a lip-splitting incision.

The skin flap is elevated over the inferior edge of the mandible and fixed with sutures. The greater auricular nerve and the external jugular vein are preserved for possible nerve grafting or as recipient vessels for microvascular transfer.

Submental and Submandibular Dissection: Level I

First, the marginal mandibular nerve is identified. It usually has multiple branches that run in areolar tissue between the platysma and the fascia surrounding the submandibular gland. The facial vessels are identified crossing the inferior border of the mandible at the anterior border of the masseter muscle. The nerve branches course above these vessels. The vessels are ligated below the nerve and retracted superiorly to get the marginal nerve branches out of the operative field.

The submental dissection begins by incising the deep cervical fascia off the contralateral anterior digastric muscle and along the inferior border of the mandible. The fascia is grasped with mosquito clamps and is carefully dissected off the mylohyoid

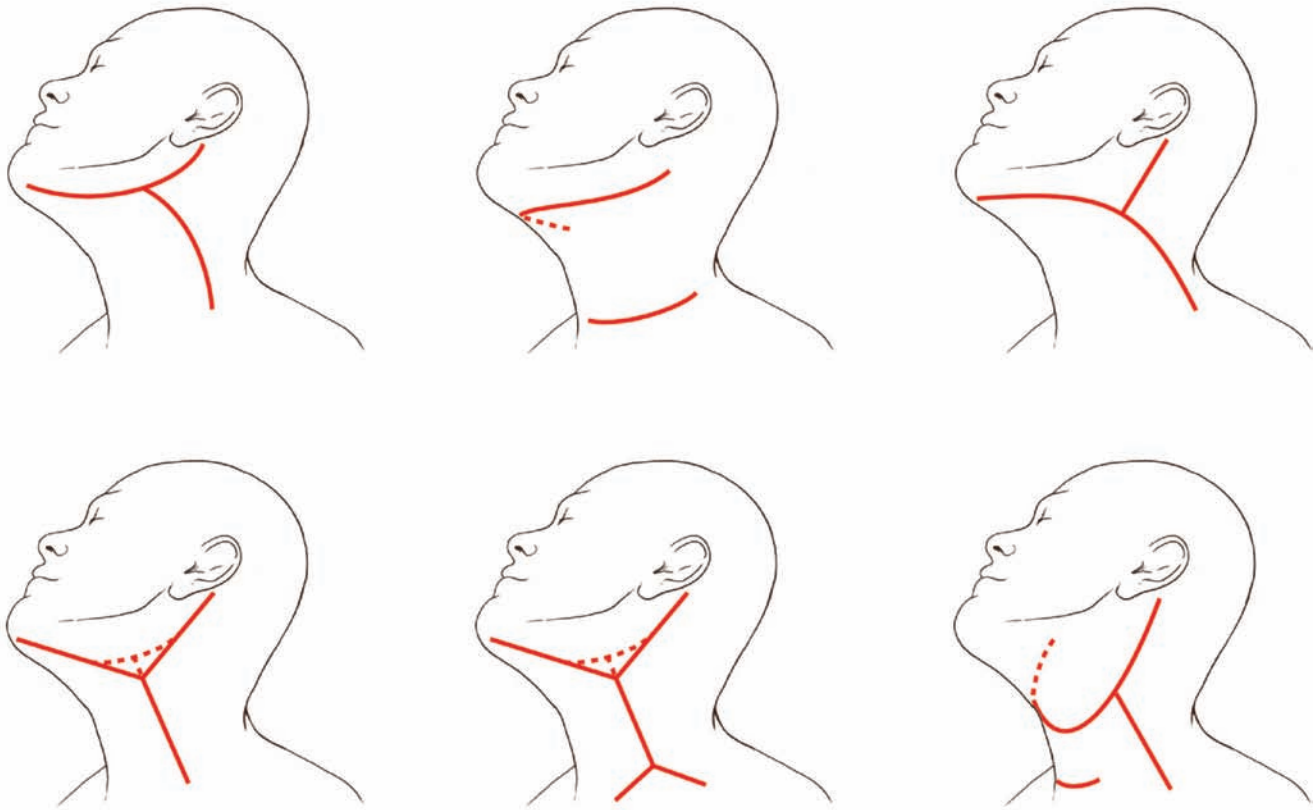


Figure 2.34

muscle, which forms the floor of the submental triangle. The dissection is continued laterally to the ipsilateral digastric muscle, where the submental vessels branching from the facial vessels are encountered. These are ligated and divided. Then the submandibular dissection is begun.

The digastric muscles provide a safe plane in which to operate. The submandibular gland is retracted laterally to expose the mylohyoid muscle. The free posterior margin of the mylohyoid muscle is key to the submandibular dissection. It is retracted medially to reveal the deep portion of the submandibular gland lying on the hyoglossus muscle. The lingual nerve is located superiorly under the mandible and attached to the gland via the submandibular ganglion. It must be carefully ligated to prevent troublesome bleeding. Wharton's duct is deep to the lingual nerve and is ligated carefully to prevent nerve injury. The hypoglossal nerve is located inferiorly below the digastric muscle (see p. 107) and is accompanied by a plexus of veins. The fascia and gland are retracted laterally with mosquito clamps. The facial artery is again ligated as it courses around the posterior surface of the gland.

Upper Neck Dissection: Level II

The posterior belly of the digastric muscle is key to the dissection in the upper neck. It is superficial to the vessels of the carotid sheath and hypoglossal nerve.

The tail of the parotid gland is carefully divided to expose the retromandibular vein, which is then ligated and divided. The insertion of the sternocleidomastoid

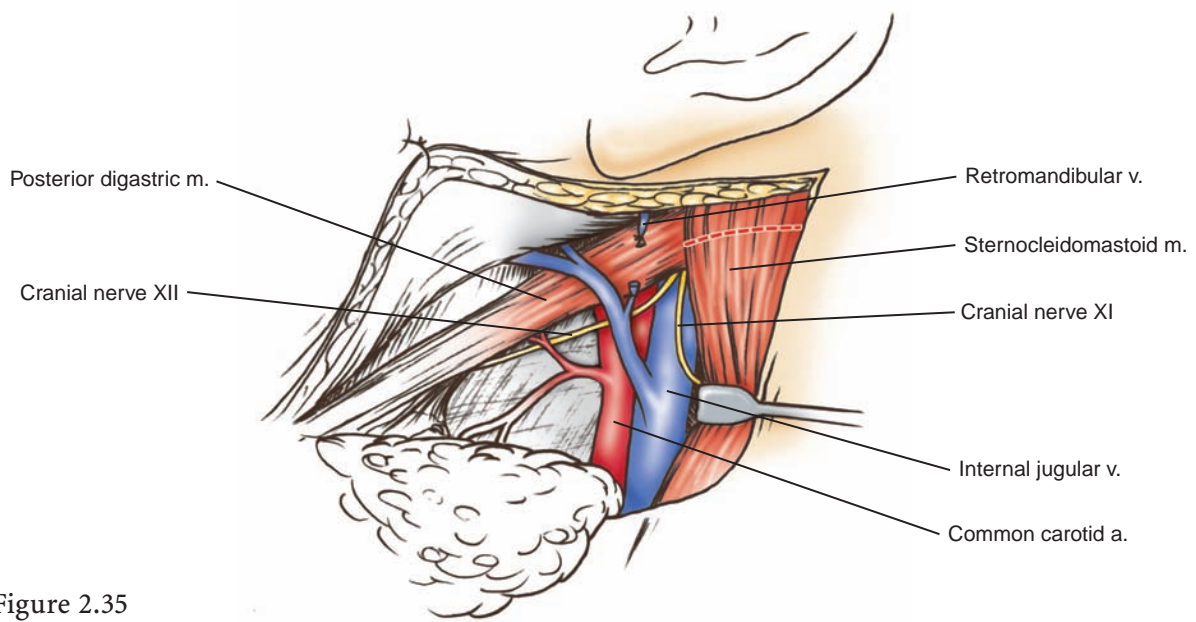


Figure 2.35

muscle is divided with the electrocautery and retracted inferiorly to expose the posterior digastric muscle. The occipital artery runs parallel and deep to the muscle, which is retracted with a vein retractor to expose the internal jugular vein and splenius capitis muscle. Cranial nerve XII crosses over the bifurcation of the carotid vessels at a variable distance above the bifurcation. The ansa cervicalis, which provides motor innervation to the strap muscles, branches from the hypoglossal nerve, and is divided. The vagus nerve can be identified between the internal jugular vein and the carotid artery. Exposure of the carotid bifurcation may result in bradycardia and hypotension; 1% lidocaine solution can be injected into the carotid sinus if this becomes problematic. The spinal accessory nerve is usually identified exiting the jugular foramen anterior to the internal jugular vein. In as many as 30% of cases it travels posterior to the vein. Clinical assessment is made to determine whether nerve preservation is possible. If a short segment of nerve is adherent to tumor, it can be resected and a greater auricular nerve graft interposed using 9-0 nylon interrupted epineural sutures. The internal jugular vein is divided after placing two right-angle clamps proximally and one distally. The proximal stump is suture ligated, and a second tie is placed behind the second clamp. The contents of the submandibular triangle and upper neck dissection are now reflected inferiorly.

Posterior Neck Dissection

The posterior neck is dissected in continuity with the midneck dissection. The sternocleidomastoid muscle, nodal contents, and internal jugular vein have been reflected inferiorly and anteriorly, baring the splenius capitis muscle, which forms the floor. The prevertebral fascia is identified and removed with the specimen, thus transecting the cervical plexus branches of nerves C2–C4 as they emerge from the

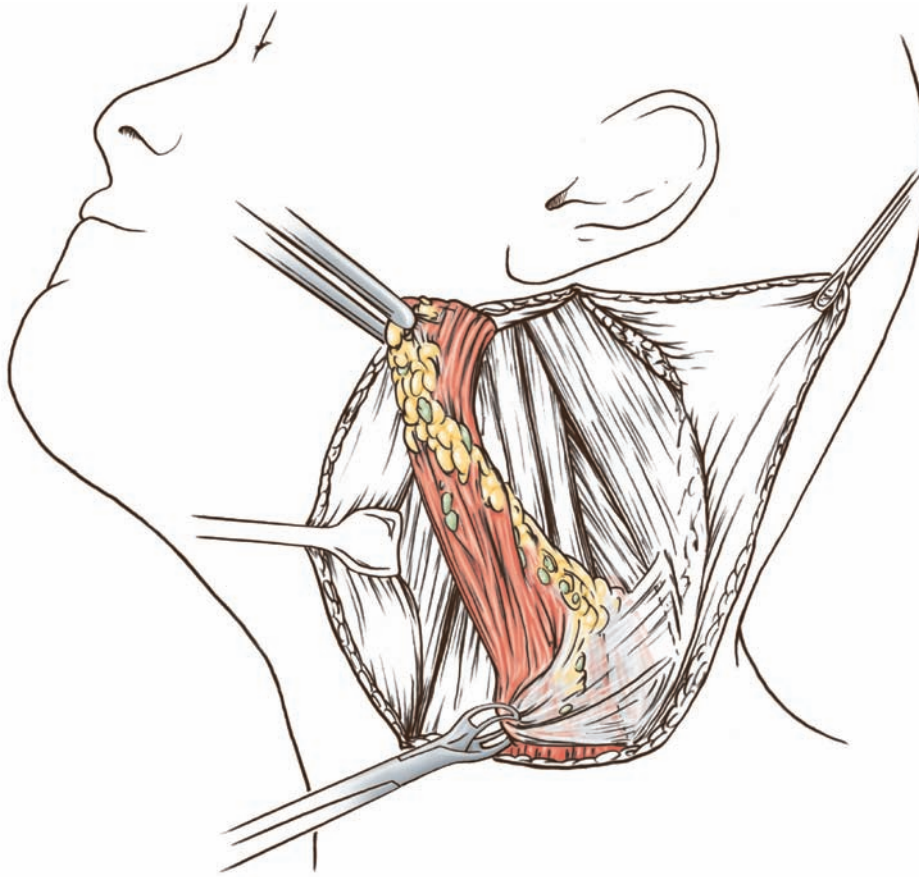


Figure 2.36

fascia. Dissection continues along the anterior border of the trapezius muscle, exposing the levator scapulae muscle until the omohyoid muscle is identified. The spinal accessory nerve emerges from under the sternocleidomastoid muscle at the midpoint of the muscle. This posterior plane is relatively avascular.

Lower Neck Dissection

The omohyoid muscle is key to the inferior neck dissection. It is superficial to the carotid sheath and is used as a guide to divide the sternocleidomastoid muscle. The brachial plexus and the phrenic nerve are behind and on top of the anterior scalene muscle and are carefully preserved. The subclavian vein can sometimes be seen behind the clavicle and in front of the scalene muscle. The thoracic duct is located behind the junction of the internal jugular vein and subclavian vein.

The sternal and clavicular heads of the sternocleidomastoid muscle are divided, exposing the omohyoid muscle, which is also divided. The proximal portion of the internal jugular vein is dissected in a manner similar to that previously described. The supraclavicular fat surrounding the omohyoid muscle contains the transverse cervical vessels. The vein is more superficial than the artery and courses parallel to the omohyoid muscle, which may be superficial or deep to it. The vein enters the external jugular vein laterally and can be sacrificed without difficulty. Care is taken to not pull the fatty tissue from behind the clavicle. The entire specimen is removed en bloc.

Wound Closure

Two flat, closed suction drains are placed through separate inferior stab incisions. The platysma muscle is reapproximated with interrupted absorbable sutures. Interrupted absorbable dermal sutures are placed and the skin edges reapproximated with a running nylon suture. Neck dressings are not used, and a light film of antibiotic ointment is applied for 48 h.

Modified Neck Dissection

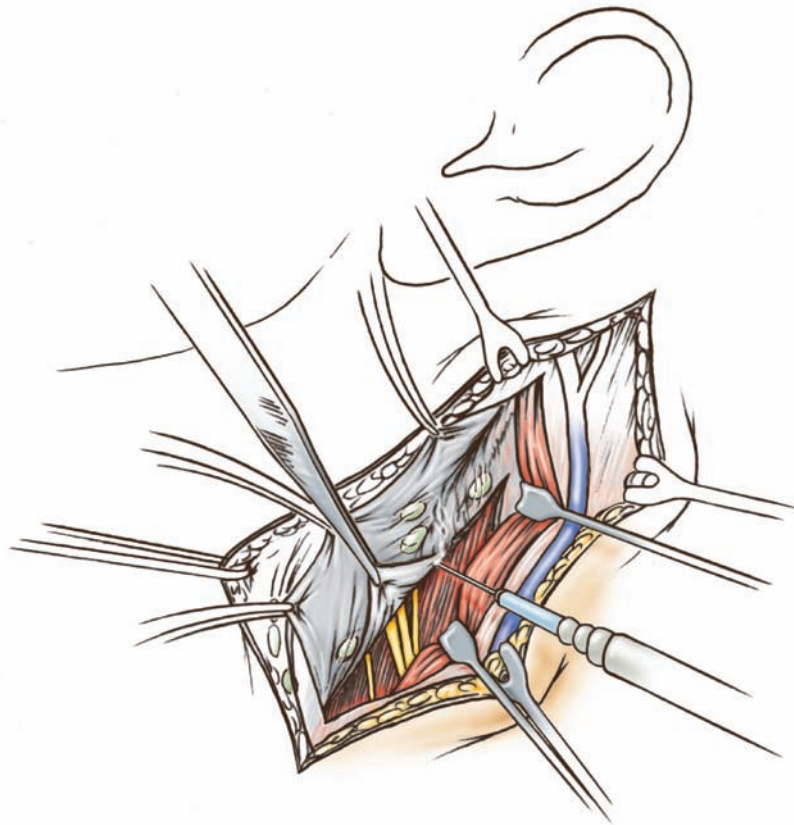
Surgical Approach

The cervical lymphatics are removed by careful dissection of the investing and prevertebral layers of the deep cervical fascia. The sternocleidomastoid muscle, internal jugular vein, and spinal accessory nerve are preserved if possible. The entire dissection is performed through an anterior approach by retracting the sternocleidomastoid muscle laterally. The posterior triangle is dissected from underneath the muscle, with preservation of the cervical plexus. The exposure and submandibular dissection are identical for that described for the radical neck dissection.

Fascial Dissection

The investing layer of the deep cervical fascia is incised along the anterior border of the sternocleidomastoid muscle. When possible, the greater auricular nerve is preserved by carefully dissecting it out of the parotid tail. The investing fascia is grasped

Figure 2.37



and retracted medially. The sternocleidomastoid muscle is retracted laterally, and the small perforating vessels entering the muscle from the fascia are cauterized. The fascial dissection is carried to the posterior edge of the sternocleidomastoid muscle where the investing fascia joins the prevertebral fascia. This fascia is reflected medially off the deep cervical muscles (splenius capitis, levator scapulae, and scalene muscles), preserving the cervical plexus and phrenic nerve branches.

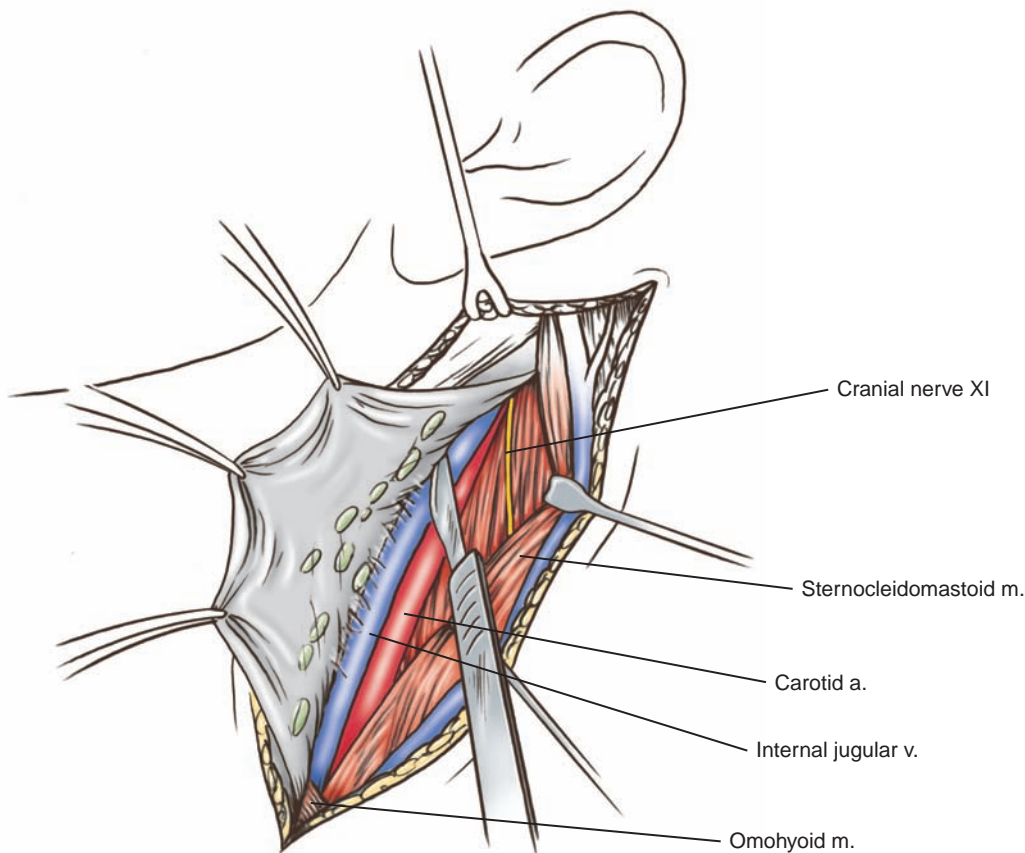
Posterior Neck Dissection

The spinal accessory nerve exits behind the sternocleidomastoid muscle at approximately its midpoint (Erb's point). The greater auricular nerve courses obliquely over the sternocleidomastoid muscle at this point. Working from underneath the sternocleidomastoid muscle, the contents of the posterior triangle are reflected medially. The posterior margin of dissection is several centimeters from the edge of the trapezius muscle. The inferior limit of the dissection is the transverse cervical artery and the omohyoid muscle, usually several centimeters above the clavicle.

Central Neck Dissection

Normally the jugular vein is lateral, but traction of the investing fascia pulls it medial to the carotid artery. Thus the carotid artery is encountered first in dissection of the

Figure 2.38



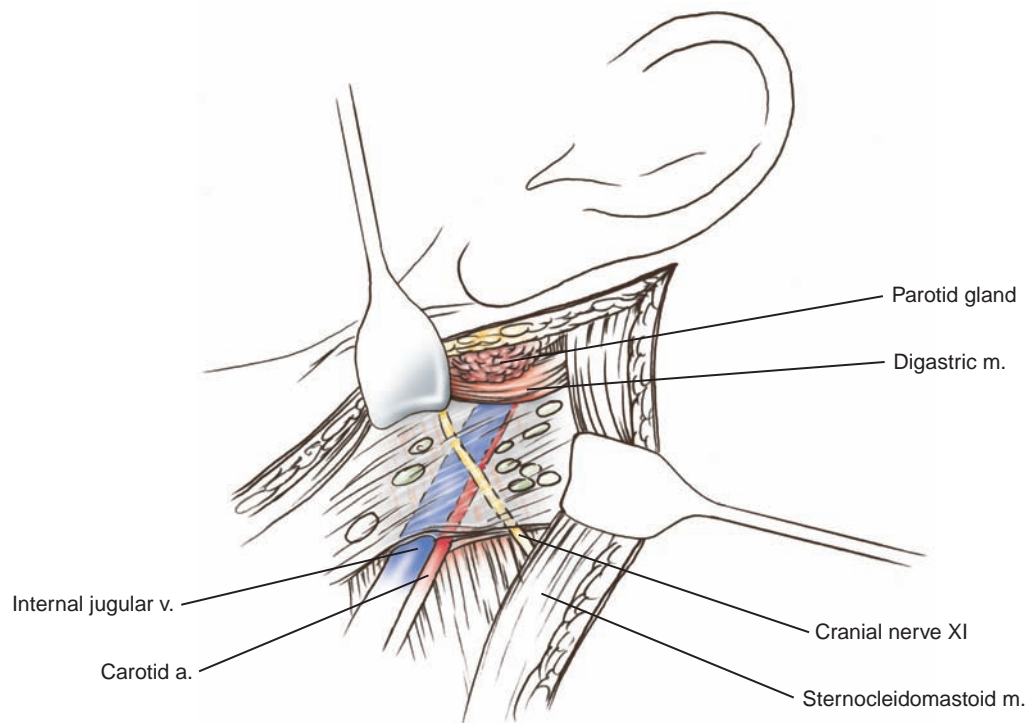
central neck. Sharp scalpel dissection directly against the vessel releases the fascia and adventitia. The vagus nerve is identified between the vessels, and the hypoglossal nerve is seen crossing the carotid artery at approximately its bifurcation. The fascial and nodal contents are then reflected over the internal jugular vein. The facial vein is ligated proximally to release the contents of the submandibular contents.

Upper Neck Dissection

Dissection of the upper neck is the most important and difficult portion of a modified neck dissection. Clinical judgment is necessary to determine whether the spinal accessory nerve can be preserved while adequately extirpating the cervical lymphatics.

The upper-third of the spinal accessory nerve must be identified prior to its entrance into the sternocleidomastoid muscle. The tail of the parotid gland is divided with the electrocautery, and the posterior facial vein is divided to expose the posterior belly of the digastric muscle. The spinal accessory nerve is identified exiting the jugular foramen underneath the digastric muscle. The nerve is carefully dissected out of the surrounding tissue until it enters the sternocleidomastoid muscle. The nerve is retracted medially with a vein retractor, and the sternocleidomastoid muscle is retracted laterally to expose the upper spinal accessory nodal tissue lateral to the nerve. The fascia overlying the splenius capitis muscle is incised and grasped with mosquito clamps. This tissue is reflected under the nerve and over the internal jugular vein and carotid artery to join the contents of the central neck dissection.

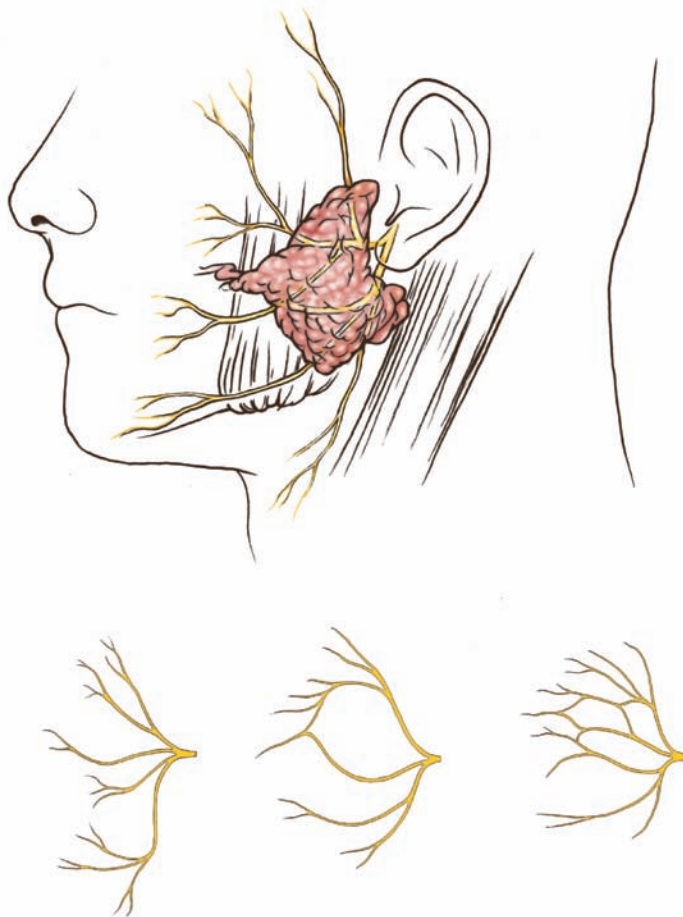
Figure 2.39



Parotid Gland

The parotid gland is the most common site of salivary neoplasms, accounting for 80% of the total. The majority of these tumors are benign, but precise knowledge of the anatomy is necessary to avoid facial nerve injury during parotidectomy. The parotid gland is an irregular, wedge-shaped organ that envelops the posterior border of the ascending ramus of the mandible. On its superficial surface it extends medially to cover a portion of the masseter muscle. The body of the gland fills the space between the mandible and the surface bounded by the external auditory meatus and the mastoid process. Deep to the ascending ramus the gland extends forward to a variable degree, lying in contact with the medial pterygoid muscle. Just below the condylar neck, above the attachment of the medial pterygoid to the bone, the gland extends between the two. In the region of the condyle, the gland lies between the capsule of the temporomandibular joint and external acoustic meatus. Laterally, at the junction of the mastoid process and sternocleidomastoid muscle, the gland lies directly on the posterior belly of the digastric muscle, the styloid process, and stylohyoid muscle. These structures separate the gland from the internal carotid artery, internal jugular vein, and cranial nerves IX to XII. Practically, these anatomic entities form the parotid bed, which is related to the so-called deep lobe of the parotid

Figure 2.40



gland. Several important anatomic entities may be remembered with the mnemonic VANS where:

V = Internal jugular vein (one vein)
 A = External and internal carotid arteries (two arteries)
 N = Last four cranial nerves (IX, X, XI, XII)
 Glossopharyngeal nerve
 Vagus nerve
 Spinal accessory nerve
 Hypoglossal nerve
 S = Styloid process plus three muscles
 Styloglossus
 Styloglossus pharyngeus
 Styloglossus hyoid

As to the topographic anatomy of these structures, remember:

Vein = Deep in the floor of the parotid bed
 Artery = Anterior to the vein
 Nerves
 Glossopharyngeal = Related to the S muscles
 Vagus = Between internal carotid artery and jugular vein
 Spinal accessory = Superficial to the carotid sheath but proceeding downward behind the posterior belly of the digastric muscle
 Hypoglossal = Same course as the spinal accessory

Remember also that the posterior belly of the digastric muscle is an excellent anatomic landmark because behind it are the carotid arteries, jugular vein, cranial nerves X, XI, and XII, and the sympathetic chain.

Stenson's duct passes from the anterolateral edge of the gland, over the masseter muscle. At the anterior margin of the muscle it turns medially to pierce the buccinator muscle and enters the oral cavity at the level of the upper second molar tooth. Accessory gland is occasionally found along the course of the duct and follows a line drawn from the floor of the external auditory meatus to just above the commissure of the lips. These are important landmarks in evaluating facial lacerations with possible duct injury.

There is no natural plane between the gland and the overlying skin. Surgical exposure requires raising the cheek flap in the subcutaneous plane just beneath the hair follicles. The gland is fixed by fibrous attachments to the external acoustic meatus, mastoid process, and fibrous sheath of the sternocleidomastoid muscle. These must be released to mobilize the gland, facilitating exposure of the facial nerve. One of the fascial attachments, the stylomandibular ligament, passes deep to the gland from the styloid process to the posterior border of the ascending ramus just above the angle, separating the parotid gland from the submandibular gland.

Together with the mandibular ramus, it forms a tunnel through which a process of the gland can extend into the parapharyngeal space. Occasionally tumors can

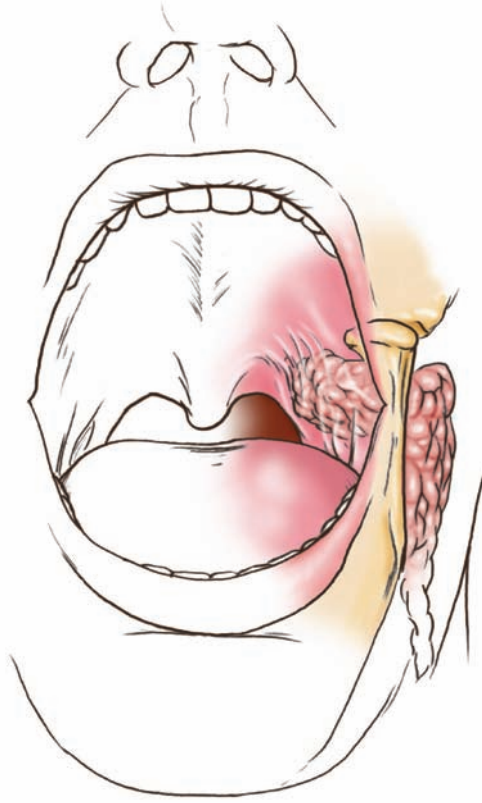


Figure 2.41

develop in the process, resulting in swelling in the facial and lateral pharyngeal area rather than externally.

The facial nerve is intimately associated with the parotid gland. It emerges from the skull through the stylomastoid foramen, immediately posterior to the base of the styloid process and anterior to the attachment of the digastric muscle. The main trunk of the facial nerve is always located in the triangle formed by the mastoid, the angle of the mandible, and the cartilaginous ear canal, medial to the mastoid. The trunk of the nerve bisects the angle between the mastoid and the cartilaginous ear canal 1.5 cm deep to the surface of the parotid gland. Before entering the gland the nerve has three branches: to the posterior auricular muscle, to the posterior belly of the digastric muscle, and to the stylohyoid muscle. The nerve enters the posterior surface of the gland about 1 cm after exiting the skull. It is superficial to the external carotid artery and the posterior facial vein. The nerve branches into an upper temporofacial division, which takes a vertical course, and a lower cervicofacial division, which is a transverse continuation of the main trunk. The point of branching is called the *pes anserinus*. From the *pes* the nerve divides into five branches: temporal, zygomatic, buccal, mandibular, and cervical. The temporal and zygomatic branches share the motor supply of the orbicularis oculi, and the temporal branch alone supplies the forehead musculature. The cervical branch supplies the platysma, and the remaining buccal and mandibular branches share in supplying the remaining facial muscles. The primary division is constant, but there is considerable variation in the origins,

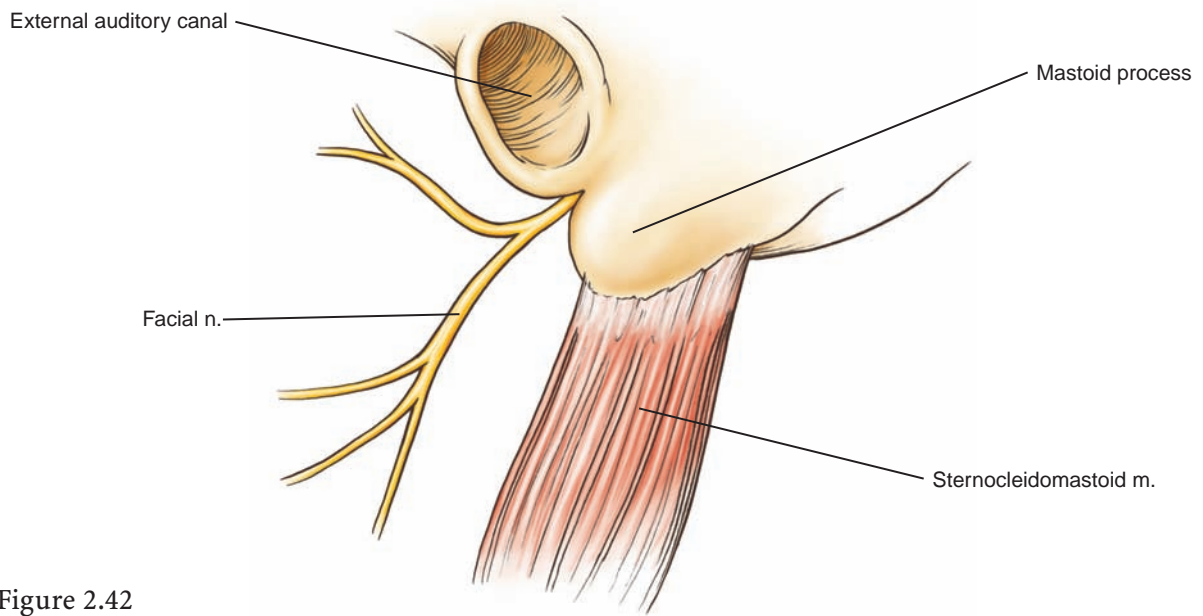


Figure 2.42

interrelations, and specific distribution of the peripheral branches. The pattern of branching is particularly variable, and rami often communicate between branches, sometimes within the gland but more often in front of its anterior border. The presence of these communicating rami explains the occurrence of unexpectedly mild paralysis following division of a branch.

The facial nerve runs within the substance of the gland, but within the gland the facial nerve is superficial, the veins are deeper, and the arterial branches are deepest. Traditionally, the path of the nerve has been used to separate the parotid gland into superficial and deep lobes, but no true facial planes separate the two. Tumors generally develop superficial or deep to the plane of the nerve; thus the distinction of superficial and deep lobe tumors. Occasionally a tumor will arise in the plane of the nerve, separating the branches.

The external carotid artery enters the inferior surface of the gland and divides into the maxillary and superficial temporal arteries at the junction between the middle- and upper-third of the gland. The superficial temporal artery gives off the transverse facial artery to supply the face before continuing upward to emerge from the upper border of the gland. The maxillary artery passes forward and slightly upward behind the condylar neck in the part of the gland lying deep to it. The artery emerges from the gland and passes into the infratemporal fossa.

The venous drainage of the area is variable, but the superficial temporal vein generally enters the superior surface and receives the internal maxillary vein to become the posterior facial vein. Within the gland, it divides into a posterior branch, which joins the posterior auricular vein to form the external jugular vein. The anterior branch emerges from the gland to join the common facial vein. The facial nerve is superficial to the vessels, the artery is deep, and the veins lie between them.

Knowledge of the lymphatic channels of the parotid gland is important in evaluating skin cancers of head. Preauricular lymph nodes in the superficial fascia drain the temporal scalp, upper face, and anterior pinna. Lymph nodes within the parotid substance drain the gland, nasopharynx, palate, middle ear, and external auditory meatus. These lymphatics drain into the internal jugular and spinal accessory nodes.

The greater auricular nerve emerges from the posterior border of the sternocleidomastoid muscle at Erb's point (see p. 108). It crosses the midportion of the muscle approximately 6.5 cm beneath the external auditory meatus and travels parallel and superior to the external jugular vein to supply sensation to the ear and preauricular region. It passes on the surface of the parotid gland and can be preserved unless invaded by tumor by retracting it posteriorly. If the nerve must be sacrificed, it is preserved in saline solution for use as a possible nerve graft. Loss of the branches to the ear can cause disturbing numbness of the lobule, making it difficult to wear earrings, and sometimes causing frostbite in the winter.

The auriculotemporal nerve is a branch of the mandibular division of the trigeminal nerve. It traverses the upper part of the parotid gland and emerges from the superior surface with the superficial temporal vessels. It carries sensory fibers from the trigeminal nerve and secretory fibers from the glossopharyngeal nerve via the otic ganglion.

Parotidectomy

Preoperative Preparation

The history and physical examination are often diagnostic of parotid masses. A slow growing mass that has been present for many years is most likely a pleomorphic adenoma. Facial nerve paralysis usually indicates a malignant process. CT can be useful in equivocal cases, when a deep lobe tumor is suspected, and when malignancy is suspected.

Fine-needle aspiration cytology is useful if malignancy is suspected. It aids in preoperative counseling about the risk for nerve injury, but should not determine operability.

Surgical Exposure and Incisions

Parotidectomy is performed under loupe magnification and headlight illumination. A bipolar cautery is used to protect the facial nerve from conducted electricity. Meticulous hemostasis is necessary to permit safe exposure of the nerve. No muscle relaxation is used, and a nerve stimulator is sometimes helpful to identify nerve branches.

The patient is positioned supine with the head extended and rotated to the opposite side. Draping allows exposure of the entire external ear, facial skin, and neck. A petroleum gauze plug is placed in the ear to prevent blood accumulation.

A preauricular incision is made, which may extend up to the zygoma depending on the location of the tumor. The incision curves around the ear and proceeds down

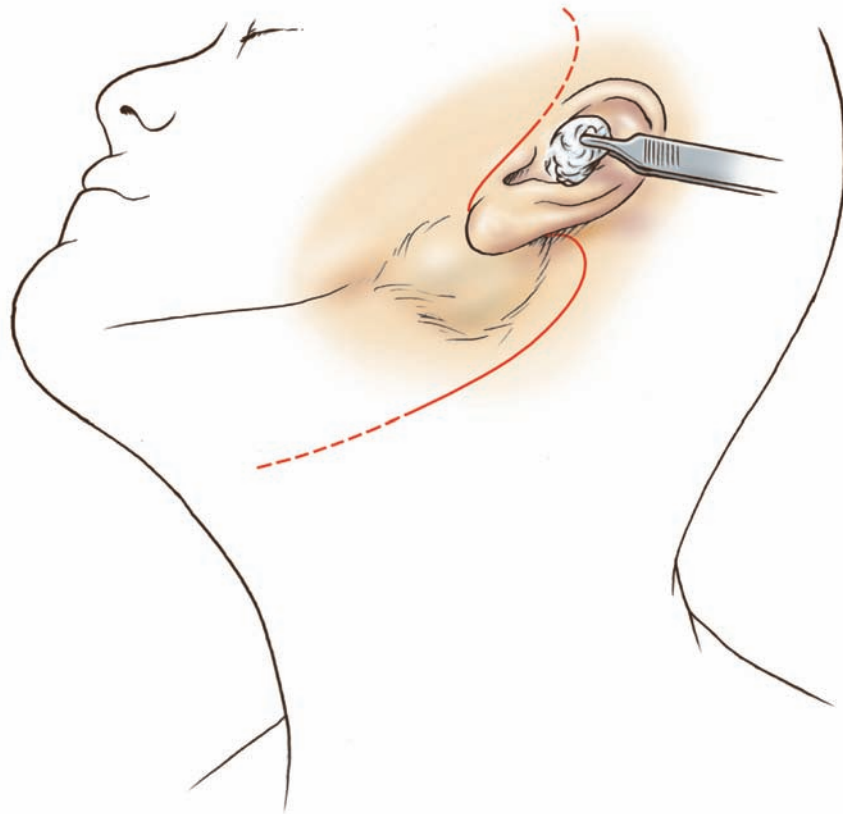


Figure 2.43

the neck in a transverse skin crease. The anterior skin flap is developed in the subcutaneous plane just below the hair follicles. This is not a natural surgical plane and is usually made with a scalpel. Dissection continues medially onto the surface of the masseter muscle.

The posterior flap is developed in the subplatysmal plane over the anterior border of the sternocleidomastoid muscle. The skin flaps are secured with sutures.

After surgical exposure is obtained, the dissection begins at the inferior portion of the gland. The posterior facial vein is divided between clamps. The greater auricular nerve is identified crossing the sternocleidomastoid muscle. The nerve may have to be divided if it crosses the superficial aspect of the gland. If the nerve is sacrificed, it is placed in saline solution-moistened gauze to be used later as a possible nerve graft.

The tail of the parotid gland is grasped with mosquito clamps and carefully dissected off the sternocleidomastoid muscle. The anterior muscle border is identified from the mastoid process to the inferior end of the incision. Careful dissection is performed anterior and deep to the sternocleidomastoid muscle. The posterior belly of the digastric muscle is identified coursing in an oblique direction from the sternocleidomastoid muscle. The internal jugular vein and internal carotid artery are deep to this muscle. All of the salivary tissue is retracted anteriorly and superiorly to the digastric muscle. The ear lobe is retracted, and the dense fibrous attachments between the parotid gland, mastoid tip, and cartilaginous auditory canal are divided.

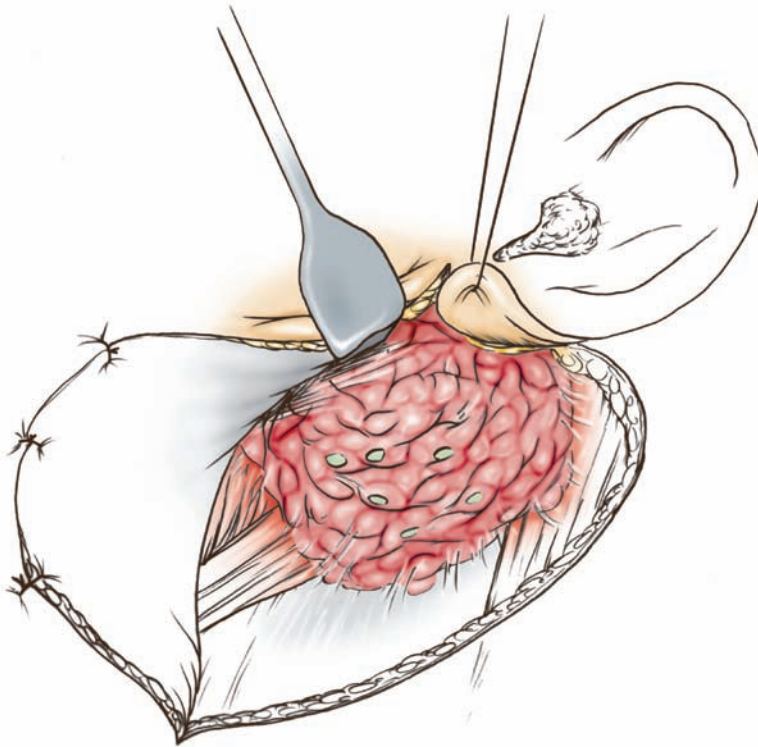


Figure 2.44

This exposes the tragal pointer. The facial nerve lies 1 cm deep and slightly inferior to the pointer. During separation from the ear canal, bleeding from the superficial temporal vessels is controlled with the bipolar cautery.

Identification of Facial Nerve

Parotidectomy requires precise identification of the facial nerve. The main trunk is constantly found between the base of the styloid process and the mastoid process. The tail of the parotid gland must be separated from the sternocleidomastoid muscle. Lateral traction of the muscle exposes the digastric muscle, which is followed to its insertion on the mastoid tip. The nerve lies between the insertion of the muscle and the styloid process. In difficult cases, the nerve can be found by removing the mastoid tip with an osteotome. This exposes the nerve in the descending portion of the facial canal as it exits through the stylomastoid foramen. If the tumor mass overlies the main nerve trunk, an optional approach is to identify the posterior facial vein as it enters the gland. The marginal mandibular nerve can be seen crossing superficial to it and can be followed to the main trunk.

Between 1.0 and 1.5 cm from the stylomastoid foramen the nerve divides into the upper zygomaticofacial and lower cervicofacial divisions at the pes anserinus.

Tumor Resection

Resection of a parotid mass should be considered an attack on the tumor and not the gland itself. The majority of tumors of the parotid gland arise in the superficial

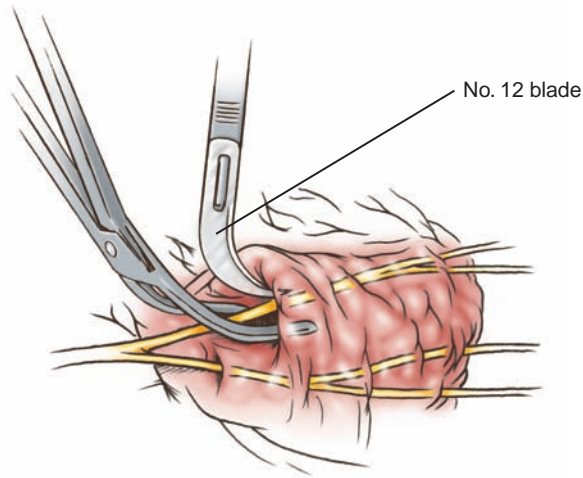


Figure 2.45

portion. Removal of tumors in this portion is usually limited by the underlying nerve unless it is sacrificed. A pleomorphic adenoma has a well-defined capsule, but enucleation results in an unacceptable recurrence rate. When nerve branches disappear into the tumor, malignancy should be suspected. Nerve resection is indicated when clinically involved. The greater auricular nerve can be used as a nerve graft. Total parotidectomy is usually performed in the case of malignant neoplasms.

The individual nerve branches are dissected with a fine mosquito clamp. The overlying parotid mass is divided with a No. 12 knife blade. Hemostasis is controlled with the bipolar cautery. Lesions deep to the facial nerve necessitate removal of the superficial parotid tissue first. The remaining tissue can then be carefully dissected out between nerve branches.

Postoperative Care

A 7-mm flat closed suction drain is brought out through the inferior edge of the wound. Several interrupted deep dermal sutures are placed, followed by a running intracuticular stitch. The drain is removed after 2–3 days if the drainage is less than 30 mL per 24 h.

Submandibular Gland

The submandibular salivary gland is the site of approximately 10–15% of salivary neoplasms. Thirty percent to 55% of tumors will be malignant, and adenoid cystic carcinoma is the most common cancer. Most neoplasms are asymptomatic, but if a patient has evidence of neural involvement, such as marginal mandibular or hypoglossal paresis or loss of sensation, an aggressive malignant neoplasm is probable. Bimanual examination through the mouth allows assessment of possible extension under the mylohyoid muscle.

Submandibular Gland Resection

Tumors involving the submandibular gland are usually contained within the gland, and resection is confined to the gland and surrounding fat or lymph nodes. A

curvilinear incision extending from the midline of the jaw to the mastoid, following the course of the digastric muscles, provides good exposure. The dissection is similar to that described for a level I radical neck dissection.

Chemodectomas or nonchromaffin paragangliomas usually arise from the carotid body or the adventitia of the carotid bulb at the carotid bifurcation and infrequently from the vagus nerve or glomus vagale. They are slow-growing tumors that if untreated will eventually cause symptoms in the majority of patients. Preoperative cranial nerve defects are seen in 10% of patients.

The diagnosis is suggested by the presence of a firm, slow-growing, nontender pulsatile mass in the region of the carotid bifurcation. The diagnosis is confirmed with an angiogram, which often reveals widening of the carotid bifurcation with prominent tumor vascularization. Rarely, a carotid body tumor can produce vasoactive amines and mimic a pheochromocytoma.

Carotid Body Tumor

Preoperative Assessment

Because a small carotid body tumor is easily removed, surgery is indicated in all but selected cases. Radiation therapy can control tumor growth in the majority of patients who are not surgical candidates. Preoperative embolization may ease the dissection and reduce blood loss. Vascular surgery consultation is indicated for large tumors, which may require resection and reconstruction of the internal carotid artery.

Carotid Body Tumor Resection

Surgical exposure can be obtained through an oblique horizontal incision in the upper neck or a vertical incision along the anterior border of the sterno-cleidomastoid muscle. Early proximal and distal control is obtained with vascular tapes. Transection of the mandibular ramus just posterior to the second molar is sometimes necessary to provide additional exposure of the extracranial internal carotid artery. This can be performed with entrance through the oral cavity.

The majority of carotid body tumors can be safely dissected from the carotid vessels. Only approximately 10% of carotid body tumors will necessitate resection of the internal carotid artery. A posterolateral approach is used to resect that portion of the tumor involving the internal carotid artery. Meticulous dissection is performed in a plane between the adventitia and the media of the vessel wall. The external carotid artery is sacrificed if patency of the internal carotid artery has been verified at preoperative angiography. Great care is taken to prevent injury to the vagus, hypoglossal, and superior laryngeal nerves, and the sympathetic chain.

Complications

Despite meticulous dissection, cranial nerve deficits (IX, X, XII) are noted postoperatively in approximately 40% of patients.

Trachea Tracheostomy

The trachea, together with the esophagus and the thyroid gland, lies in the visceral compartment of the neck. The anterior compartment comprises the sternothyroid and sternohyoid muscles, covered anteriorly by the investing layer of the deep cervical fascia and posteriorly by the prevertebral fascia. The trachea begins at the level of the sixth cervical vertebra, and its bifurcation is at the level of the sixth thoracic vertebra in the erect position or the fourth to fifth thoracic vertebrae when supine.

The chief arterial blood supply to the trachea is the inferior thyroid arteries. At the tracheal bifurcation, these descending branches anastomose with the ascending branches of the bronchial arteries. The tracheal veins join the laryngeal vein or empty directly into the left inferior thyroid vein. The pretracheal and paratracheal lymph nodes receive the lymphatic vessels from the trachea.

Surgical Exposure and Incisions

The patient is positioned with the head and neck hyperextended. Excessive neck extension can result in exposure of an excessive length of trachea, with the potential for placing the tracheostomy too low. A 4-cm transverse skin incision is made midway between the cricoid cartilage and the sternal notch. Skin flaps are developed in the subplatysmal plane superiorly to the thyroid notch and inferiorly to the sternum.

A vertical incision is made in the fascia separating the sternohyoid muscles. Staying in the midline avoids the anterior jugular veins. Retractors are inserted, exposing the cricoid cartilage above and the thyroid isthmus below. Between these structures is the anterior suspensory ligament of the thyroid, which is divided to mobilize the isthmus. The isthmus varies in size and position and may be absent in some cases. Dissection is restricted to over the trachea. Lateral dissection may result in nerve injury or may contaminate the neck with tracheal secretions.

The isthmus can usually be retracted superiorly with a vein retractor to expose the tracheal rings. Occasionally the isthmus must be divided between clamps and the ends suture ligated. Dividing the isthmus with the cautery may result in perioperative hemorrhage.

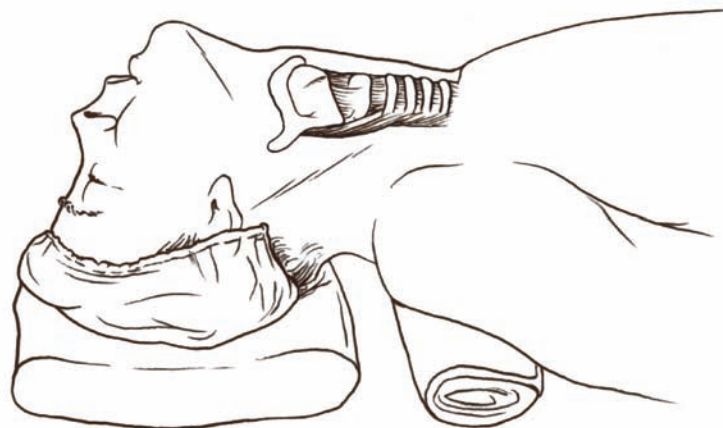


Figure 2.46

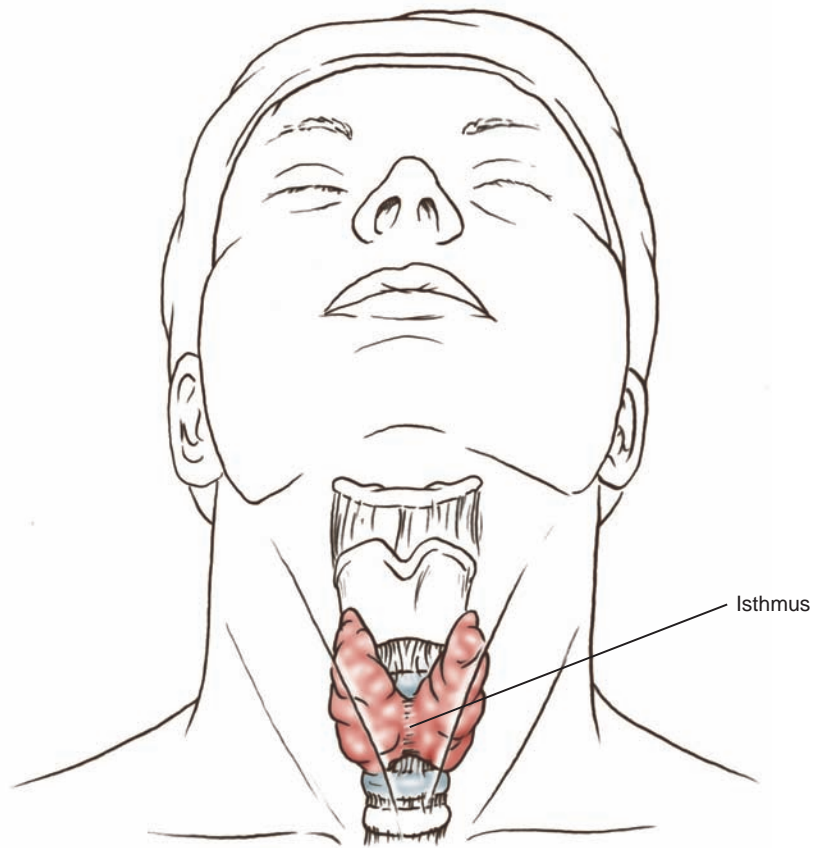


Figure 2.47

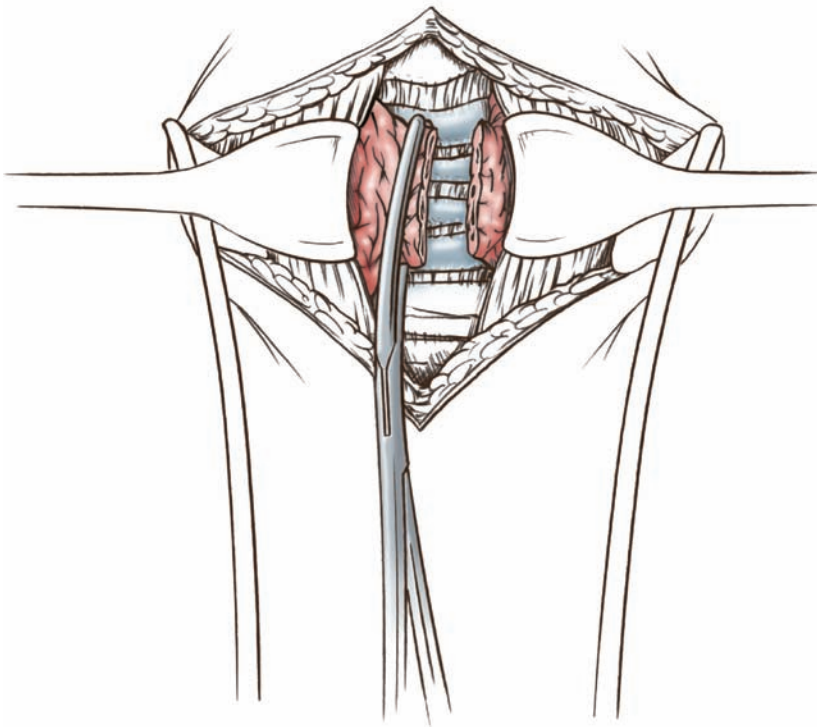


Figure 2.48

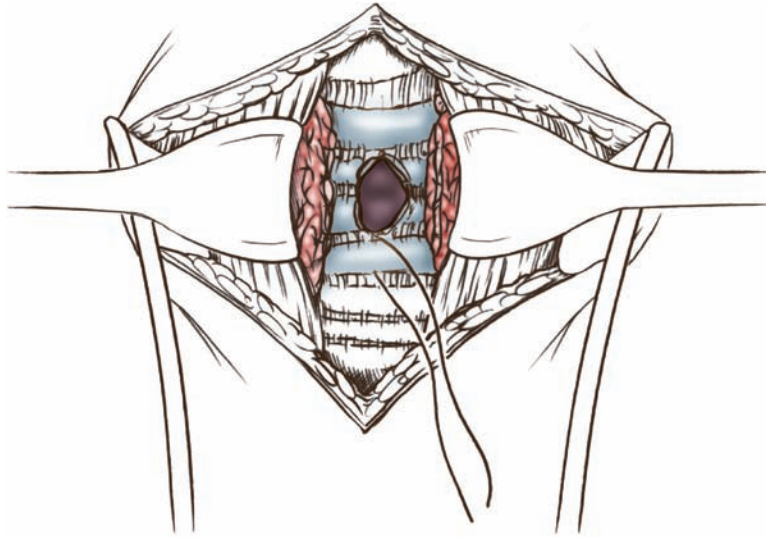


Figure 2.49

With the trachea exposed, lidocaine is injected into the tracheal lumen. Air within the syringe confirms the location within the lumen. A small portion of the second or third tracheal ring is removed to minimize the danger of fragmented cartilage being pushed into the tracheal lumen, reduce the risk of narrowing the lumen from inverted portions of trachea, and allow greater ease of reestablishing an airway if the tracheostomy tube inadvertently becomes dislodged during the first 48–72 h after surgery. A No. 11 blade is used to first make a 5-mm horizontal incision directly above the tracheal ring of choice. The cut edge is grasped with an Allis clamp, and vertical cuts are then made through the tracheal ring. A window is removed after the inferior cut is made.

A midline suture is placed through the tracheal ring inferior to the window. This provides a traction suture to expose the trachea in the event of inadvertent decannulation.

The tracheostomy tube is inserted, the obturator removed, and the cuff inflated. The flanges of the tube are sutured to the skin of the neck. The skin incision is left open to prevent development of mediastinal emphysema. Proper position of the tube is confirmed with a chest radiograph.

Anatomic Basis of Complications

- Facial nerve injury is related to tumor location and the experience of the operator. Temporary nerve paresis, especially of the marginal mandibular and temporal branches, is not uncommon. When removing the gland, care must be taken to not apply too much traction on the specimen. Hematoma and infection are extremely rare if proper surgical technique is used.

- Frey's syndrome is localized sweating and flushing during the mastication of food. This common disorder occurs in 35–60% of patients after parotidectomy with facial nerve dissection. The syndrome usually is noted several months after surgery, with varying degrees of severity. It may result from aberrant regeneration of nerve fibers from postganglionic secretomotor parasympathetic innervation to the parotid gland occurring through the severed axon sheaths of the postganglionic sympathetic fibers that supply the sweat glands of the skin. The majority of affected patients do not seek treatment.
- Bleeding from the thyroid or great vessels may occur. The innominate artery or right common carotid artery may cross the trachea above the sternal notch, so care must be taken during an emergency tracheostomy. Midline dissection prevents injury to the esophagus and recurrent laryngeal nerves.
- False passage of the tracheostomy tube may result in a pneumothorax or pneumomediastinum. Improper tube placement may result in perforation of the lateral or posterior tracheal wall. Postoperative complications include erosion into a major vessel or the esophagus. Long-term tracheal intubation may result in tracheal stenosis.

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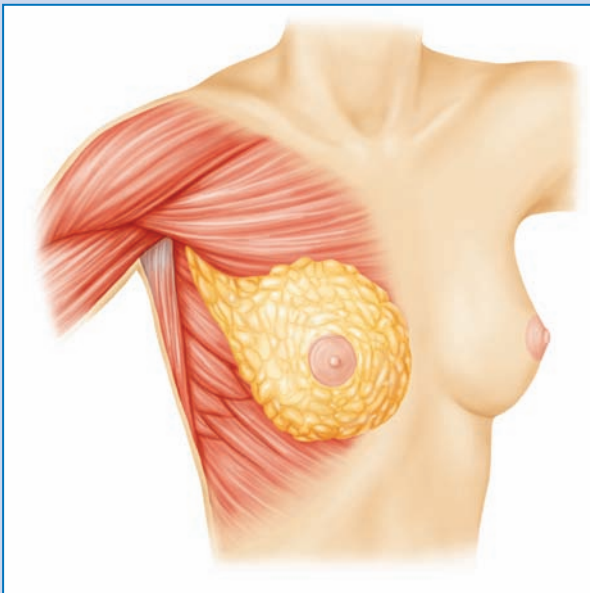
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Breast

William C. Wood,
Sheryl G.A. Gabram-Mendola,
Albert Losken,
John Bostwick III



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Breast and Axilla

William C. Wood and Sheryl G.A. Gabram

Breast diseases are among the most commonly seen in any surgeon's practice. In the United States, approximately 180,000 new breast cancers are identified each year, and 40,460 women die of the disease annually. Fluctuations of this incidence have been noted over the past several years, and the most dramatic change in incidence was documented in 2003 in the United States: A 6.7% decrease was evident, mostly in women over 50 years of age and for estrogen-receptor-positive cancers. The reason for this observation has been temporally related to the first report of the Women's Health Initiative and the drop in the use of hormone-replacement therapy among postmenopausal women in the United States. A decreasing use of screening mammography has also been implicated in this observation, and yet questions remain whether this is a temporary phenomenon and whether with time, breast cancer rates will increase again.

Worldwide, just over 1 million women are diagnosed with breast cancer annually, and 580,000 will succumb to the disease. As developing countries succeed in extending life-expectancy through better sanitation, more food, improved public health measures, and adoption of lifestyles of developed countries, cancer incidence is expected to increase. It is hypothesized that by 2020, 70% of all new breast cancers worldwide will be diagnosed in developing countries.

A trend for needle versus excision biopsy developed during the 1990s, and data support the stable use and need for breast biopsy during this time interval. The annual utilization rate of breast biopsies is about 62.6 per 10,000 women per year in the United States translating into about 870,000 breast biopsies on an annual basis.

The techniques of breast surgery have a clear relationship to outcome, not only in the local control of tumors but also in the cosmetic results that will benefit the patient throughout the remainder of her life. Both benign and malignant diseases of the breast require surgery, and the emotional responses evoked by the breast heighten the stakes for both the patient and the surgical team.

Surgical Anatomy

Topography

The adult female breast is located on the anterior chest wall. It extends from the second rib above to the sixth or seventh rib below, and from the sternal border medially to the midaxillary line laterally. The majority of the breast lies anterior to the pectoralis major muscle; the remainder lies anterior to the serratus anterior muscle; and the inferior margin is situated over the aponeurosis of the external oblique muscle. In 95% of women, the upper outer quadrant of the breast extends through a hiatus

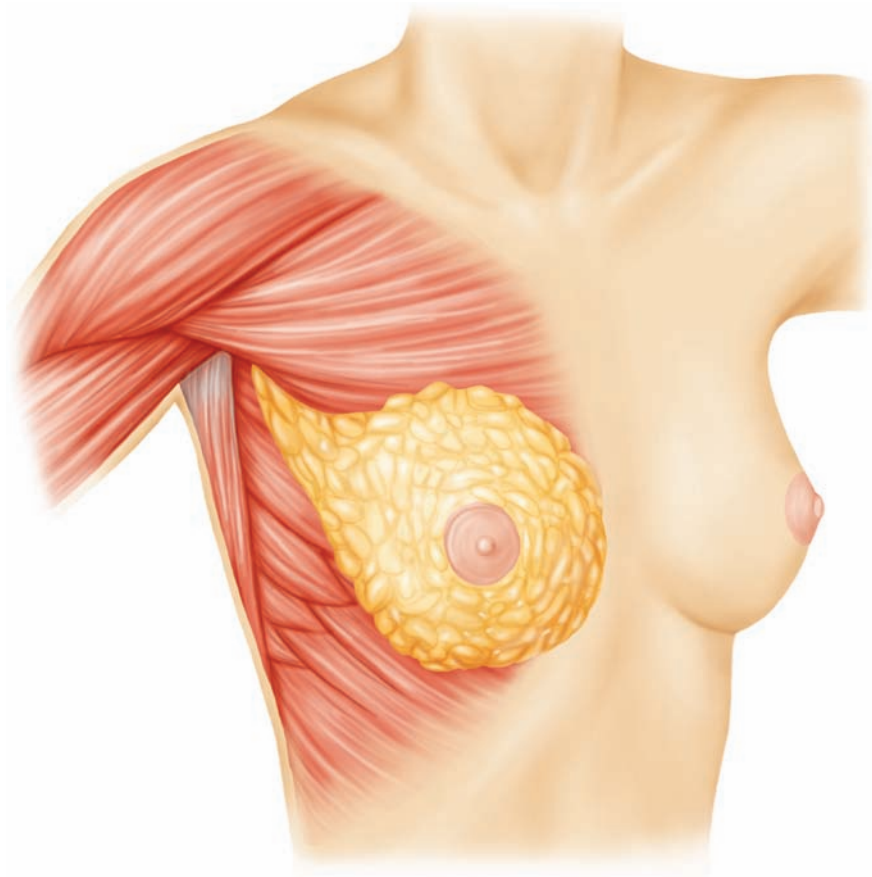


Figure 3.1

in the deep fascia (hiatus of Langer) into the axilla proper. This, the axillary tail of Spence, is the only portion of the breast parenchyma beneath the deep fascia. In about 5% of women, a distinct upper pole of palpable breast parenchyma extends directly superiorly. A retromammary space lies between the superficial fascia enveloping the breast and the deep fascia investing the pectoralis muscle. This space contributes significantly to the mobility of the breast on the chest wall.

The breast is contained within layers of superficial fascia. The superficial layer of this superficial fascia is located near the dermis and is not distinct from it. The deep pectoral fascia envelops the pectoralis major muscle. The clavipectoral fascia surrounds the pectoralis minor muscle and a portion of the subclavius muscle.

The axillary vessels and nerves to the arm are enclosed in a flimsy tubular fascial sleeve, the axillary sheath.

Deep Fascia

The nipple develops as a budding of the epidermis and the duct system, and potential glandular tissue arises from the epidermis in fetal life, forming a nipple bud at birth. Absence of the breast (amastia) or nipple–areola complex (athelia) is rare; in these instances, the underlying pectoralis muscles are often absent as well. Bilateral amastia is associated in 40% of cases with multiple congenital anomalies such as craniofacial abnormalities, including cleft palate as well as deformities of the hands and feet. When

Nipple and Areola

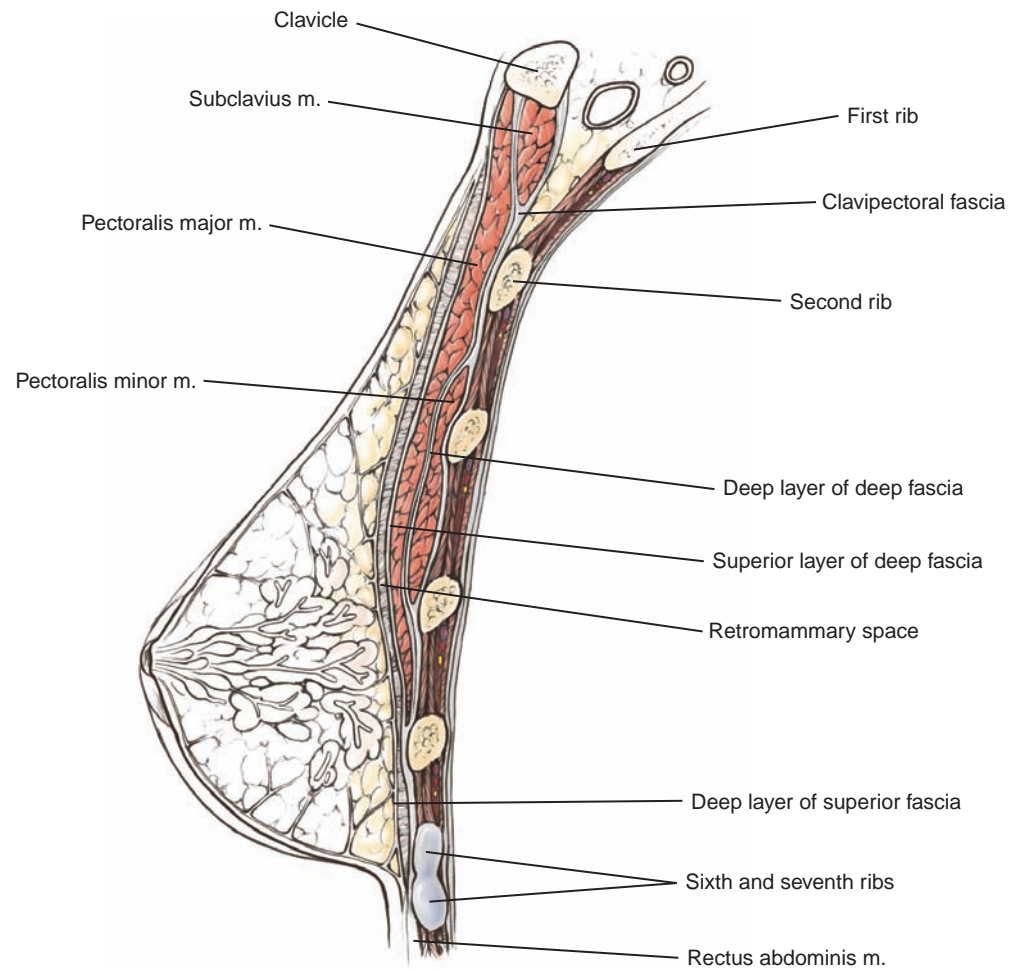
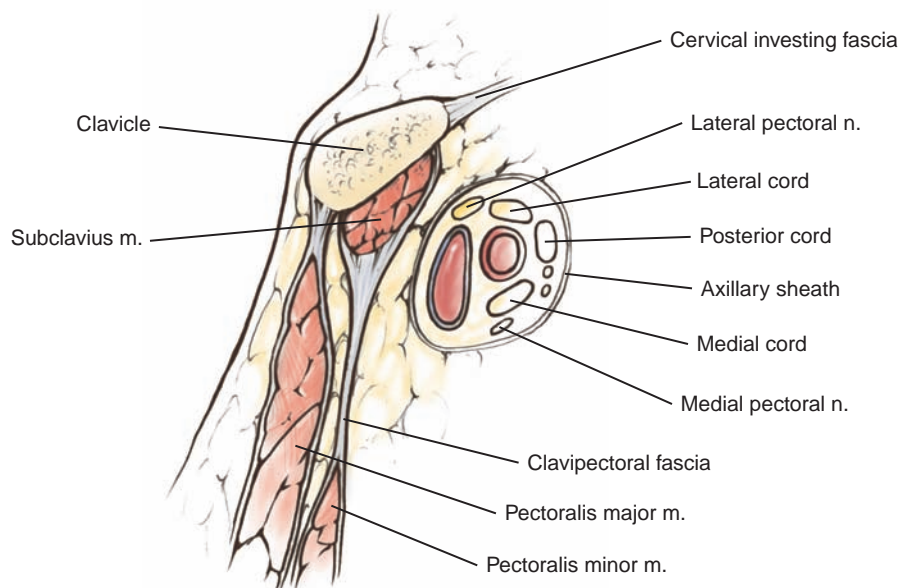
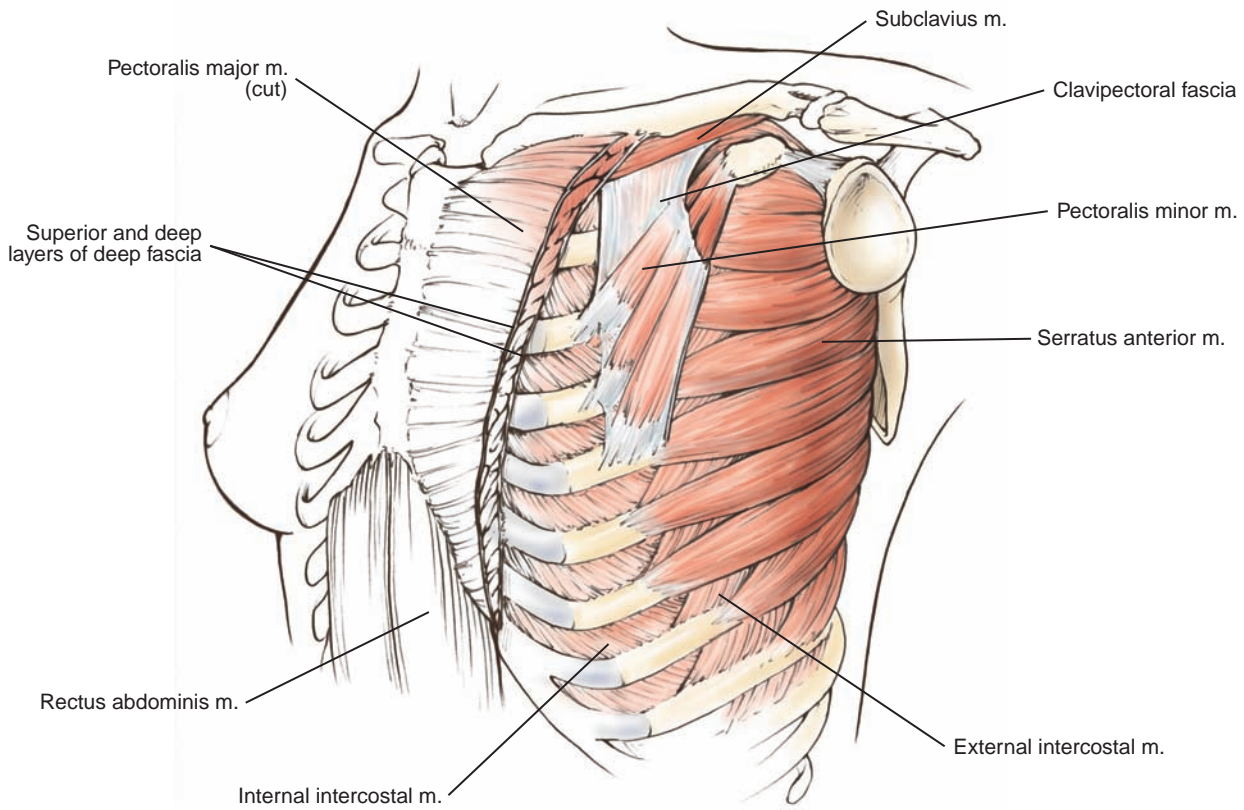


Figure 3.2

the nipple is present but no breast forms, the condition is termed amazia. Supernumerary nipples or breasts are termed accessory if they are along the embryonic milk line (Fig 3.4) or ectopic if they lie elsewhere. Ectopic nipples or breasts are extremely rare. Breast cancer may arise in any of these areas of extramammary breast tissue.

The nipple is pink in the nulliparous Caucasian breast but becomes pigmented to brown in early pregnancy. The pigmentation is correspondingly darker in women of darker complexion. The nipple is covered in keratinized stratified squamous epithelium. Its stroma contains dense connective tissue, with smooth muscle surrounding the lactiferous ducts.

The skin surrounding the nipple is the areola, which undergoes the same pigment changes as the nipple during pregnancy. The areola contains the large areolar glands of Montgomery which can be seen by the naked eye and become more prominent during pregnancy. The function of the Montgomery glands is to produce a lubricant that bathes the nipple and areola tissue during lactation. Occasionally Montgomery glands can become obstructed and develop a localized infectious process. Beneath the nipple and areola is the erector areola muscle: bundles of smooth muscle fibers arranged circumferentially and radially that produce erection of the nipple when stimulated.



SECTION THROUGH CLAVIPECTORAL FASCIA
AND AXILLARY SHEATH

Figure 3.3

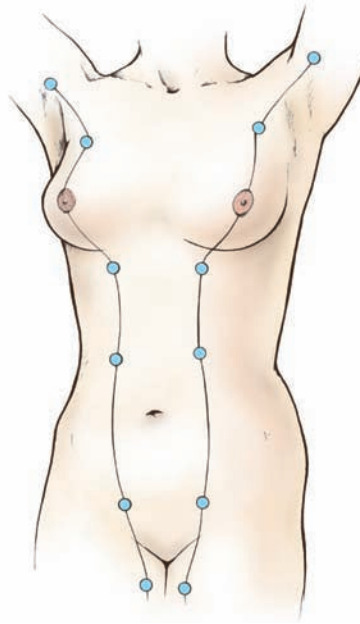


Figure 3.4

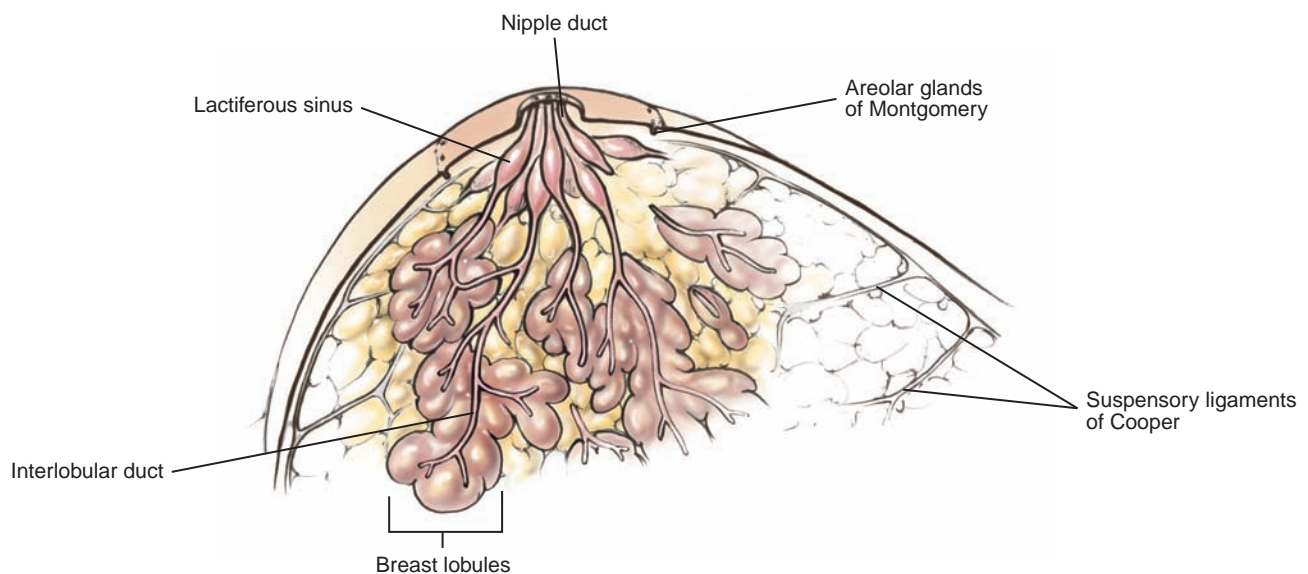


Figure 3.5

Parenchyma

The breast parenchyma consists of 8–15 lactiferous ducts branching and terminating in lobules of breast glandular tissue. Just beneath the nipple the lactiferous ducts converge into expanded lactiferous sinuses lined by stratified squamous epithelium. These constrict into a terminal duct that runs vertically upward to end in the papilla of the nipple in the narrow orifice. Each of these ducts serves a segment of breast tissue. Although these ducts are sometimes represented as anatomically separate and distinct areas, that is an infrequent finding.

Radiographic imaging of the ductal system demonstrates the diffuse nature and interconnectedness of the breast lactiferous duct systems, precluding dissection of true segments of the breast.

The breast parenchyma is arranged in lobules suspended by fibrous bands that connect with the overlying dermis and the underlying superficial fascia. These are

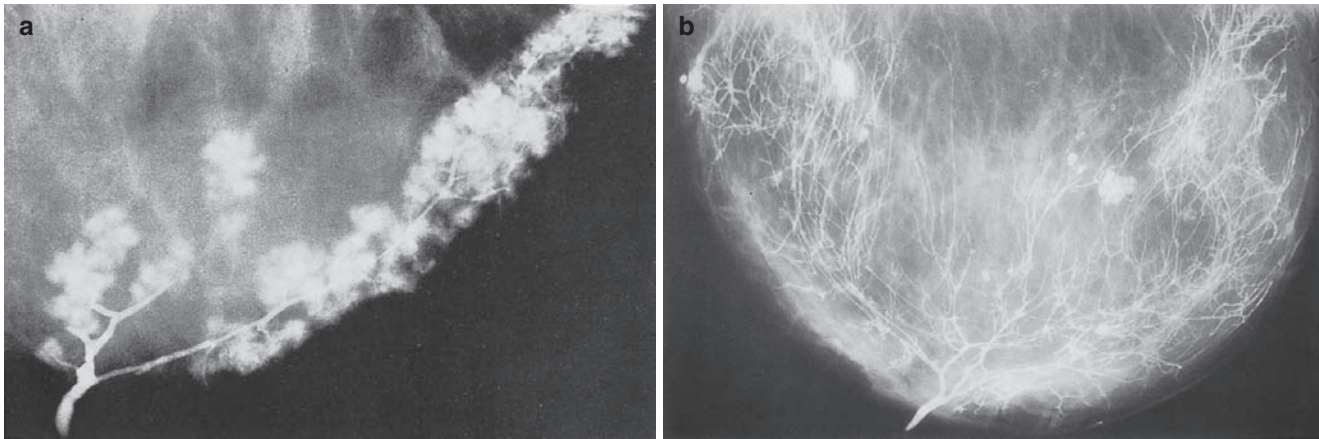


Figure 3.6

called the suspensory ligaments of Cooper and provide internal support to the breast. Interlaced throughout the breast is abundant adipose tissue between the lobules.

The axilla is a pyramidal space with an apex, base, and four walls. The apex is the junction of the clavicle, scapula, and first rib. The base is the axillary fascia beneath the skin of the axillary fossa. The anterior wall is composed of the pectoralis major, pectoralis minor, and subclavius muscles and the clavipectoral fascia enveloping the muscles and conjoining them. The posterior wall is formed by the scapula and its overlying muscles: the subscapularis and latissimus dorsi. The medial wall consists of the lateral chest wall containing the second to sixth ribs and the serratus anterior muscle. The lateral wall is the narrowest, formed by the bicipital groove of the humerus. Within the axilla are lymph nodes and fatty tissue, the axillary sheath covering blood vessels and nerves, and the tendons of the long and short heads of the biceps and the coracobrachialis muscles. Surgery of the breast and axilla, particularly in patients with tumors that have distorted the normal anatomy or in those in whom the anatomy has been disrupted by prior surgery, requires a precise knowledge of the blood supply and nerves traversing these tissues, as well as the location of the breast parenchyma and the draining lymphatic vessels and lymph nodes.

Axilla

The major nerves of the breast and axilla are the brachial plexus, the lateral and medial pectoral nerves, the thoracodorsal nerve, the long thoracic nerve, the intercostobrachial nerve, and the anterolateral intercostal sensory nerves.

The brachial plexus lies within the axillary sheath. If dissection in the axilla is kept caudad to the inferior border of the axillary vein, the brachial plexus will neither be seen nor injured. The lateral pectoral nerve, named for its origin from the lateral cord of the brachial plexus, passes medially around the medial border of the pectoralis minor muscle together with the thoracoacromial vessels. It is the medial of the two pectoral nerves in its anatomic position. In the surgical anatomic literature some authors describe these nerves in terms of their origin and others by their location, creating needless confusion. We will follow the traditional terminology based on the cord of origin. The lateral nerve often divides with one or more branches penetrating the fibers of the pectoralis minor muscle to enter and innervate the pectoralis major muscle. Dividing these branches produces atrophic areas in the upper half of the pectoralis major muscle.

Nerve Supply

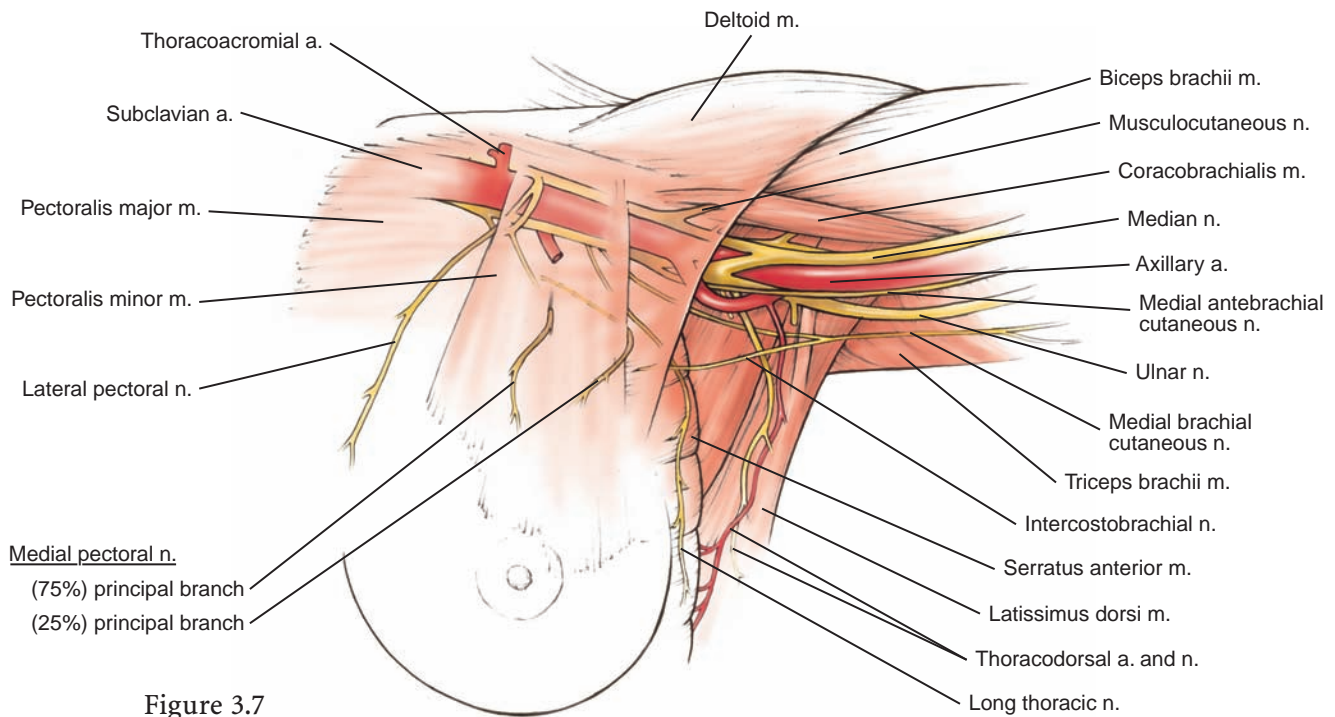


Figure 3.7

The medial pectoral nerve, named for its origin from the medial cord of the brachial plexus, passes laterally around the pectoralis minor muscle to innervate the lateral half of the pectoralis major muscle. It sometimes has a branch that perforates the pectoralis minor muscle belly to supply the pectoralis major muscle. Injury to the medial pectoral nerve causes atrophy of the lateral and/or middle portion of the pectoralis major muscle, resulting in an aesthetic defect.

The thoracodorsal nerve emerges from beneath the axillary vein and approximately 1 cm medial to the thoracodorsal vein. As it courses caudad it joins the thoracodorsal vein and artery running together with it onto the latissimus dorsi muscle, where it crosses over or beneath the thoracodorsal vein to innervate the latissimus dorsi muscle. Injury to the thoracodorsal nerve results in atrophy of the latissimus dorsi muscle.

The long thoracic nerve emerges from behind the axillary vein and runs along the chest wall in the fascia of the serratus anterior muscle in exactly the same antero-posterior plane as the thoracodorsal nerve. Once the thoracodorsal nerve is identified in the axilla, proceeding 2 cm directly medially to the chest wall leads to the long thoracic nerve and aids in its identification in difficult axillary dissections. It lies beneath the investing fascial plane of the serratus anterior muscle, but with traction may be drawn away from the chest wall into the axillary soft tissues. Injury to the long thoracic nerve is the most troubling complication of axillary dissection. The serratus muscle fixes the shoulder to allow its motion and lifting. The defect of a paretic serratus is known as winged scapula deformity. The intercostobrachial nerve, the highest of the anterolateral intercostal sensory nerves, supplies the upper axilla and medial posterior skin of the upper arm. It is usually easy to identify by palpation in the midplane of the axilla 1–2 cm beneath the axillary vein and anteriorly 1–2 cm to the plane of the thoracodorsal and long thoracic nerves. If the intercostobrachial

nerve is cleared of its surrounding tissue and spared, there is less numbness associated with dissection of the axilla. The more inferior anterolateral intercostal sensory nerves are usually sacrificed during axillary dissection.

The lymphatic vessels of the breast drain both medially to the internal mammary lymph nodes and laterally to the axillary lymph nodes. Even from the most medial aspect of the breast, both lymphoscintigraphy and analysis of lymph-node metastases suggest that the majority of lymphatic flow is toward the axillary lymph nodes. Three levels are illustrated. Level I nodes are lateral to the pectoralis minor muscle, level II nodes lie behind it, and level III nodes are medial to it.

Lymphatic Drainage

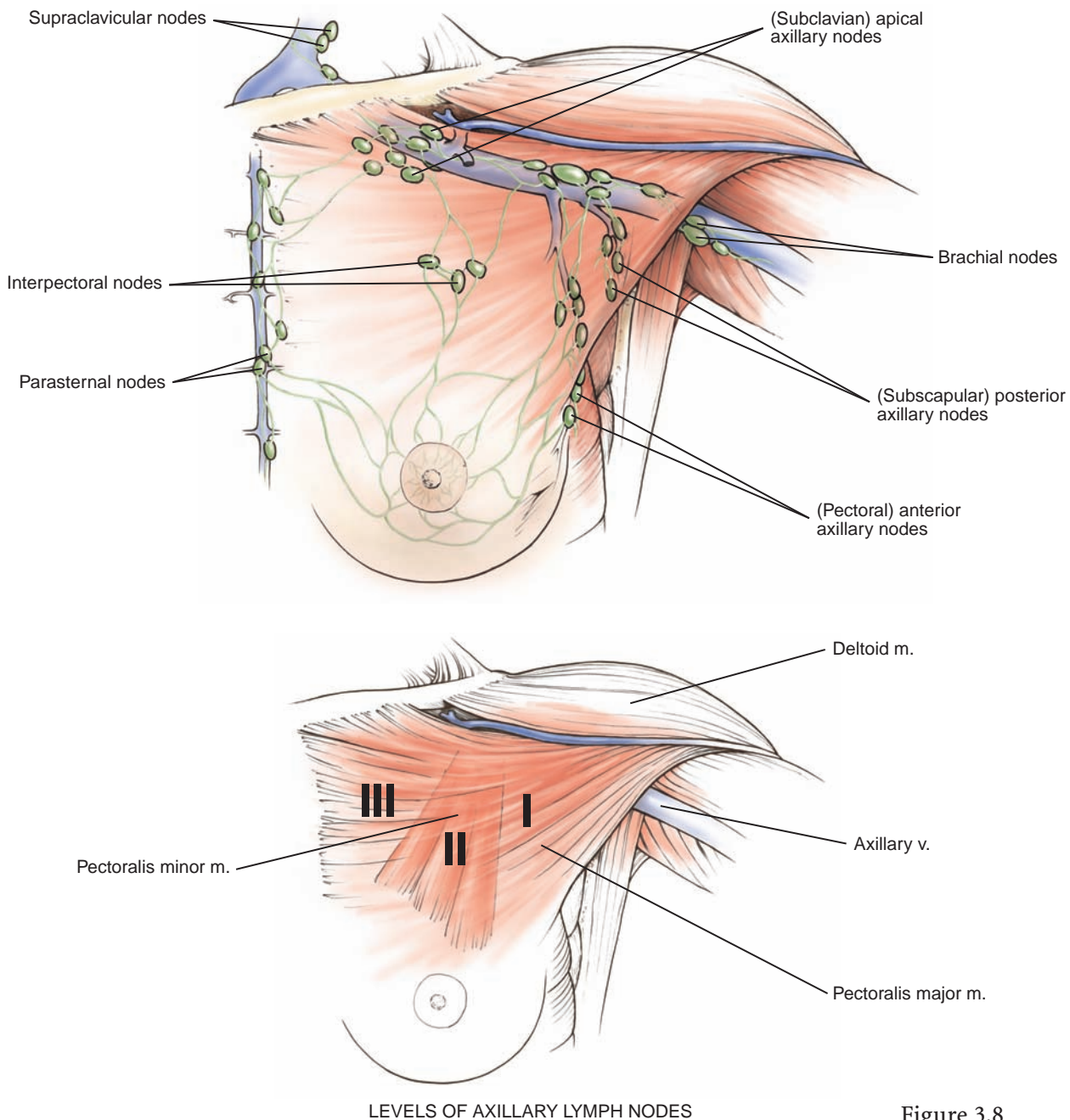


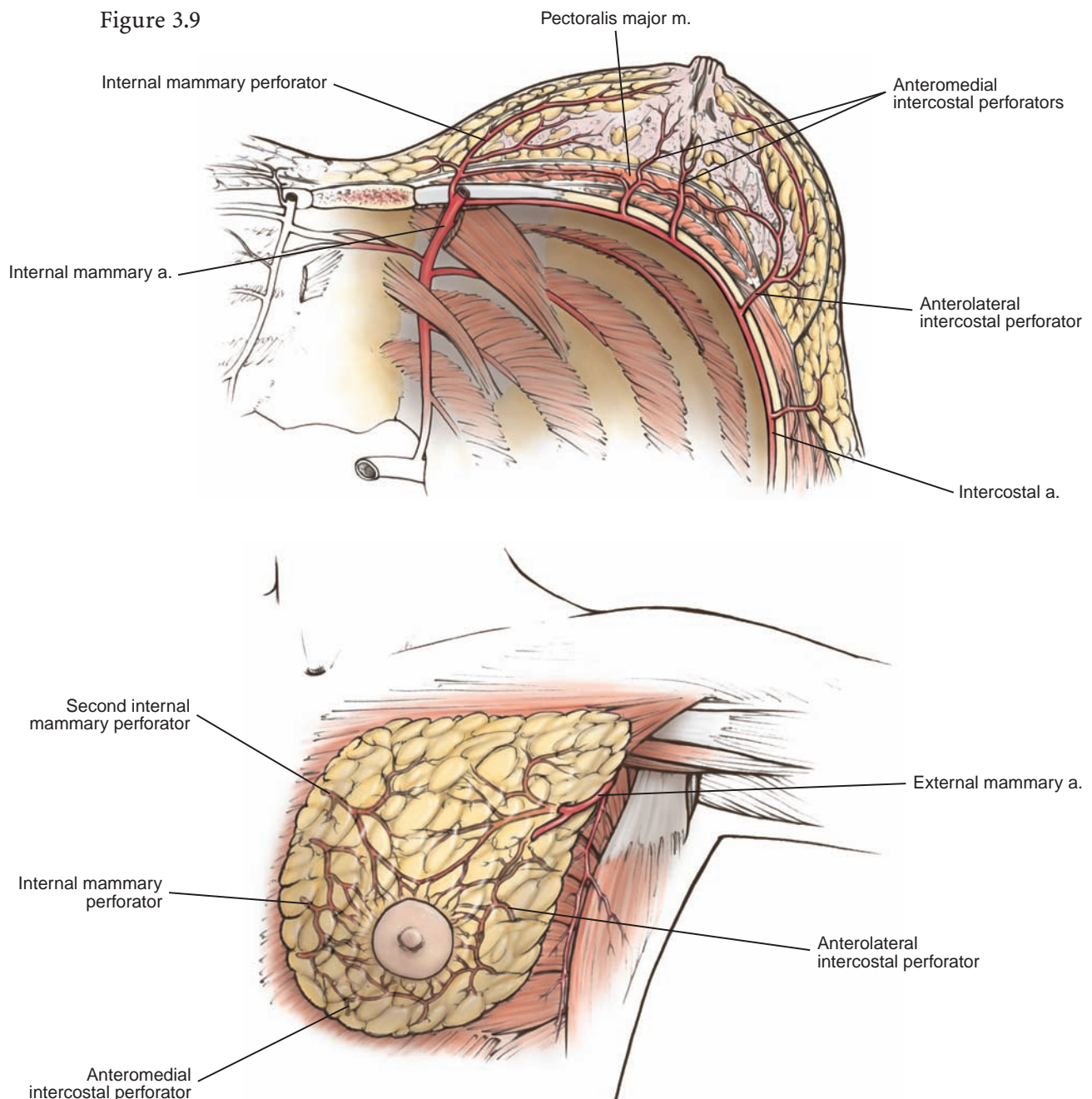
Figure 3.8

The lymphatic vessels draining the arm and those from the breast, transverse the axilla. More radical axillary dissections (removing level III nodes or carrying the dissection anterior to the axillary vein) are associated with a higher incidence of arm and breast edema. A modified en bloc approach is used to clear the axillary nodal tissue. All the lymphatic vessels and nodes with interlacing fat and vessels are removed while carefully preserving the transversing essential structures.

Blood Supply

The blood supply to the breast is through the external mammary artery and perforating branches from the internal mammary artery. The venous drainage parallels this arrangement. These vessels may be divided as required, but may influence breast reconstructive options.

Figure 3.9



Underlying Musculature

The breast overlies the deep fascia and underlying musculature. The upper medial portion of the breast is over the pectoralis major muscle. The lower portion of the breast covers the anterolateral serratus anterior muscle digitations, the upper external oblique muscle origins and its fascia, and the fascia over the upper origins of the rectus abdominis muscle. The breast parenchyma extends laterally to the lateral margin of the latissimus dorsi muscle, and the upper lateral breast parenchyma extends to the axilla. A substantial portion of the breast's blood supply, innervation, and lymphatic drainage passes up through these muscles. An intact muscular layer ensures maximal blood supply to the breast and can act as a biologic barrier between the breast parenchyma and a breast implant during reconstructive breast surgery. Current breast reconstruction techniques depend on an accurate knowledge of this musculature with its blood and nerve supplies.

Pectoralis Major Muscle

The pectoralis major muscle is a primary muscle of the upper chest wall. It extends from its broad origins over the anteromedial chest to insert onto the upper portion of the humerus. Located just beneath the upper medial breast area, it forms the anterior wall of the axilla, is the major component of the anterior axillary fold, and provides the primary fill for the infraclavicular area.

The pectoralis major muscle originates from the medial sternal half of the clavicle and from the outer anterior half of the sternum, from the sternal notch down to the

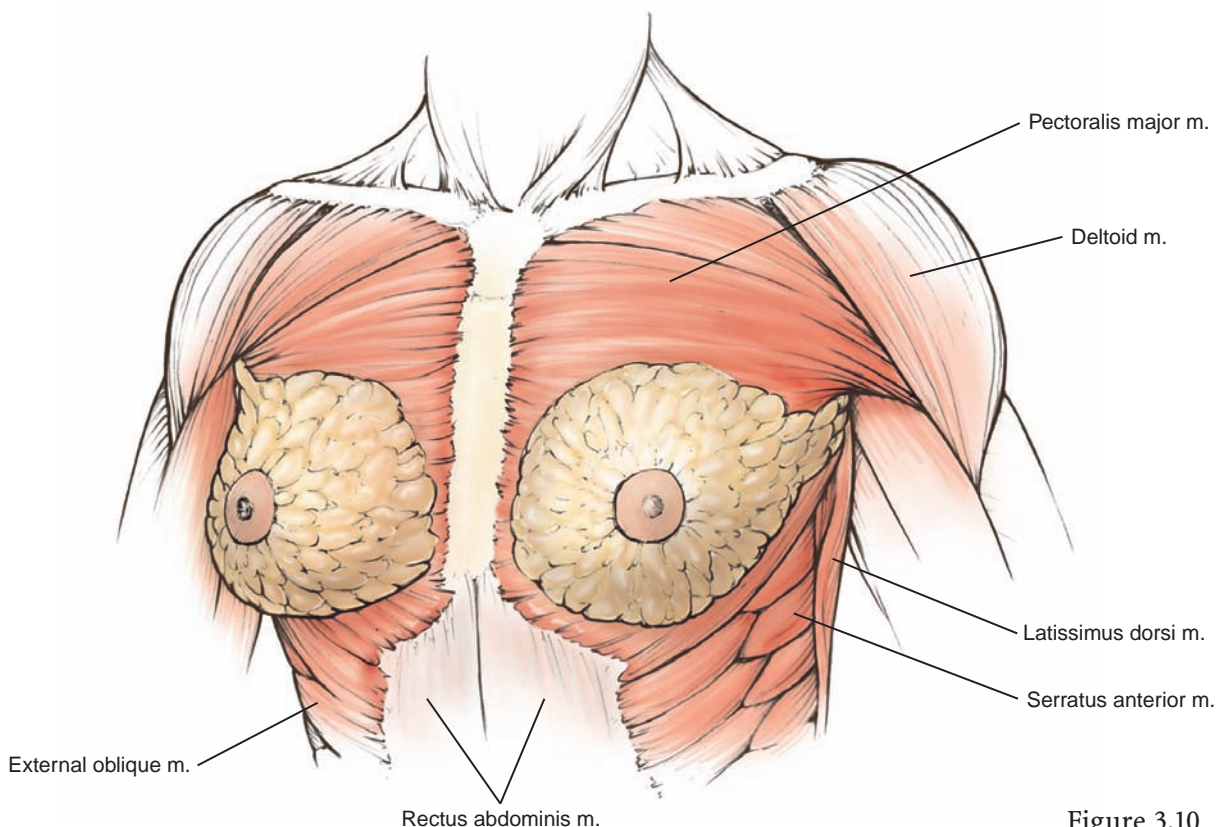


Figure 3.10

sixth or seventh costal cartilages. It also originates from the medial cartilages of the second through sixth or seventh ribs, and below from the external oblique and rectus abdominis fascia. The sternal and clavicular portions of the pectoralis major are usually distinct and separated by a fascial interval. The superficial layer of the deep fascia also extends from the external surface of the pectoralis major muscle across the sternum and joins the fascia above the opposite muscle.

The pectoralis major muscle fibers converge spirally toward the axillary region and form a broad origin for a double-laminated 5 cm tendon of insertion that attaches to the lateral lip of the intertubercular sulcus of the upper humerus.

Nerve Supply

The medial and lateral pectoral nerves innervate the pectoralis major muscle. C5–6 supply the clavicular portion of the muscle fibers, and C7–8 supply the sternal muscle fibers. These nerves are named for their respective cords of origin from the brachial plexus rather than for their position in relation to supply of the pectoralis major muscle. Two to five filaments of each pectoral nerve lead into the pectoralis major muscle. Some of these motor nerve filaments to the pectoralis major muscle course through the pectoralis minor muscle and are removed or can be damaged if this muscle is resected during an axillary dissection.

Division of the pectoral nerves during a modified radical mastectomy results in muscle atrophy and decreased muscle thickness. At least 60% of the muscle bulk is generally lost 4–6 months after motor nerve division, simulating the appearance of a radical mastectomy in the infraclavicular area with localized flattening of this area. This is especially noticeable when a significant thickness of the subcutaneous tissue is removed from the infraclavicular region. The anterior axillary fold, however, is preserved even when there is muscle atrophy, but it may be deficient because of muscle atrophy and removal of axillary breast tissue, which also contributes to the fullness of this fold. Pectoralis major muscle atrophy and infraclavicular hollowness are areas of concern that must be addressed during breast reconstruction.

The medial pectoral nerve fibers provide motor innervation to the lateral and middle portion of the pectoralis major muscle. Selective interruption of these nerve fibers reduces the pectoralis major muscle pull over the upper portion of a subpectoral breast implant without producing significant functional compromise or noticeable atrophy of the upper breast area.

It is desirable that during an axillary dissection the medial pectoral nerve fibers and the pectoralis minor muscle are spared if pectoralis major function and bulk are to be preserved. It is difficult, however, to remove the lymph nodes at the apex of the axilla (level III) without sacrificing the medial pectoral nerve. Most oncologic surgeons believe that sufficient clearance of the lymph nodes can be obtained without taking the pectoralis minor muscle and the pectoral nerve.

Blood Supply

The blood supply to the pectoralis major muscle originates from a number of sources. The thoracoacromial artery, a major branch of the axillary artery, enters the deep surface of the pectoralis major muscle near its upper lateral portion and sends branches throughout the muscle. Perforating vessels from the thoracoacromial artery

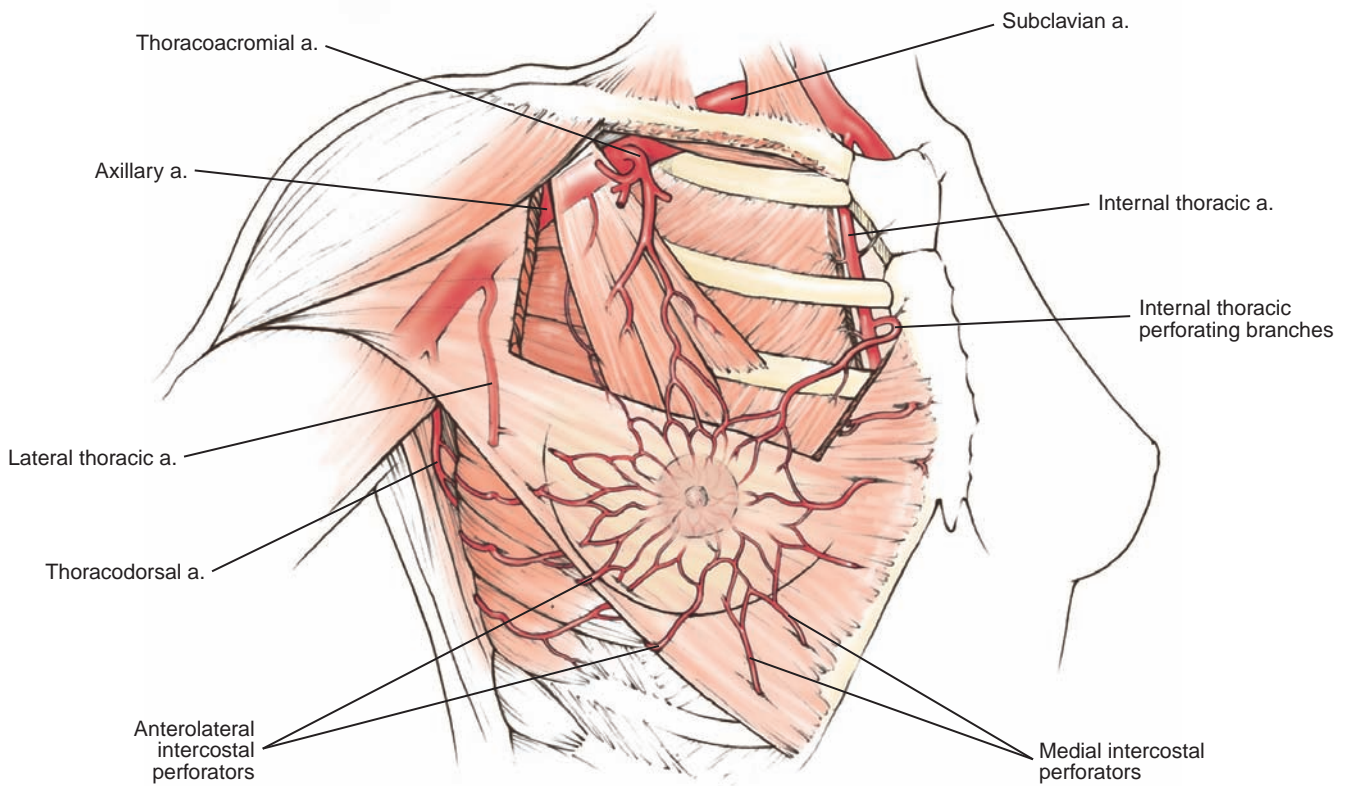


Figure 3.11

enter the deep surface of the breast. The thoracoacromial artery is a substantial vessel, 2–3 mm in diameter, and can nourish the entire pectoralis major muscle and the overlying skin and breast.

Another major group of vessels, branches of the internal thoracic artery, enter the pectoralis major muscle from the second to sixth intercostal spaces medially. Large direct perforating branches from the internal thoracic artery continue through the muscle and its fascia to enter the overlying medial breast. The entire pectoralis major muscle, skin, and breast can also be nourished by these internal mammary vessels from the internal thoracic artery.

The second intercostal arterial perforator is the longest of these perforating vessels. Located high and medial, this arterial branch provides the most direct flow to the upper inner quadrant of the breast. Because of the major collateralization within the breast, it can supply the entire breast parenchyma when there is normal microcirculation. The other three major perforating vessels of the internal mammary artery, the third, fourth, and fifth, are also major sources of inflow into the breast.

Another group, the medial intercostal perforating vessels, supplies the lower portions of the pectoralis major muscle. They enter through the costal origins of the pectoralis major muscle through the fourth, fifth, and sixth intercostal spaces, then course superficially to supply the breast and overlying skin.

The anterolateral intercostal perforating vessels course anteriorly and enter at the junction of the lateral pectoralis major muscle through the intercostal spaces at the medial aspect of the serratus anterior muscle. Branches of these arteries supply

the pectoralis major muscle; their primary flow enters the deep surface of the breast along with the accompanying veins and nerves. These intercostal perforators are from segmental vessels that communicate with the aorta posteriorly and the internal thoracic artery anteriorly.

Serratus Anterior Muscle

The serratus anterior muscle is a broad, flat shoulder girdle muscle that extends from the undersurface of the scapula to the lateral and anterolateral chest. It originates from extensive costal attachments of the anterolateral aspects of the first through the eighth or tenth ribs. These segmental muscular digitations are covered by a thick layer of deep fascia and are densely and broadly attached to the chest wall. The muscle passes backward posteriorly to insert beneath the tip as well as on the deep lateral surface of the scapula. The serratus anterior muscle holds and stabilizes the scapula to the chest wall, assists in rotating the scapula laterally, and draws the scapula forward around the chest. It is essential for reaching and pushing movements of the arm. It also functions and assists in respiration. The muscle and its fascia are beneath the lateral and inferior portions of the breast.

The fascia of the serratus anterior muscle is continuous with the pectoralis major fascia. It is dense and substantial in its lower portions and becomes thinned in its upper portions near the axilla, where it is associated with the pectoralis minor muscle. A musculofascial dissection that proceeds bluntly from the pectoralis major muscle laterally beneath the lower breast area goes below the lower serratus anterior fascia and elevates some of the serratus anterior muscle. Sharp dissection is necessary to elevate the full thickness of the serratus anterior muscle beneath the lateral breast. Blunt dissection laterally from the pectoralis major muscle in the upper breast often pushes out through the thin fascia over the pectoralis minor muscle and serratus anterior muscle, and the dissecting finger or instrument will go on top of this fascia to the subglandular breast position. Although the serratus anterior muscle and fascia form a distinct layer of coverage, it is not as substantial as the cover provided by the pectoralis major muscle and fascia.

Nerve Supply

The long thoracic nerve from the posterior roots of C5–7 supplies the serratus anterior muscle. This nerve is situated laterally and is covered by the external serratus fascia, but is superficial to the external surface of the serratus anterior muscle in the midaxillary line. The long thoracic nerve is carefully spared during mastectomy and axillary dissection. It may be identified by moving the operating fingers along the chest wall in an upward and downward motion. Once found, it is important to gently strip the overlying axillary soft tissue from it for the length of its course, thus removing it from potential injury during the axillary dissection. A gauze sponge over the finger tip accomplishes this easily. The long thoracic nerves location must be kept in mind during breast reconstruction when the serratus anterior muscle and fascia are elevated for breast implant coverage and when elevating a latissimus dorsi flap.

The external oblique muscle is a primary muscle of support for the anterior abdominal wall and is an important consideration after a transverse rectus abdominis myocutaneous (TRAM) flap breast reconstruction procedure. It arises from the outer surfaces of the lower anterior and lateral ribs and curves around the lateral and anterior parts of the lower thorax and abdomen. These slips of origin are closely related to the origins of the serratus anterior muscle in the lower breast area and the origins of the lateral latissimus dorsi muscle farther down on the chest wall.

External Oblique Muscle

Surgical Applications

Four types of biopsies are used in diagnosing breast pathology and they include: Fine-needle aspiration (FNA), core needle biopsy, excisional biopsy, and incisional biopsy. Over the last 20 years, there has been a transition to needle biopsy from an open biopsy procedure. Advantages to this approach are often quicker accessibility and therefore diagnosis, obtaining less tissue and reducing cosmetic deforming especially if the lesion is benign, the increasing role of neoadjuvant chemotherapy prior to definitive surgery with the ability to follow the in vivo effect of various agents prior to surgical intervention. It allows excision margins to be based on the known diagnosis of the lesion.

Breast Biopsies

Each of the above procedures can be performed with or without image guidance using ultrasound, mammographic, or magnetic resonance imaging (MRI) modalities. Ultrasound core biopsy allows for a patient to be in a supine position and for this reason may be easier to tolerate than stereotactic procedures. A stereotactic biopsy is performed either in the upright standing or prone position and mammographic guidance is used for this core biopsy technique. Core biopsies under MRI are performed in the prone position. It is essential for those centers performing breast MRI to have the capability to perform MRI breast biopsy. When a lesion is identified on MRI, a corresponding area is often identified on ultrasonography, however, in approximately 10–20% of cases a definitive lesion is not seen on other imaging modalities and MRI biopsy is necessary.

In general, because of the paucity of tissue obtained, FNA for breast lesions is performed for distinct palpable masses. Decisions to perform an FNA are based on triple test concordance. The triple test includes clinical exam, imaging characteristics, and final FNA cytological assessment. It is appropriate to select the use of FNA for diagnostic purposes if clinically and radiographically the mass is suspicious for cancer (by default this includes palpable lesions). If a positive FNA cytological assessment is made in this setting, this becomes a triple positive test and the likelihood of mis-diagnosis is less than 1%. Likewise at the other end of the spectrum, an FNA may be indicated for the triple negative scenario: not clinically suspicious but distinct on exam, imaging negative of that particular region, and a negative FNA

Fine-Needle Aspiration

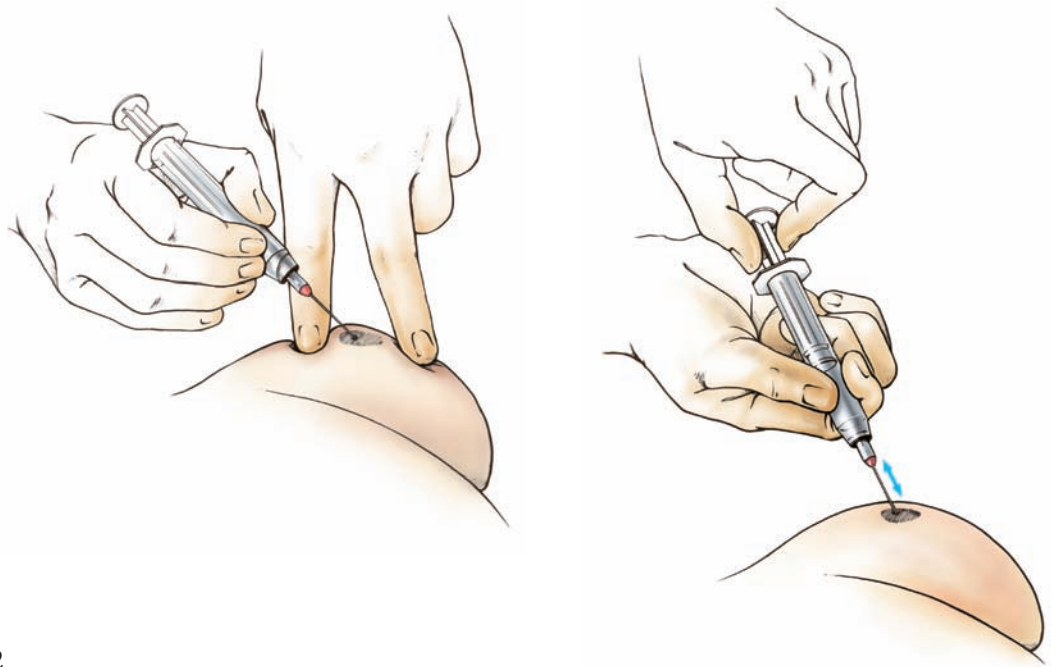


Figure 3.12

cytological assessment in this triple negative setting again is highly accurate. The patient should be educated that if atypical cells are found in the triple negative setting, more tissue may need to be obtained (either by core or excision) to completely rule out neoplasia.

Image guidance is being used increasingly, even for the aspiration of simple cysts routinely encountered as palpable breast masses in clinical practice. It is advisable to complete all breast imaging for a patient prior to an interventional procedure so tissue is not disrupted prior to initial imaging.

The technique of FNA is illustrated. The tip of the needle is passed up and down 10–15 times, traversing the palpable lesion by several millimeters. Minimal pressure is applied on the plunger of the syringe to collect discohesive cells in the barrel of the needle. When the needle has been removed with no force of aspiration applied, the air-filled syringe may be replaced and the contents of the needle expressed onto a slide, smeared, and immediately placed in 95% alcohol. A few seconds of air drying may greatly diminish the diagnostic value of the aspirate smears. The advantage of FNA is the immediacy of diagnostic accuracy which can play a significant role in discussing next steps of care with a patient who presents with an obvious breast cancer and has already undergone appropriate imaging. It should be noted that the material collected from the FNA procedure is also placed in a cell block for further analysis and at times this information is necessary for a final determination.

Core Needle Biopsy

Core needle biopsies are advantageous for histologic diagnosis of fixed tissue because they accurately distinguish between invasive and preinvasive lesions. An image-guided core needle biopsy is illustrated. Whenever possible, a small incision is made with the tip of a No. 11 blade and the site of this incision placed where it can be

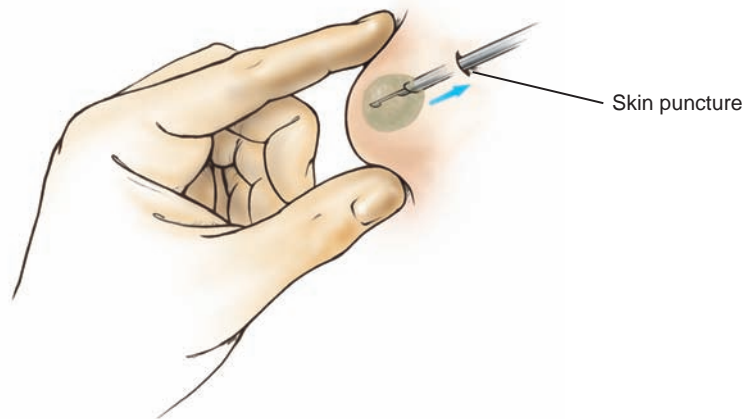


Figure 3.13

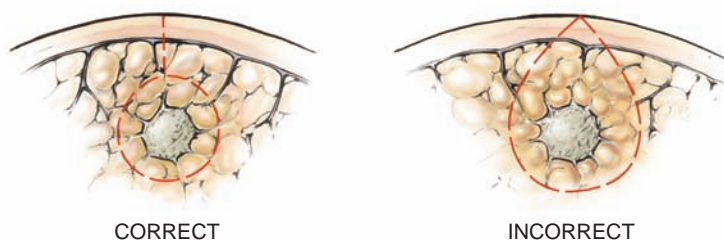


Figure 3.14

excised if a mastectomy is necessary. If the site is to be irradiated as part of breast-conserving therapy, the stab biopsy site incision does not need to be excised. When preoperative systemic therapy will be used, it is essential to place a clip at the site of the core biopsy, at the center of the lesion, as 30% of breast cancers will have a complete clinical remission with induction therapy.

Both fine-needle aspiration and core needle biopsy may be used to diagnose clinically occult axillary lymph nodes. This information is often vital in planning neoadjuvant chemotherapy strategies and may omit prechemotherapy surgical assessment of the axilla if positive nodes are identified on needle biopsy.

If a mass is excised prior to diagnosis and the likelihood of it being benign is high, it is advisable to remove just a minimal margin (few millimeters) of normal tissue surrounding the mass to yield the best cosmetic result. There is extensive literature about the anatomic and cosmetic basis for orienting skin incisions for these procedures.

Incisions placed at the interface between the areola and the surrounding breast skin tend by their location to heal with very inconspicuous scars. These circumareolar incisions should be used when possible in excising lesions, especially if a benign lesion is suspected. Other acceptable incisions are illustrated in Figure 3.16. If there is a chance that the lesion is malignant, location of the incision is selected keeping in mind there may be a slight chance the patient may ultimately require a mastectomy and the incision should be incorporated in the elliptical incision for this procedure. For five to seven o'clock lesions, some surgeons use a vertical incision at the six o'clock site. This

Excisional Biopsy

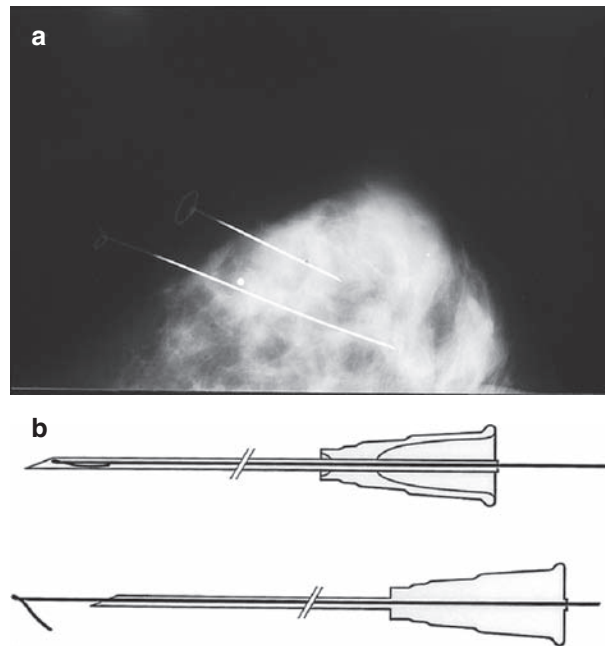


Figure 3.15

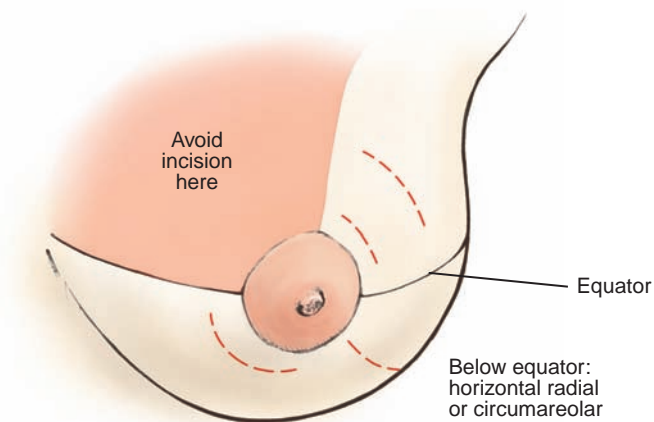


Figure 3.16

mimics the incision used for reduction mammoplasty and allows proper positioning of the nipple–areolar complex. Skin ellipses should not be excised as part of a biopsy as these shift the location of the nipple–areolar complex creating visual asymmetry.

In some situations, FNA or core biopsy cannot be performed either because the lesion is too close to the chest wall. Another indication to consider excision is for patients with architectural distortion because sampling by fine needle or core biopsy could potentially miss the target lesion. Occult lesions requiring excision are localized by placement of a fine guiding wire hook (e.g., Kopans) or stiff tack (e.g., Wood-Kopans). These guidewires should be placed by a mammographer who understands the surgical approach to be used to remove the lesion. It is essential that the localizing wire pass directly through the clustered microcalcifications. What may appear to be tangential to or very near a cluster of calcifications on breast compression may actually be several centimeters away when compression is released.

All excision biopsy specimens should be marked with suture material to designate specific margins and orientations to the pathologist. When processing the tissue, different color stains can then be used in pathology to designate the various margins (examples: inferior, superior, medial, lateral, anterior, and posterior). This procedure is vital should a malignant diagnosis be made on excision with the need to evaluate the exact distance of the lesion from the various margins.

Occasionally an incisional biopsy is used to diagnose a patient with breast symptoms. By definition this implies removal of a piece or section of a suspicious finding. As an example, a patient may present with nipple–areolar eczema and Paget’s disease needs to be excluded. Again imaging the patient prior to an interventional procedure is preferred. A punch incisional biopsy can be performed in the office setting using a 4 or 5-mm punch device. For a patient with locally advanced disease eroding the breast and chest wall, again a simple office incisional procedure could be considered as the first diagnostic maneuver.

Incisional Biopsy

Special Considerations for Specific Benign Lesions

Both bloody discharge from the nipple and spontaneous clear discharge from a single nipple duct require excisional biopsy. Each has approximately 20% likelihood of being caused by a neoplastic lesion. Often, prior to being evaluated by the surgeon, a patient has undergone a ductogram in the radiology suite of the offending duct. The indication for performing such a procedure is if there is a suspicion for deeper duct obstruction/lesion and wire localization of this deep structure may be necessary for surgery. Otherwise, if the symptomatology can be elicited in the peri-areolar area, there is no strong indication for a preoperative radiological ductogram. Likewise, sending the fluid for cytological analysis is not accurate enough to avoid surgery if the discharge meets biopsy criteria.

Nipple Duct Excision

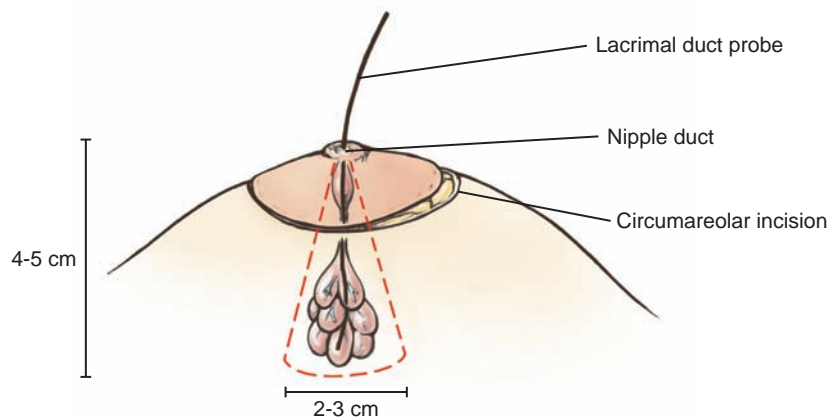


Figure 3.17

Excision of the involved nipple duct involves placement of a fine (4–0) lacrimal duct probe down the nipple duct, from which the discharge can be expressed. When the lacrimal probe is inserted into the breast, a trumpet-shaped piece of breast tissue is removed through a circumareolar incision that includes the terminal duct at the nipple skin, the lactiferous sinus beneath it, and a deeper section of tissue 3–5 cm of enlarging breast tissue surrounding that duct.

The most common histological finding for pathological nipple discharge is an intraductal papilloma or mammary ductal ectasia, with intraductal carcinoma and more rarely infiltrating ductal carcinoma occurring in approximately 10–20% of cases. This procedure is most comfortably performed with heavy IV sedation/local or general anesthesia of short duration.

Lactiferous Fistula Excision

A rare but chronic disabling condition is Zuska's disease, a recurrent condition characterized by a draining fistula usually at the edge of the areolar tissue. The disease arises from multiple breast abscesses either incised and drained in an open fashion, creating an iatrogenic cause for this disorder or it may result in deep keratin plugging of ducts with resultant chronic infections and eventual development of a fistulous tract. Because of the potential iatrogenic etiology of a lactiferous fistula, current initial management of breast abscesses should be aspiration of the abscess, which may often require multiple aspirations for resolution in combination with moist heat and appropriate antibiotics. Prior to surgical excision of the fistula tract, all active infection needs to be resolved.

Regardless of the etiology of Zuska's disease, this chronic condition is definitively addressed surgically by cannulating the fistula tract with a fine (4–0) lacrimal probe up to the involved duct on the nipple. Skin overlying the probe is then incised and the fistula tract completely excised around the probe. The skin is reapproximated with inert suture (3–0 or 4–0 nylon) and deep sutures are avoided to decrease the inflammatory response. Complete excision of the fistula tract ensures the lowest recurrence of chronic abscess formation and drainage.

Fibroadenoma and Phyllodes Tumor

If a fibroadenoma is to be excised in a young woman, there is no need to remove an additional surrounding margin of normal tissue. If the lesion is larger (greater than 2.5–3 cm) or the woman older and it may represent a phyllodes tumor, a margin of normal breast tissue should be removed in all directions to ensure total tumor excision and decrease local recurrence rates.

Special Considerations and Procedures for Malignant Lesions

Breast conservation therapy involves surgical removal of all gross tumors in the breast, an axillary staging procedure and breast irradiation. Breast conservation therapy results in equivalent local recurrence and overall survival rates in women

with early-stage carcinomas of the breast compared to mastectomy. Increasingly the role of neoadjuvant therapy, otherwise known as induction chemotherapy or preoperative chemotherapy is being offered not only to women with locally advanced disease but also to those who qualify for adjuvant chemotherapy. Consideration is made to deliver this therapy upfront prior to surgery. The rationale behind induction chemotherapy is to observe an in vivo response to various regimens and follow the response in some cases with tissue sampling during treatment intervals. Additionally, larger lesions in a smaller breast may be excised after preoperative chemotherapy with superior cosmetic results. The safety of this approach has been documented in that few patients will progress in such a setting (less than 1–3%) but close monitoring by the surgical oncologist is necessary if this path is chosen.

A group of women from the onset will require mastectomy; those with diffuse suspicious calcifications throughout the breast that on core biopsy demonstrate ductal carcinoma in situ or patients with disease that significantly crosses over two quadrants. Patients with contraindications to radiation therapy also require mastectomy. Even in those patients with invasive disease who require mastectomy, there may be a role for induction chemotherapy to monitor the tumor response to treatment regimens.

A variety of terms are used to describe excision of a breast lesion with a margin of normal tissue enveloping it. These imply something about the margin of normal-appearing tissue removed, but are so imprecise that the generic term “lumpectomy” has become common terminology. The term “partial mastectomy” implies a larger area of tissue to be removed; however, it may equally refer to the procedure performed for a malignant lesion with additional margin resection in order to achieve negative margins. In the United States, partial mastectomy is often used for coding purposes since the technique used to resect a malignant lesion is different (wider margins or additional margin re-excision are taken) than an excisional biopsy where in most cases, the lesion will be benign.

Both retrospective analysis and prospective studies suggest that the greater the margin of normal-appearing breast tissue removed the lower the local recurrence rate. On the other hand, the greater the margin of tissue removed the poorer the resultant cosmetic appearance. The optimal balance of histologic tumor type and grade, nature of the tumor margin (infiltrative vs. pushing), size of the tumor, margin of surgical excision, and use of irradiation boost dose to the area closest to the resection cavity are still being debated based on prospective data. Several principles are clear, however. Higher failure rates follow failure to establish a margin clear of invasive breast cancer. Tumors that have an extensive intraductal component (greater than 25% of the tumor mass of intraductal tumor or ductal carcinoma in situ in the adjacent tissue) have a more diffuse pattern of infiltration in the adjacent breast and benefit from a slightly wider margin of excision designed to leave no residual tumor. A margin of “no ink on tumor” in prospective trials has proved sufficient for a purely invasive tumor with a pushing margin, but a more generous margin (>2 mm) will produce a lower failure rate in more diffuse tumor patterns. In unusual circumstances

**Lumpectomy,
Segmental
Resection,
and Partial
Mastectomy**

where excision biopsy yielded the diagnosis of cancer and the margin is insufficient, a re-excision of the cavity is necessary during the axillary staging procedure. If margins are distinctly marked during the original excision biopsy, then a re-excision of that particular margin may be all that is necessary to achieve complete excision and free margins.

For breast carcinomas that are treated with breast-sparing surgery followed by irradiation, there is no evidence that operating through a circumareolar incision located farther from the mass has any oncologic risk compared with a direct incision overlying the mass. Similarly, there is no oncologic justification for making a cosmetically less desirable incision; those lesions that can be easily approached through a circumareolar incision should be. See Excisional Biopsy section for in-depth discussion of other potential incisions.

Some surgeons perform additional small resection margins after the main lumpectomy specimen has been excised. For example, with a wire localization procedure for a nonpalpable lesion, if the specimen radiograph returns demonstrating on imaging that the target is close to one of the edges of excision, an elliptical excision margin of the close edge can be performed. It is important to mark these re-excision margins for orientation as well; often a stitch on the inside of the cavity provides adequate orientation to clear the outer surface of the re-excision margin.

The cosmetic result of a lumpectomy is related to both the percentage of the breast that was resected as well as the manner of closure. The resection cavity should be addressed with fine snaps and the Bovie electrocautery until it is completely dry. Skin closure is achieved with absorbable suture in either a single or double layer technique. Deep cavity suturing or drains should be avoided; the small hemoseroma that forms will be absorbed by natural retraction more evenly than can be achieved by surgical approximation of the breast tissue. Drains or deep cavity suturing, often lead to indentations. An external supportive dressing that shapes the breast tissue into ideal position and form should then be placed and supported by the patient's own bra-siere. The dressing should be kept in place for 3–5 days.

For larger lesions in smaller breasts, treatment options for optimal cosmesis include (1) induction chemotherapy with excision of a considerably regressed primary lesion, (2) tailoring of the breast or insertion of a small subpectoral implant or flap (oncoplastic techniques), and (3) wrapping of the breast after resection so that it heals in the desired shape. Quadrantectomy, which often implies excising overlying skin as well as the entire breast quadrant of tissue, is not an appealing option as a stand-alone procedure and often requires oncoplastic surgery for adequate closure and long-term acceptable cosmesis.

Paget's Disease

Intraductal carcinoma involving the skin of the nipple and areola can be treated with partial mastectomy with excision of the nipple–areolar complex and the underlying central ducts, provided deeper disease of the breast is excluded with appropriate imaging. An elliptical incision surrounding the nipple–areola complex is the incision of choice. If the breast is wrapped in such a way that the breast tissue is coapted and the skin closed in a single or double layer, the result is a very normal breast mound

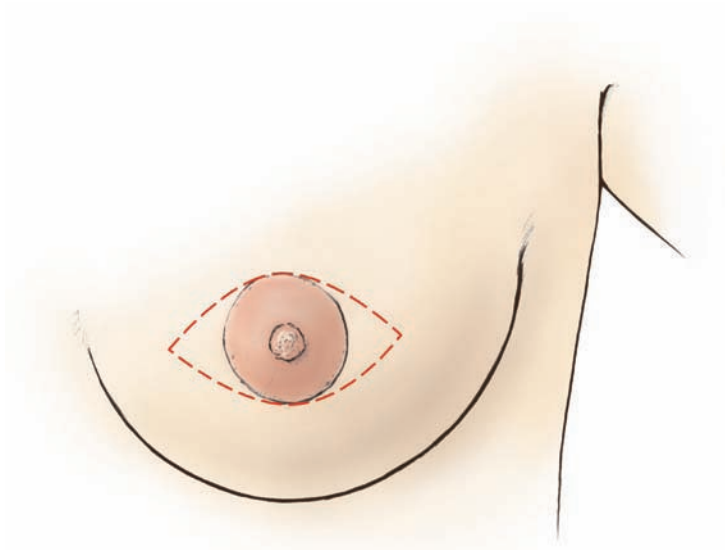


Figure 3.18

with a transverse incision. Orientation of the specimen is important to allow the pathologist to describe any close or positive margin in a way that can permit localized reexcision. The conserved breast can then be irradiated. Patients who desire may undergo nipple–areolar reconstruction 3–6 months after radiation and can expect a natural-appearing result.

Sentinel Node Biopsy

The concept of sentinel lymph-node biopsy is based on the theory that a particular area of tumor drains through a lymphatic pathway to a discrete number of lymph nodes. If the lymph node(s) draining the area where a tumor is located is(are) subsequently removed, analysis of this smaller number of lymph node(s) should be more specific than the entire regional lymph-node basin and, if free of metastatic cells, implies that the other nodes in the region are also free. The sentinel lymph node can

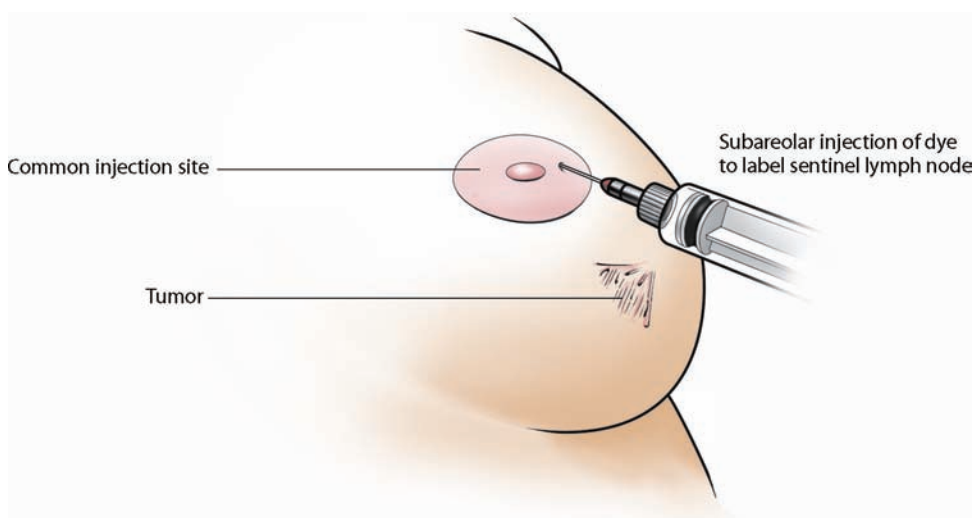


Figure 3.19

be identified by injection of lymphazurin or methylene dye blue. In less than 0.1% of cases, lymphazurin can elicit an anaphylactic reaction and some surgeons prefer pretreatment with steroids, H2 blockers, and antihistamines to minimize this rare but unexpected occasional reaction to this dye. Alternatively, methylene blue can be substituted for lymphazurin but a deeper injection is necessary since superficial injection of this dye can produce tissue reaction and skin breakdown. Another technique is to use radioactive technetium sulphur colloid with or without blue dye for sentinel node localization. A nuclear medicine image can identify whether the sentinel nodal structures are adjacent or separate from each other and a handheld Geiger counter probe used in the operating room provides additional localization guidance for sentinel node identification and removal. Note the average number of sentinel lymph nodes identified and removed for breast cancer surgery ranges from 2.2 to 2.5 lymph nodes, and rarely will removing more than 2 or 3 sentinel nodes change a “negative axilla” to a “positive” one in breast cancer.

Many surgeons inject blue dye in the subareolar tissue of the breast. Sappey’s plexus is a network of rich lymphatic channels that is located in this area and the dye is easily taken up and mapped to the axilla. The depth of injection can either be in the subcutaneous tissue (for lymphazurin) or deeper in the breast parenchyma (more desirable if methylene blue is used). Massage of the area injected then takes place for 3 min after the injection of about 3–5 mL of dye. A transverse axillary incision is made just at the base of the hair-bearing axillary skin and dissection takes place down through the clavipectoral fascia while search for the blue-dyed lymphatic vessel(s) takes place. When seen, these lymphatics will be smaller than the veins, which will also stain a deeper blue, usually 1 or 0.5 mm in diameter. These channels are then dissected out carefully and traced proximally to identify the most proximal lymph node along its course. This is the sentinel node and will usually be bright blue at this time, fading over the next 5–10 min. The region is searched for additional blue nodes or a second lymphatic vessel by bringing up the axillary tissue in the small transverse incision. Sometimes the tumor in a node prevents the node from turning blue even though it lies along the course of an identified sentinel lymphatic vessel.

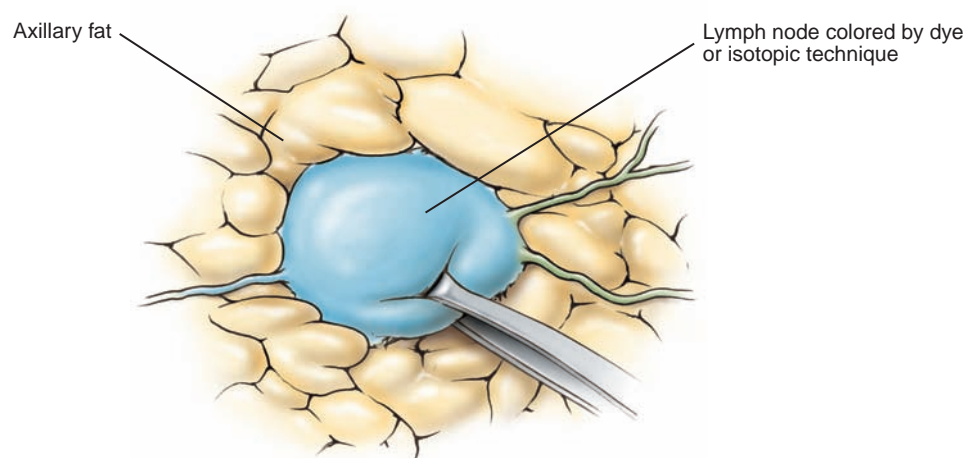


Figure 3.20

Provided a blue stained lymphatic directly enters a node, this node is considered a sentinel node and can be removed for analysis. With the isotopic technique the incision and search for the lymph node are directed by the handheld probe. The removed nodes are checked for activity with the probe. Palpation of the axilla from within the incision can re-veal a hard node replaced by tumor, on occasion, where dye in lymphatics is blocked by the tumor.

Most surgeons will send the sentinel lymph node(s) for frozen-section and/or touch preps at the time of the outpatient procedure and then proceed to axillary dissection if the sentinel lymph node is positive while others will wait for final histological analysis to act on the result. There is a 5–10% false negative immediate pathology rate and patients should be counseled that occasionally a small deposit of tumor is found during H&E examination. False positive sentinel node interpretation is rare and yet can occur with crush artifact. Handling of the sentinel node at the time of surgery is important and it is advantageous to pick up tissue around the node to avoid maceration of the lymph node during the process of removal.

A transverse skin incision is made just lateral to the pectoralis major muscle extending toward the latissimus dorsi lateral border ideally positioning the incision just below the axillary hairline. Often a natural skin crease can be followed for better cosmesis. The skin incision is carried through the skin and immediate subcutaneous tissue, but only 2–3 mm of subcutaneous tissue is spared because the lymphatic vessels are rich and approach the level of the skin. Consequently the skin flaps for an axillary dissection are relatively thin and are raised superiorly and inferiorly to the level of the pectoralis muscle. The lateral border of the pectoralis muscle is

Axillary Dissection

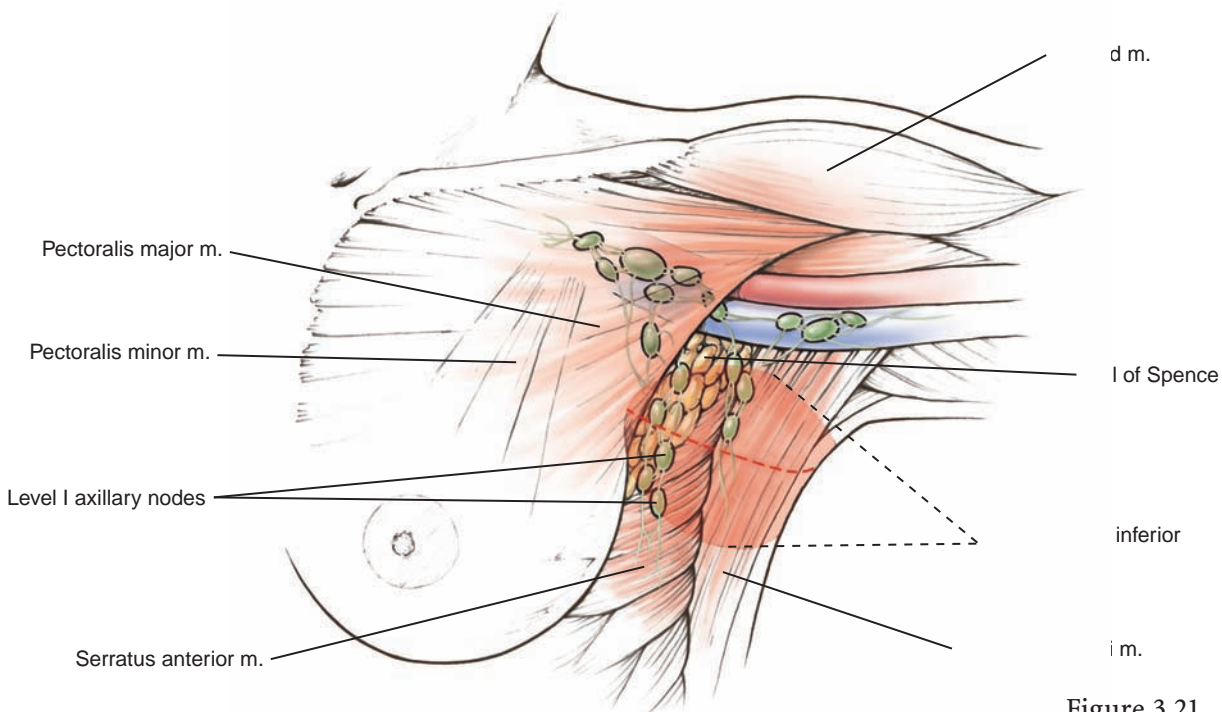


Figure 3.21

identified and its fascia incised at its lateral edge. The lateral border of the latissimus dorsi muscle is then palpated, and its lateral border cleared up to where it exhibits white tendon superiorly.

A retractor is then placed underneath the pectoralis major muscle, between the muscle and the pectoral fascia, sweeping up to the origin of the pectoralis along the clavicle. Dropping down 3 cm from the highest portion of the interpectoral fascia, a transverse incision is made through the pectoralis fascia and immediately deeper the clavipectoral fascia. Making the transverse incision at this level spares the axillary lymphatic vessels returning from the arm, minimizing the risk of later arm swelling. This approach reveals the inferior margin of the axillary vein immediately subjacent to the clavipectoral fascia. Sweeping the fatty tissue inferiorly and away from the axillary vein will reveal some external thoracic and axillary vein branches entering the inferior margin of the axillary vein. These can be divided after securing with absorbable ties. Dorsal to these the thoracodorsal vein enters the axillary vein 2–2.5 cm from the chest wall.

The subscapular vein and thoracodorsal vein may enter separately, adjacent to one another, or more commonly fuse as a common trunk. Some anatomists refer to this as the thoracodorsal vein with a subscapular branch, others to the subscapular vein with a thoracodorsal branch. Just medial to the thoracodorsal vein the thoracodorsal nerve emerges from beneath the axillary vein in a triangular fashion to join the thoracodorsal vein and the thoracodorsal artery. These pass inferiorly to enter the latissimus dorsi muscle. Just lateral to the thoracodorsal vessels the surgeon's finger can pass between the lateral aspect of the thoracodorsal vessels immediately below the axillary vein and the latissimus dorsi lateral border previously identified. The tissue encompassed between the surgeon's two fingers may now be completely divided, with one exception. The highest intercostobrachial nerve supplying sensation to the skin of the axilla and medial posterior arm is now palpated against the

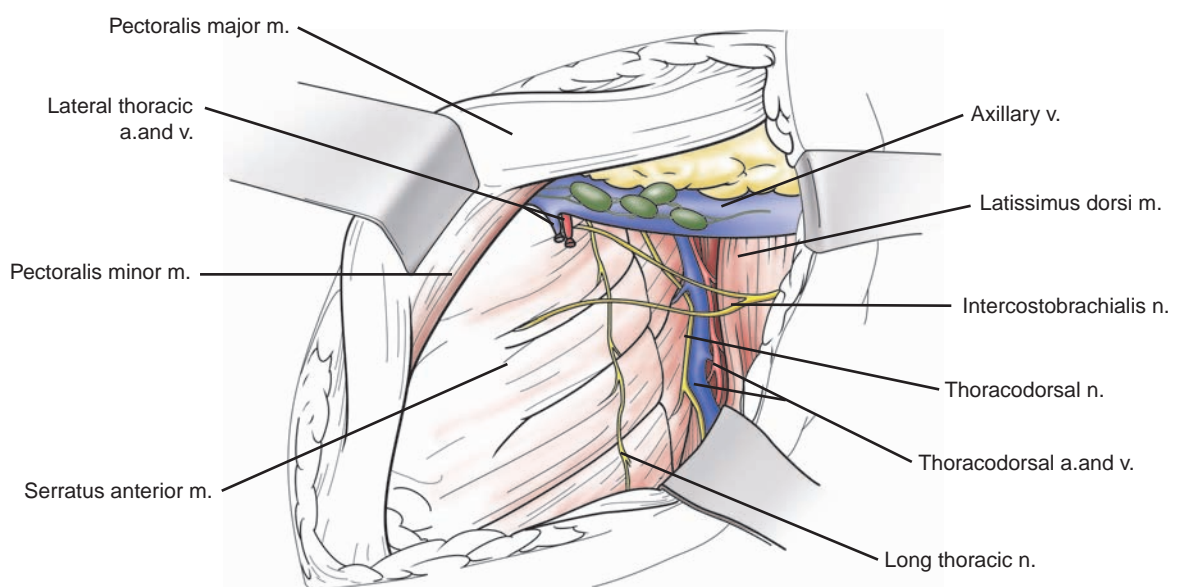


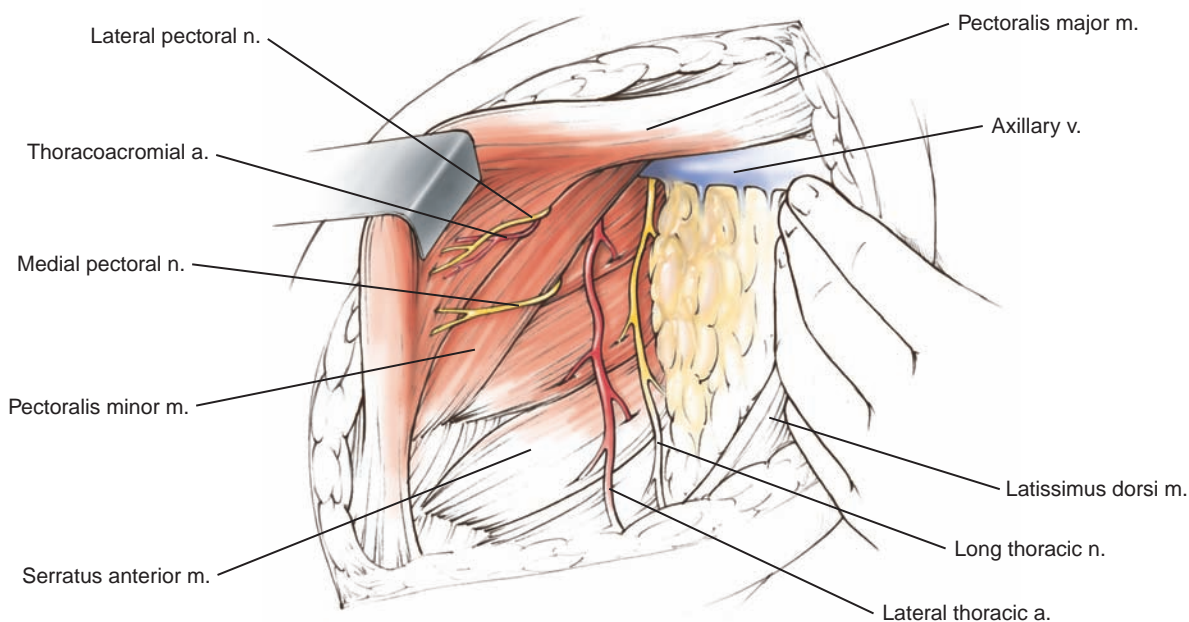
Figure 3.22

surgeon's finger. Drawing down on the axillary contents just described, causes sufficient tension that the intercostobrachial nerve is easily identified. It may be dissected free of the surrounding axillary contents, and should be spared whenever possible. With that nerve spared, but the other lateral axillary contents divided, visual access into the medial axilla is excellent. Dissection can then take place anterior to the thoracodorsal complex where at times there are lymph nodes adherent to this complex that need to be separated off carefully. Small arterial branches to the thoracodorsal complex can be divided between ties or clips.

Next, the long thoracic nerve is identified on the chest wall beneath the fascia of the serratus anterior muscle, at exactly the same anteroposterior depth as the thoracodorsal nerve. If it is not readily visible, moving the finger anterior and posterior along the chest wall yields a guitar-string-like structure on palpation. Once the nerve is identified it is helpful to dissect it along the length of its course keeping it adherent to the chest wall.

The axillary contents may be cleared away, sparing only the medial origins of the two intercostal contributions of the intercostobrachial nerve. The medial pectoral nerve is also visualized and carefully spared when removing the level II lymph nodes. These are the lymph nodes that lie behind the pectoralis minor muscle. The medial pectoral nerves sweep around the border of the pectoralis minor muscle or may have an additional branch that penetrates the lateral fibers of the pectoralis minor muscle. They pass anteriorly to innervate the lateral half of the pectoralis major muscle. If these nerves are inadvertently removed, the lateral aspect of the pectoralis major muscle atrophies, producing thinning that is more important cosmetically than functionally. All the lymphatic tissue behind the pectoralis minor muscle is swept out inferiorly with the other axillary contents. These include breast tissue comprising the tail of Spence that has entered the axilla.

Figure 3.23



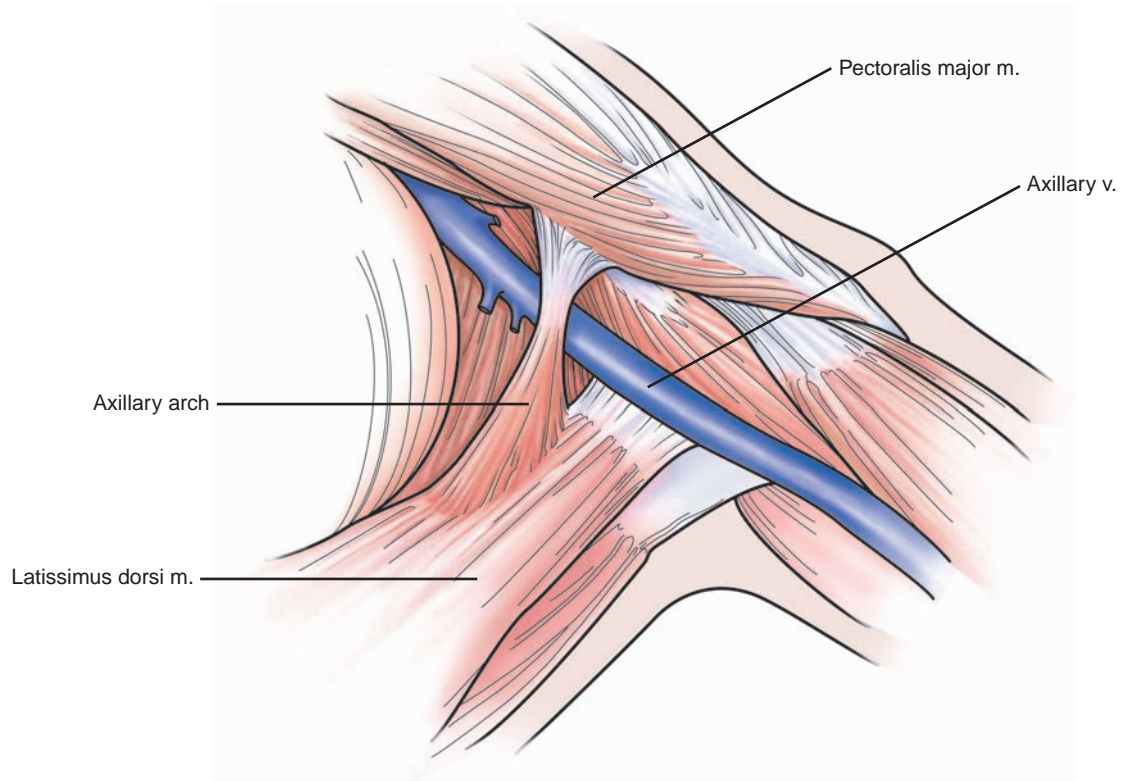


Figure 3.24

In approximately 5% of patients an axillary arch is present. Those fibers forming the arch may be divided to provide access to the axilla. This anomaly can easily confuse the operating surgeon when searching for strategic landmarks in the axilla and should be kept in mind during an axillary dissection.

In patients with melanoma or squamous cell carcinoma, lymph-node metastases to all three levels of axillary lymph nodes should be removed. One or two suction drains are placed through a separate stab wound and secured with a nonabsorbable suture.

Axillary Dissection with Lumpectomy

Axillary dissection is typically limited to levels I and II lymph nodes when performed with lumpectomy for breast conservation. When the two operations are combined, the axillary staging procedure is generally performed first especially if a sentinel-node dissection is planned. During analysis of the sentinel lymph node on frozen-section, removal of the breast tumor takes place.

Then the lumpectomy is performed. If word is returned that the sentinel nodes contain tumor, axillary dissection may be performed under the same anesthetic. Clean instruments should be used to avoid contaminating the axilla with tumor from the breast, as the breast will be irradiated but the axilla may not be.

Mastectomy Procedures

Total mastectomy (simple mastectomy)
 Skin-sparing mastectomy
 Modified radical mastectomy (includes levels I and II lymph nodes)
 Subcutaneous mastectomy (total mastectomy sparing the nipple–areolar complex)
 Historical procedures: Patey’s modified radical and radical mastectomy

Total Mastectomy

From the near universality of radical mastectomy for all breast cancers in the first half of the twentieth century, a selective role for removal of the total breast has evolved. Earlier detection of breast cancer with mammography and randomized trials demonstrating equivalent survival with breast conservation therapy have contributed to the diminishing role of mastectomy. The diffuse nature of some in situ ductal carcinomas, the large size of some invasive carcinomas relative to the size of the breast, the presence of diffuse suspicious breast microcalcifications rendering assessment of the extent of tumor impossible, the inability to use breast irradiation in some patients such as those with active collagen vascular disease, and the occurrence of multiple primary breast tumors continue to require removal of the entire breast in some women. Others, who are biologically good candidates for breast conservation therapy, have personal reasons for choosing mastectomy. Finally with the ability to test patients for the BRCA1 and BRCA2 mutation, a role for bilateral prophylactic mastectomy has emerged. As a result, a variety of mastectomy procedures have evolved that are directed toward the biology of the tumor being treated or the specific desires of the patient.

Total mastectomy is performed by making an elliptical incision surrounding the nipple–areolar complex. The skin flaps are elevated to just beneath the clavicle superiorly, onto the sternum medially, inferiorly along the inframammary fold down to the depth of the rectus aponeurosis, and laterally to the lateral border of the latissimus dorsi muscle. Skin flaps can be constructed with the electrocautery, the Freeman plastic surgery scissors in a downward excising fashion or with a straight knife. When flaps have been raised and the described margins outlined, the breast is lifted off the pectoralis major fascia using electrocautery, taking the investing fascia of that muscle. It is essential to enter the lower axilla to remove the tail of Spence and the breast tissue lying within the first level of the axilla.

This approach ensures removal of the entire breast parenchyma. Once removed the breast tissue is oriented and marked with a stitch for pathological assessment. Two suction drains are placed, one to drain the axilla and one in the anterior chest

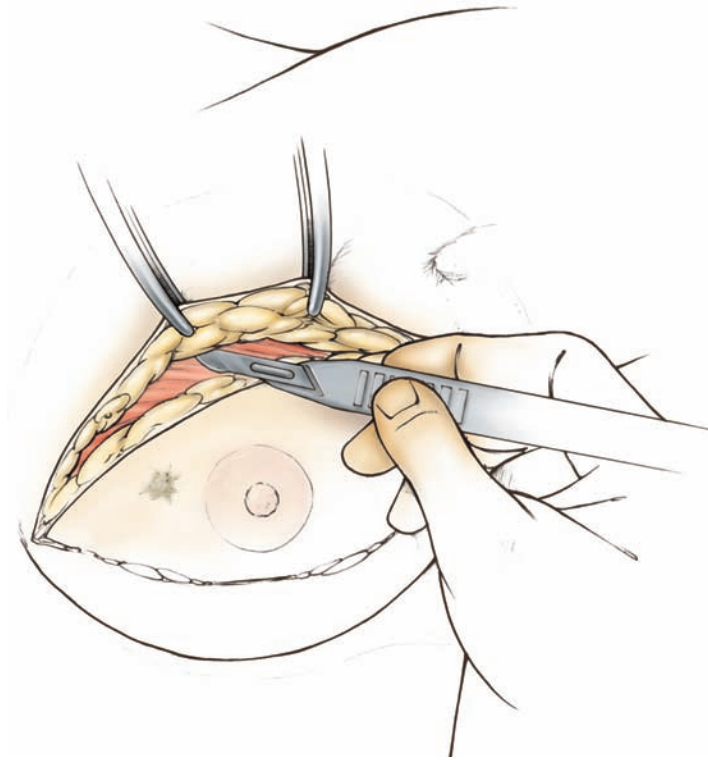


Figure 3.25

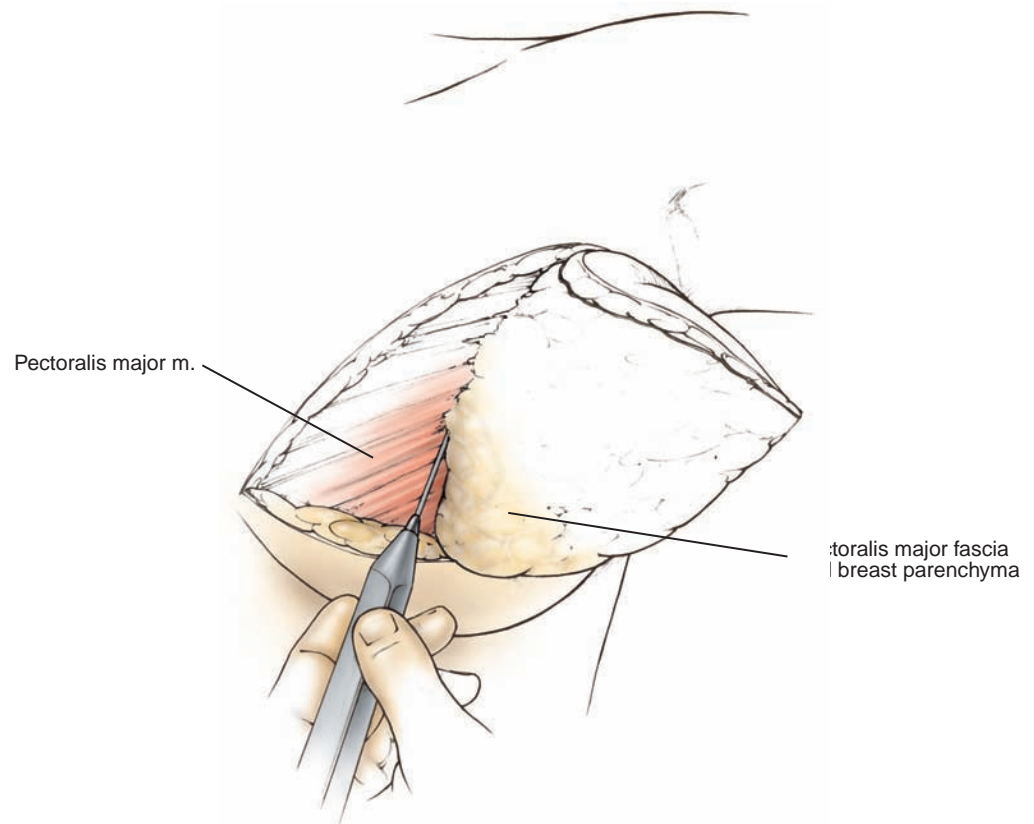


Figure 3.26

wall. The skin is then closed as a single or double layer with absorbable sutures or the reconstructive portion of the procedure is begun.

Skin-Sparing Mastectomy

In the setting of immediate breast reconstruction, skin-sparing mastectomy can be considered for those patients with early-stage breast cancer and limited tumor volume. The concept involves creating a breast envelope by sparing the skin and leaving this space for the plastic surgeon to fill with tissue in an immediate reconstructive procedure. The skin surrounding the nipple–areolar complex is incised in a circular or elliptical fashion. Skin overlying superficial cancers and previous biopsy incisions are removed. When developing skin flaps, the usual breast anatomic landmarks are used to ensure complete removal of breast tissue. For a woman with a less than generous nipple–areolar complex, a short lateral extension of the incision may be required to deliver the breast and axillary tissue. If the patient has had a prior excisional biopsy, it is optimal to include that incision in the skin sparing procedure or excise that incision separately during the mastectomy procedure. Consideration can be made to excise core biopsy sites if the patient will not receive chest wall radiation post mastectomy.

Prospective and retrospective data have demonstrated the safety of a skin sparing mastectomy in terms of local recurrence. Circumstances that increase the risk of local recurrence include: more advanced stage at the time of presentation (especially if neoadjuvant chemotherapy is not given) and overlying skin is not excised, surgical margins less than 1 mm (especially for patients undergoing SSM for diffuse DCIS), and grade of tumor (higher grade increases local recurrence). Complications of skin-sparing mastectomy include native skin flap necrosis due to the longer pedicles that are created with this technique. Smokers and those with poor chest wall perfusion are at risk for skin flap loss. Flap viability can be assessed in the operating room by trimming skin margins and assessing for adequate bleeding.

Modified Radical Mastectomy (Total Mastectomy with Levels I and II Axillary Dissection)

The incision for a modified radical mastectomy is planned to encompass the biopsy incision, the nipple, and the areola. This incision generally gives sufficient access to allow modified radical mastectomy. It can be extended laterally to the anterior axillary line if required by the size and shape of the breast. There is no reason to extend the skin incision medially. If immediate reconstruction is not planned, an elliptical excision, usually oriented horizontally, is outlined. The extent of the ellipse medial to the nipple can be dropped downward to allow the maximum amount of anteromedial skin to be spared for later reconstruction without the scar being obvious in low cut attire. The width of the ellipse is chosen to allow flaps long enough to touch without stretching for coaption at the conclusion of the procedure. If excess skin is left, it tends to form pachydermatous folding. Consequently, the tension on the closed flap should be similar to that of the remainder of the thoracic skin. The

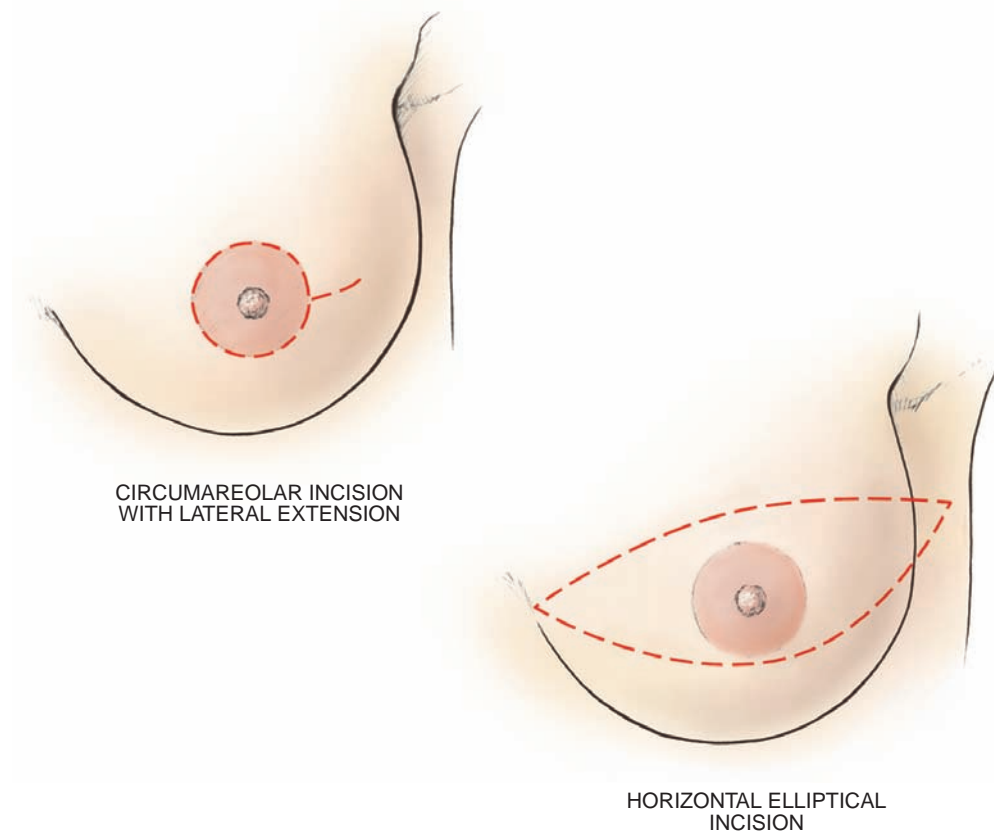


Figure 3.27

skin incision is carried down through the skin and subcutaneous tissue, stopping short of the parenchyma of the breast. In very slender patients the breast parenchyma may abut the skin. Typically there are several millimeters of adipose tissue that are clearly subcutaneous before any breast parenchyma is encountered. The details of removing the breast and performing the axillary dissection are described above in the total mastectomy and axillary dissection sections.

Novel Procedures: Subcutaneous (Nipple Sparing) and Areolar Sparing

This controversial technique involves sparing the nipple–areolar complex by using an incision at the inframammary fold. Skin flaps are raised in a similar fashion to a total mastectomy keeping in mind the margins for breast tissue excision. Some argue that residual breast tissue is left behind the nipple–areolar complex and in fact in a retrospective review of women undergoing bilateral prophylactic mastectomy, those who developed recurrence were the patients who had subcutaneous mastectomies. Another disadvantage is loss of sensation over the nipple–areolar complex yet native tissue is maintained. In this era of advanced nipple–areolar reconstruction, this procedure is not as common as in the past.

Another novel technique is an areolar sparing procedure where just the nipple is excised using an S incision or an extension of the inverted T reduction type incision.

The areola is left intact and skin flaps are developed through this smaller nipple incision. The areola can be assessed for tissue viability prior to reconstruction. For this procedure, more ductal tissue is theoretically removed; however, the cosmetic outcome may not be as desirable as a nipple-sparing procedure. Some argue whether there is a real advantage of this procedure over a traditional skin-sparing total mastectomy using current reconstructive nipple–areolar techniques.

Historical Procedures: Patey's Modified Radical Mastectomy and Radical Mastectomy

The operation described by Patey includes removal of the level III lymph nodes by taking down the insertion of the pectoralis minor muscle. This is accomplished by preparing the arm into the operative field so that it may be brought across the chest, relaxing the pectoralis major and minor muscles. With a retractor beneath the relaxed pectoralis major muscle, the pectoralis minor muscle is encircled and divided. Complete removal of Level III axillary lymph nodes extending to Halstead's ligament (the dense fascia far medial residing under the pectoralis muscle) can then take place. This procedure is rarely necessary for debulking of metastatic lymphatic disease given current multimodality therapy. In the Patey procedure particular attention was directed toward sparing the lateral and medial pectoral nerves. This procedure is mentioned for completeness, but evidence of benefit from including the level III axillary nodes in the setting of multimodality therapy is lacking. On the other

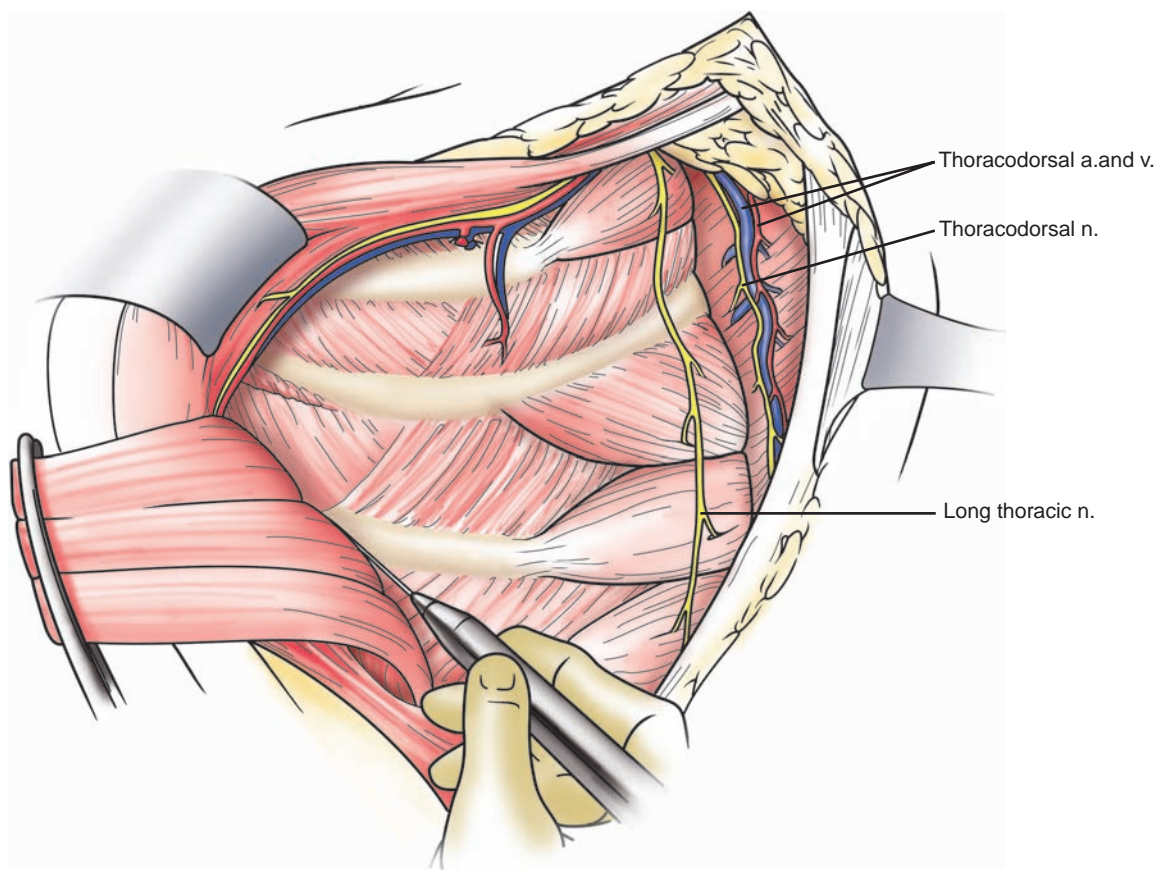


Figure 3.28

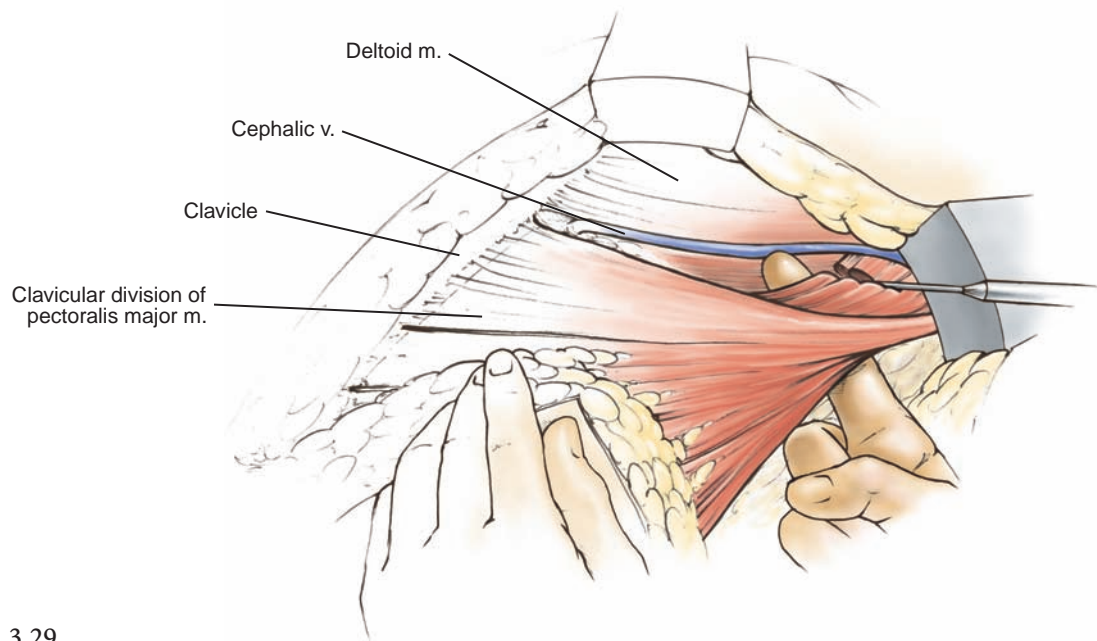


Figure 3.29

hand, evidence of more frequent lymphedema from removing the level III lymph nodes is present.

Radical mastectomy is included, despite virtually no role in clinical practice, because it served as the basis for the proliferation of mastectomy procedures. In an era of multimodality therapy, induction chemotherapy and radiation therapy have all but eliminated the indications for radical mastectomy. Although radical mastectomy is no longer of clinical utility, technically this is an easier procedure than modified radical mastectomy. After skin flaps are elevated as described for modified radical mastectomy, the pectoralis major muscle is divided just before it inserts on the humerus. The cephalic vein marks the level at which the pectoralis major muscle is separable from the deltoid muscle above.

In taking the origin of the pectoralis major muscle medially, perforating branches from the internal mammary vessels are seen. These are grasped and ligated, clipped, or electrocoagulated. If allowed to retract beneath the intercostal muscles, they could

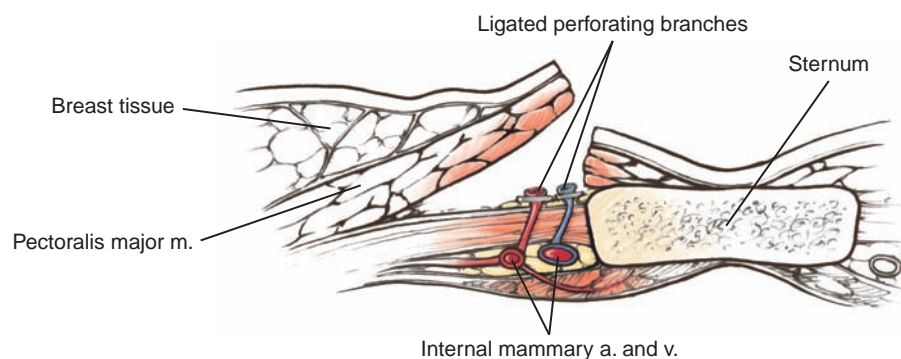


Figure 3.30

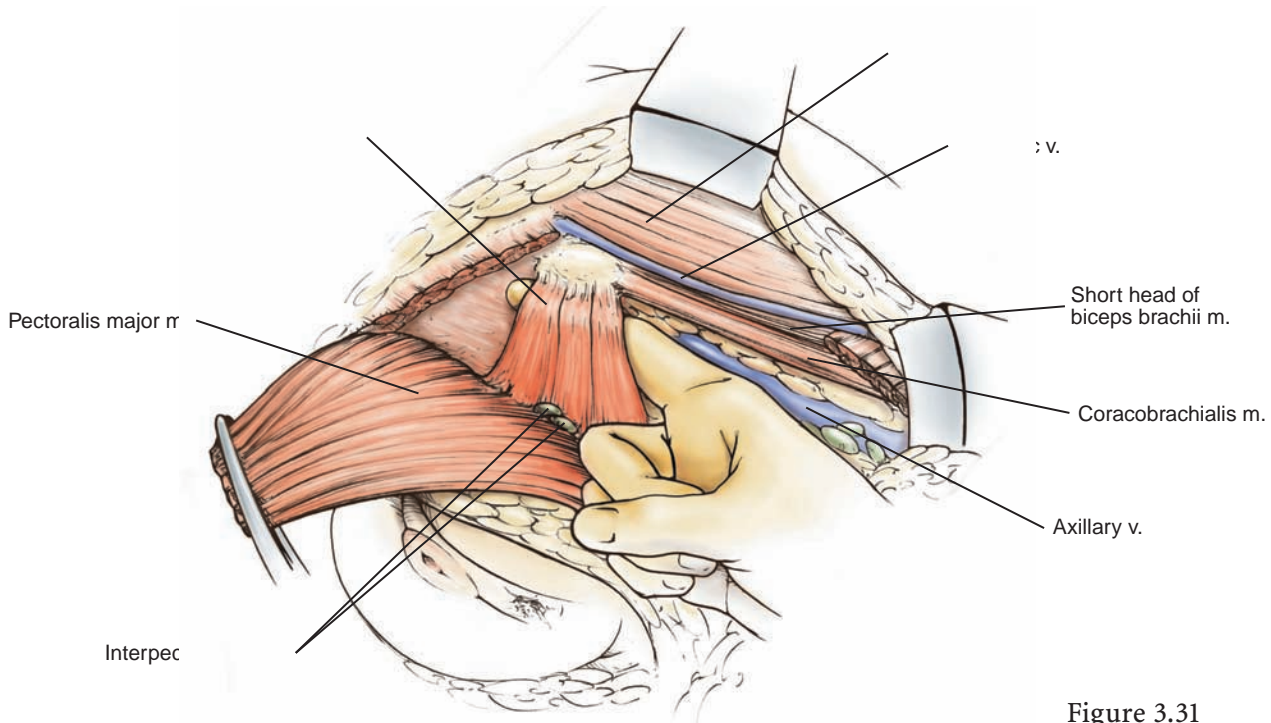


Figure 3.31

cause considerable hemorrhage in the subpleural space between the chest wall and the pleural cavity. Beneath the pectoralis major muscle, the clavipectoral fascia and pectoralis minor muscle are divided. Removal of the pectoralis major and minor muscles in addition to those structures incorporated in a modified radical mastectomy completes the procedure.

More commonly, a portion of the pectoralis muscle may need to be resected for those primary tumors or tumor recurrences that penetrate into the muscle layer. Again, this is an unusual finding but occasionally the operating surgeon will encounter extensive tumor growth.

Another indication for consideration of a radical mastectomy is for a primary sarcoma of the breast. Wide margins extending 3–5 cm around the tumor in some cases may necessitate chest wall en bloc resection.

Anatomic Basis of Complications

- Injury to long thoracic nerve results in a winged scapula.
- Too extensive resection of brachial lymphatic vessels results in increased risk for arm lymphedema.
- Injury to the thorocodorsal nerve weakens the latissimus dorsi muscle and leads to decreased ability for adduction

Major

Minor

- Injury to the medial pectoral nerves results in partial atrophy of the pectoralis major muscle.
- Total division of the intercostobrachial nerve results in numbness and dysesthesia under the arm.
- Axillary web syndrome: An axillary syndrome related to extensive lymphovenous disruption during axillary lymph-node or sentinel-node dissection. Occurs in some women who develop a palpable cord of subcutaneous tissue from the axilla down the ipsilateral arm in the postoperative period. This may often be relieved by early physical therapy.

Possible Causes of Lymphedema Following Axillary Dissection

- Too radical excision of lymphatic vessels, including those draining the arm
- Obesity
- Infection with scarring of the lymphatic vessels draining the arm
- Node dissection coupled with irradiation of the axilla
- Tumor involving and blocking lymphatic vessels

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Breast Reconstruction

Albert Losken and John Bostwick III†

Introduction

As the management of women with breast cancer continues to evolve, we have similarly noticed improvements in breast reconstructive options. The type of reconstruction varies depending on the extent of the defect, and generally involves either autologous tissue or implants. Breast reconstruction started becoming popular in the latter half of the twenty-first century, and since then numerous refinements have been made based on patient and surgeon expectations, improved technology (endoscopic and microscopic techniques, implants, and biomaterials), as well as a better understanding of the basic surgical anatomy. Attention to anatomical details have led to the development of modifications of older techniques to improve donor site morbidity while maintaining breast shape (i.e., muscle sparing flap techniques). These adaptations enhance outcomes not only from a cosmetic standpoint, but also from a functional one. The ultimate goal in breast reconstruction today is not only to create the most natural appearing, symmetrical breasts, but also to minimize any potential donor site sacrifice and maintain quality of life. A thorough knowledge and familiarity with surgical anatomy is critical to achieving these goals and to the successful execution of various reconstructive techniques.

Major advances in breast reconstruction over the years have come not only from improvements in surgical technique, but from changes in the principles and thought process in breast oncology as a whole. The mastectomy defects have been discussed earlier; however, the introduction of skin sparing techniques, which preserve important breast structures such as native breast skin and the inframammary fold has significantly improved the reconstructive options. Reconstruction becomes more of a filling procedure, relying less on tissue expansion or transferring large amounts of skin on autologous flaps, which does not often look as natural as the native breast skin. The inframammary fold is one of the few major breast landmarks, the preservation of which significantly improves symmetry and shape following breast reconstruction. This has been made possible in part by changes in the timing of breast reconstruction. Once it became accepted that reconstruction has no impact on breast cancer surveillance and was safe from an oncological standpoint, immediate reconstructions provided psychological, financial, and cosmetic advantages, and subsequently became the standard of care. Delayed reconstruction remains an option when reconstruction was not available or safe at the time of mastectomy, or when

† deceased

post-mastectomy radiation therapy is anticipated. Although the reconstruction then requires reconstruction of the IMF, breast volume, and soft tissue envelope, complication rates are less, and results are improved when compared to post-reconstruction radiation therapy. The type of reconstruction following total mastectomy essentially involves either implant or autologous tissue reconstruction, or a combination of both, which will be discussed in detail below.

Implants and Expanders

Expander-implant reconstructions are relatively short procedures with less recovery and no donor-site-related issues. Improvements in tissue expander technology, as well as implant materials have further enhanced cosmetic results. Factors influencing the use of this approach include patient desire, breast size and shape, quality of the overlying skin, the availability of autologous tissue, and general health of the patient. Patients who are ideal candidates for this type of breast reconstruction are thin with small-to-moderate-sized breasts without ptosis. Other candidates include bilateral reconstructions, or patients with contralateral breast implants. Breast contour is much easier to match than that seen in heavier women with large ptotic breasts. The operation is appropriate for a woman who has some ptosis or heaviness of the opposite breast if she is amenable to undergoing a procedure to modify the other breast. A thorough knowledge of the local breast anatomy is important when using these techniques.

Surgical Anatomy

The anatomic borders of the breast are from the second rib superiorly to the inframammary fold located at the seventh rib inferiorly, the lateral border of the sternum medially to the mid-axillary line laterally. Local muscles available for improved implant coverage include the pectoralis major muscle and the serratus muscle. Viability of the soft tissue skin envelope relies on preservation of the subdermal plexus, perforating vessels at the periphery, and length of the skin flaps. Consideration must be given to the normal or desired topographic position of the breast mound, and the devices must be positioned to give the most natural appearance. Achieved by attention to lower-pole projection with various anatomically shaped tissue expanders, or anatomically shaped implants, and better soft tissue coverage achieving better symmetry and a more natural contour. When the skin coverage is thin, certain implants such as the silicone-type cohesive gel devices might provide better results.

If an immediate reconstruction is being performed, the implant can be placed through the mastectomy incision. When the mastectomy scar is not in the best location, a small incision can be made near the new inframammary crease and the implant or expander placed through this new incision. When implant or expander reconstruction is used, the implants and expanders are usually placed beneath the chest wall musculature, that is, the pectoralis major muscle and serratus anterior muscle. Sometimes the lower portions of the breast implant are covered with the fascia of the external oblique muscle and the rectus abdominis muscle. When oncologic requirements permit, the external fascia of these muscles is maintained to provide an additional layer of cover for these devices. This muscle and fascia cover protects the breast implant from exposure through overlying thin skin, especially during immediate breast reconstruction. It also appears to protect the device from capsular contracture.

Surgical Applications

A two-staged reconstruction is more common as this minimizes tension on tenuously perfused skin flaps, and allows controlled creation of the skin envelope and pocket once the incisions have completely healed. The second procedure will then allow a more scientific selection of implant type and size (based on base width, projection, and volume), as well as minor adjustments in pocket size, location, and inframammary fold when necessary.

The location of the inframammary fold, medial and lateral breast borders are marked preoperatively. The tissue expander selected should be based on breast width, height, projection, and shape of the desired breast, and is typically contoured with an integrated port. The placement is either through the old mastectomy scar in delayed reconstructions, or through the mastectomy incision (typically periareolar) in immediate reconstructions.

Various options exist for coverage of the tissue expander. The most common approach today is to create a subpectoral pocket by dividing the pectoralis major muscle inferiorly and releasing laterally to provide coverage of the upper two-thirds of the expander with muscle. The muscle is released medially to the parasternal region not being detached from the sternum. The muscle is then either sutured to the lower mastectomy skin flap, or more recently sutured to a piece of allogenic dermal material such as Alloderm (Lifecell, Branchburg, NJ) which is then sutured to the IMF and lateral mammary fold. This prevents the muscle from window-shading superiorly and places vascularized muscle beneath the mastectomy incision. It also allows more lower-pole expansion especially at the time of mastectomy. When necessary, the IMF is recreated by internally suturing the dermis or superficial fascia back down to the muscular fascia of the chest wall with permanent sutures. Other options include complete submuscular placement by positioning the expander beneath the

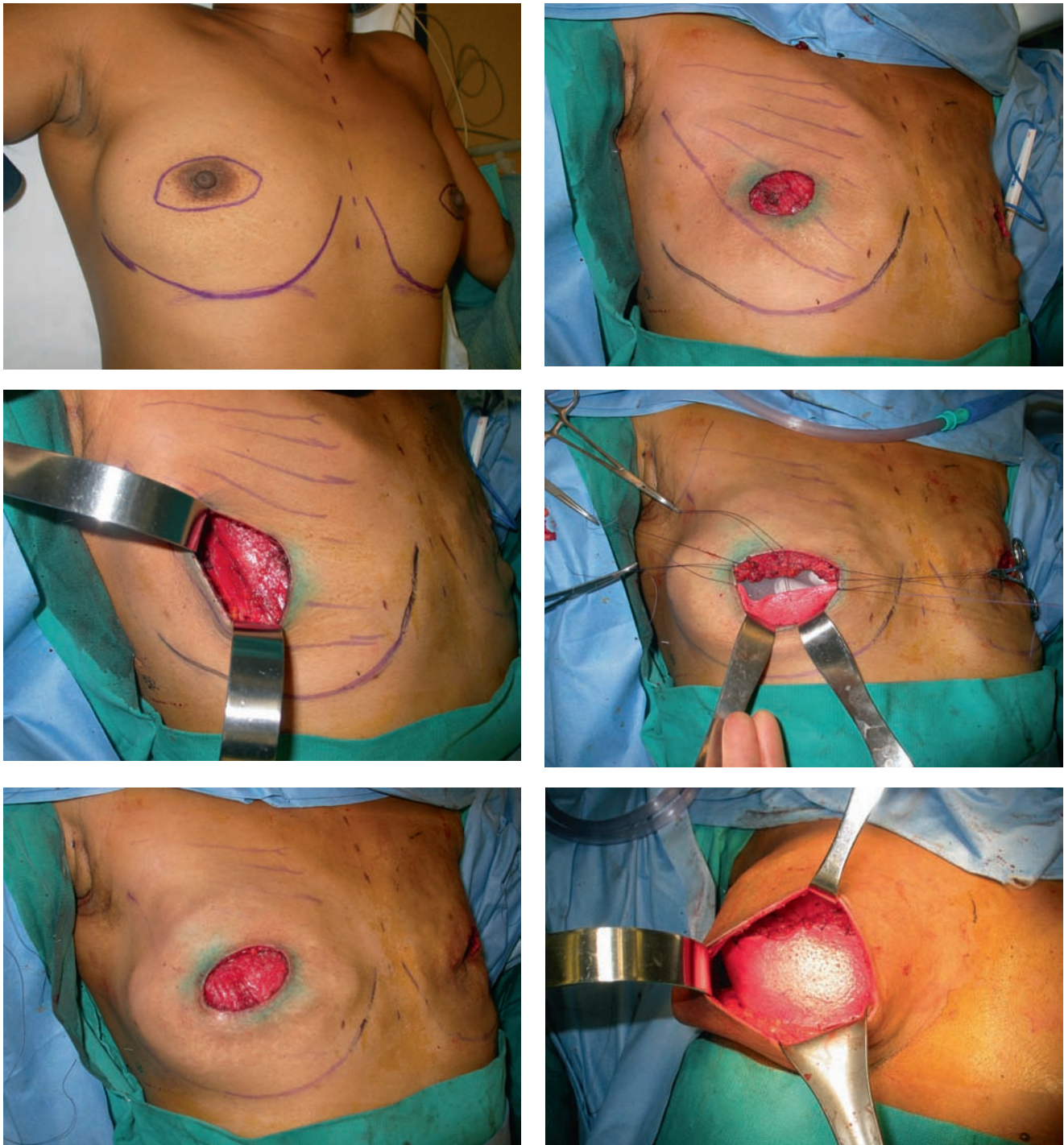


Figure 3.32a

pectoralis and serratus muscle and releasing the pectoral origins deep at the IMF to allow lower pole expansion.

Delayed reconstruction involves access through the lateral mastectomy scar, with dissection to the lateral margin of the pectoralis major muscle. The skin is elevated superiorly and inferiorly to expose a segment of the pectoralis major muscle.

The pectoralis major muscle is split in the direction of its fibers, and lifted from its underlying attachments with blunt finger dissection. A lighted retractor is useful

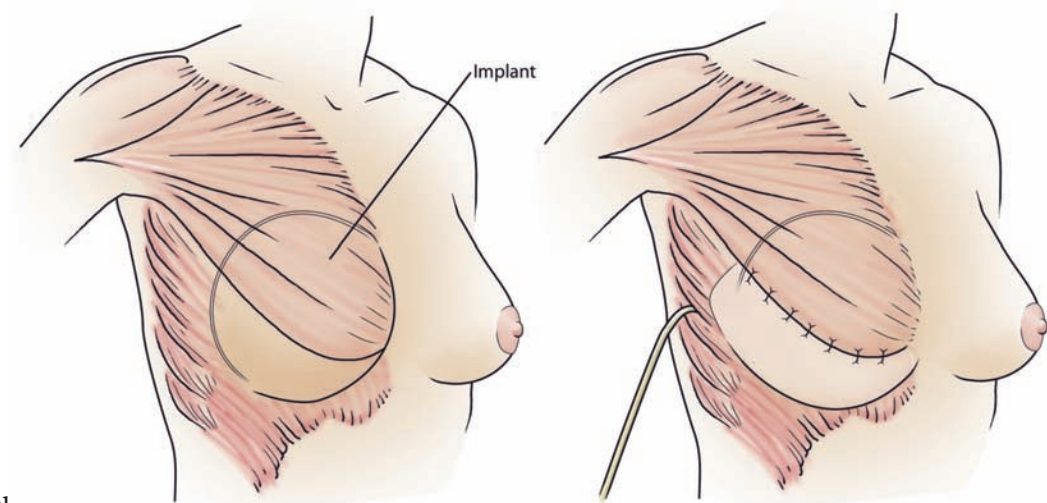


Figure 3.32b

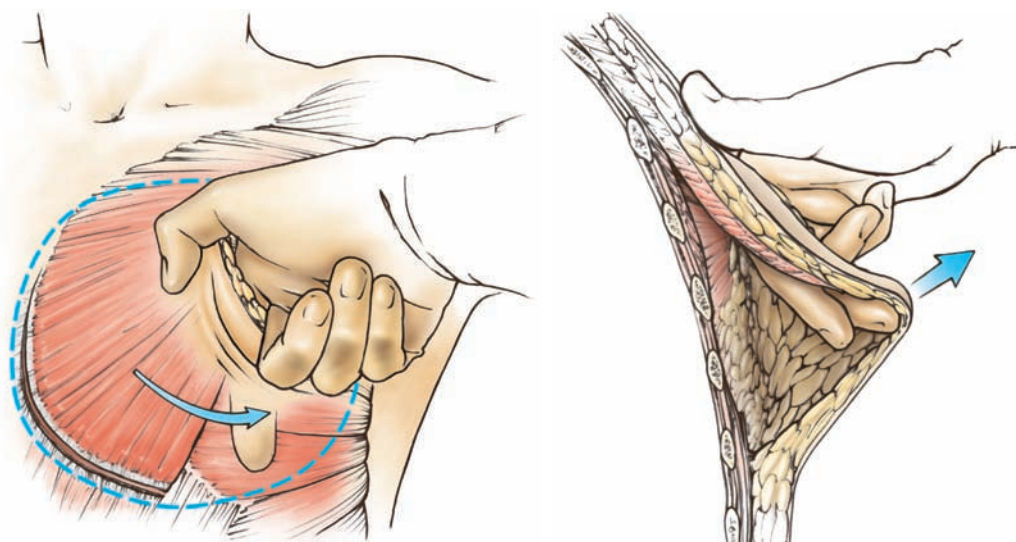
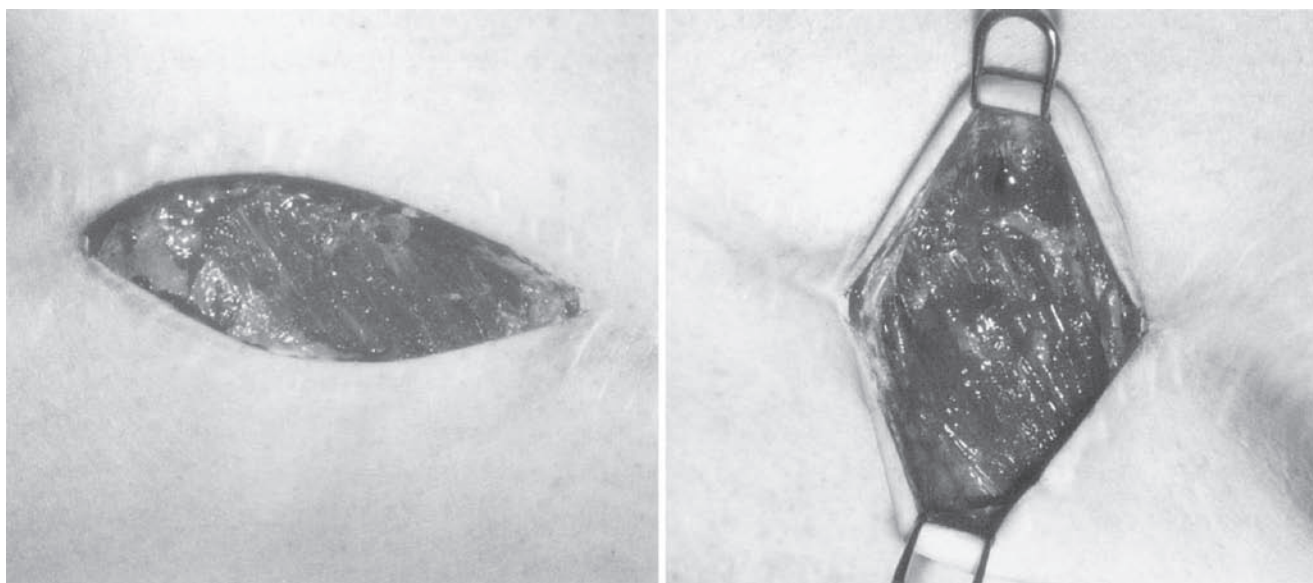


Figure 3.33

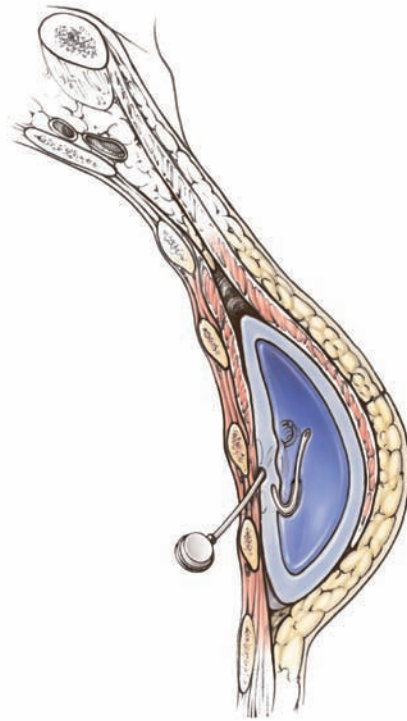


Figure 3.33

at this point for dividing the origins of the pectoralis major muscle from the second rib down to the new inframammary crease. The inferior dissection is most critical. It is essential to free any tight restricting cicatrix in the lower breast region so there is less resistance to expansion than encountered in the upper portion. Dissection then swings laterally to lift the mastectomy skin off the lateral fascia. The upper dissection is completed by elevating the upper fibers of the serratus anterior muscle and its attached fascia.

The contoured tissue expander is then position in the proposed position of the desired breast mound. The muscular layer is then closed, followed by alignment of the skin incision. The final volume is adjusted in the postoperative period. Following slight overexpansion, the second stage (typically 1 month following final expansion) then involves removal of the expander, and placement of the permanent implant. Implants vary in surface texture (smooth and rough), shape (round and contoured), and filler material (saline and silicone). Smooth round silicone gel implants are the most common device employed, and adjustments in implant pocket are made. The IMF is often recreated at this stage to improve breast ptosis providing a more natural lower pole and a less round and flat appearance. Newer implants with more projection also contribute improved outcomes and are chosen based on breast size, shape, and chest wall dimensions. Contralateral breast shape adjustments can be performed as needed to improve symmetry, and most commonly consist of implant augmentation. The nipple is reconstructed using local skin flaps either at the time of implant exchange, or as a later procedure under local in the office.

Results

This is a 39-year-old female with bilateral mastectomy defects, reconstructed with a temporary tissue expander placed beneath her pectoralis muscle superiorly and a piece of alloderm attached to the inframammary fold. The final result is 1.5 years following completion of reconstruction which involved exchange of the expanders for moderate profile gel implants. She deferred nipple reconstruction for areolar tattoo.

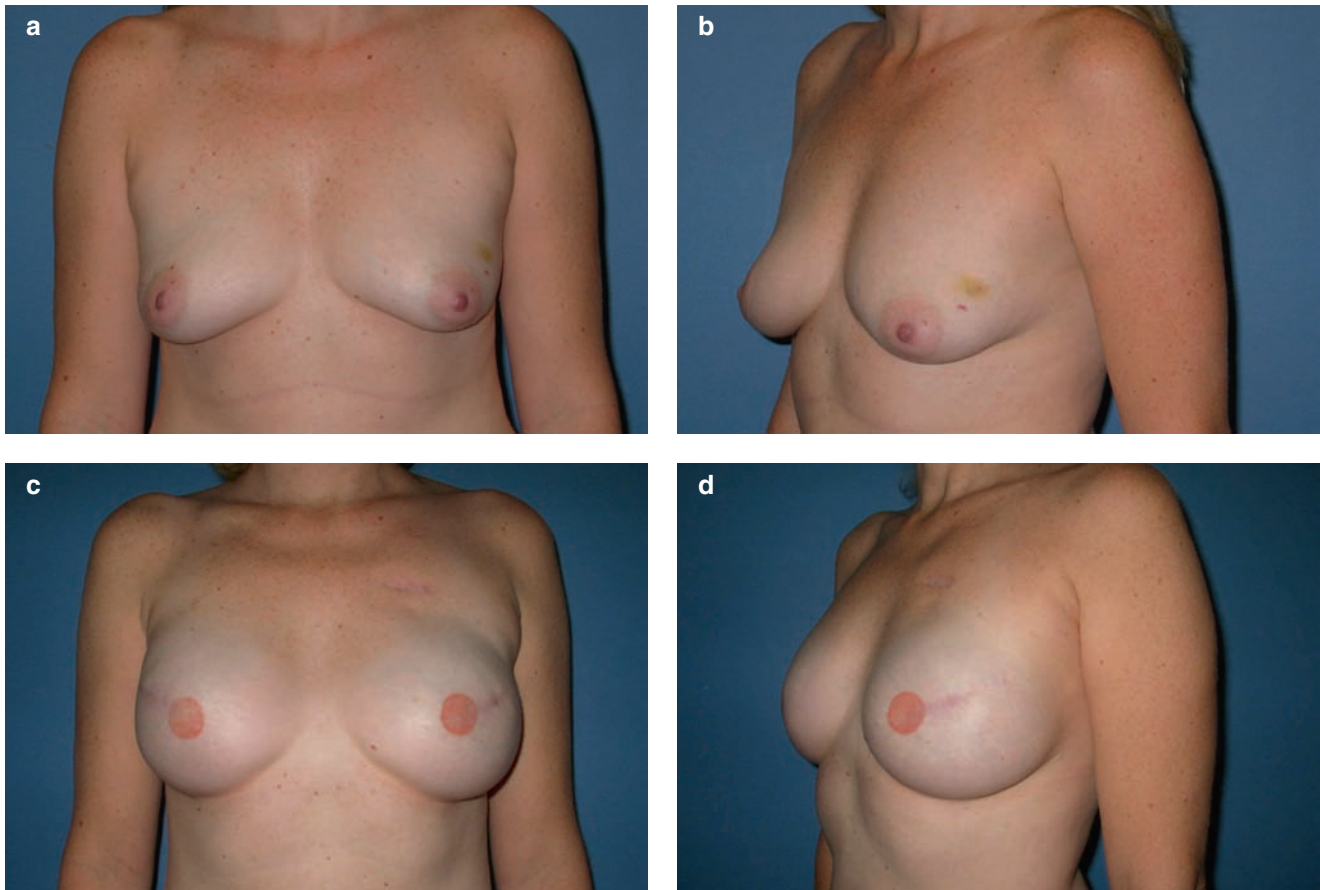


Figure 3.34

Latissimus Dorsi Flap

The latissimus dorsi flap was the first major musculocutaneous flap used for breast reconstruction. The flap provides muscle, subcutaneous tissue, and skin coverage, and is particularly useful for providing a layer of vascularized tissue over the expander, and replacing the previous nipple with skin from the back. This along with the skin-sparing type mastectomy preserves breast shape, and gives healthy tissue with which a nipple can be reconstructed at the secondary stage. When the

patient has excess back tissue and does not require a large breast reconstruction, additional subcutaneous tissue in the subfascial plane can be harvested from the back for autologous tissue breast reconstruction. The latissimus dorsi flap is often not enough volume to reconstruction the breast mound and small implant are usually required.

The latissimus dorsi muscle is a broad, flat muscle on the posterior chest wall that originates over the posterolateral thorax, overlies the tip of the scapula superiorly, extending in to the axilla joining with fibers of the teres major muscle to form the posterior axillary fold. It is overlain by the trapezius muscle in the superomedial corner, and thins into the aponeurosis that joins the lumbosacral fascia along the back medially. The muscle then extends down to the iliac crest, fusing with fibers of the external oblique and intercostal muscles of the lower 3–4 ribs laterally. The surgeon should also be familiar with the anatomy of the insertion of the latissimus dorsi muscle, which is through a 3-cm broad tendon attached to the bottom of the intertubercular groove of the humerus.

Surgical Anatomy

The blood supply to the latissimus dorsi is constant, and based on the thoracodorsal artery. The subscapular system arises from the axillary artery giving two branches: the thoracodorsal artery and the circumflex scapular artery. These are usually spared with axillary lymph-node dissections (not the case after radical mastectomy). The thoracodorsal artery has a relatively large diameter, 1–2.5 mm. An intramuscular vascular pattern radiates from the thoracodorsal pedicle to nourish the latissimus dorsi flap. Successful latissimus dorsi flap reconstruction, both primary and secondary, depends on the reconstructive surgeon's knowledge of this intramuscular branching of the thoracodorsal artery. The primary intramuscular vessel courses vertically in the same direction as the pedicle, approximately 3 cm inside the lateral edge of the latissimus dorsi muscle. The intramuscular network, radiating from the entrance of the thoracodorsal pedicle into the latissimus dorsi muscle 9–11 cm below the axillary artery, permits splitting the latissimus dorsi into two or three muscle strips to support several skin islands if these are needed for specialized secondary procedures. The largest perforating vessels branch from this primary vessel; therefore, verticalolateral orientation of the latissimus dorsi flap provides the safest skin island. Several other major branches extend in a radial manner from the primary pedicle. The intramuscular branching pattern permits division of the latissimus dorsi muscle while preserving the proximal blood supply and the integrity of the musculocutaneous unit. A collateral pedicle from the serratus anterior fascia is also usually preserved and is a constant vessel in this region. The latissimus dorsi flap can survive on this vessel when the thoracodorsal pedicle has been injured or divided. The flap can be harvested either laterally or transversely for a variety of flaps that can be customized to replace the tissue needed for the reconstructed breast. Patient selection is important when using the latissimus dorsi flap. If there is severe radiation damage of the axilla there may be some concern about the patency of the thoracodorsal pedicle and the ultimate vascular nourishment of the flap.

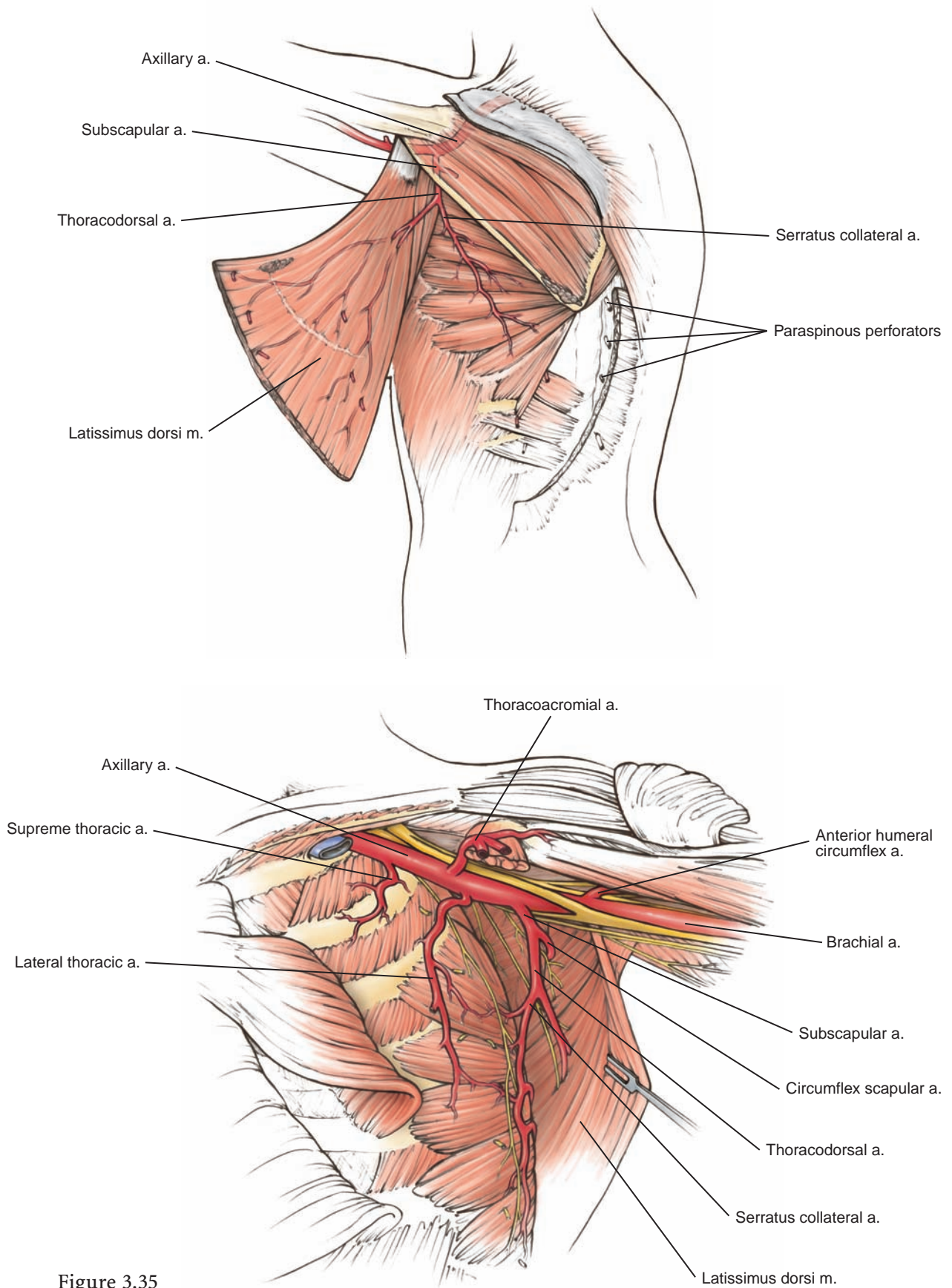


Figure 3.35

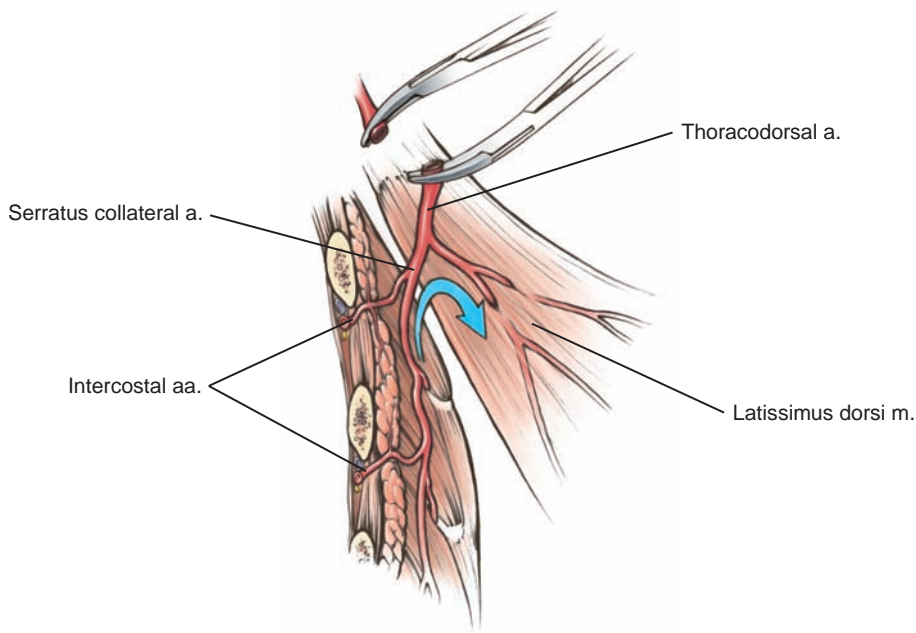


Figure 3.35

The thoracodorsal nerve, arising from the C6–8 roots of the posterior cord of the brachial plexus, is the motor nerve to the latissimus dorsi muscle. This nerve along with the thoracodorsal vessels passes downward through the axilla and enters the muscle with the thoracodorsal vascular pedicle. The thoracodorsal nerve is responsible for muscular contraction of the latissimus dorsi muscle. If this muscle contraction is a problem to the patient after latissimus dorsi flap reconstruction, it can be divided during a secondary procedure. This division paralyzes the muscle and induces denervation atrophy of the latissimus dorsi muscle without compromising the blood flow to the flap through the muscle and skin island as long as the collateral vessels from the serratus anterior muscle are preserved.

The latissimus dorsi flap with or without implant is ideal for women with relatively small-to-moderate-sized, round breast with no or minimal ptosis, who are not candidates for abdominal flap reconstruction. This procedure is able to match a natural-appearing contralateral breast, or one which is augmented. This flap has a vigorous, extremely reliable blood supply, and which allows it to be used safely even in smokers. The latissimus dorsi is also an ideal flap for reconstructing the partial mastectomy defect, and can be used as a salvage for failed TRAM flap reconstruction. In some patients undergoing lumpectomy plus radiation therapy the defect is large relative to the breast size or a large breast parenchyma resection is necessary to adequately remove the breast cancer. For these patients, after determination that the tumor is completely excised, endoscopic harvest of the latissimus dorsi muscle and its overlying subcutaneous tissue is also a possibility to provide fill for the breast defect through the axillary lymph-node dissection incision. This living tissue is usually radiolucent on mammograms and does not present problems for patient follow-up.

Surgical Applications



Figure 3.36a

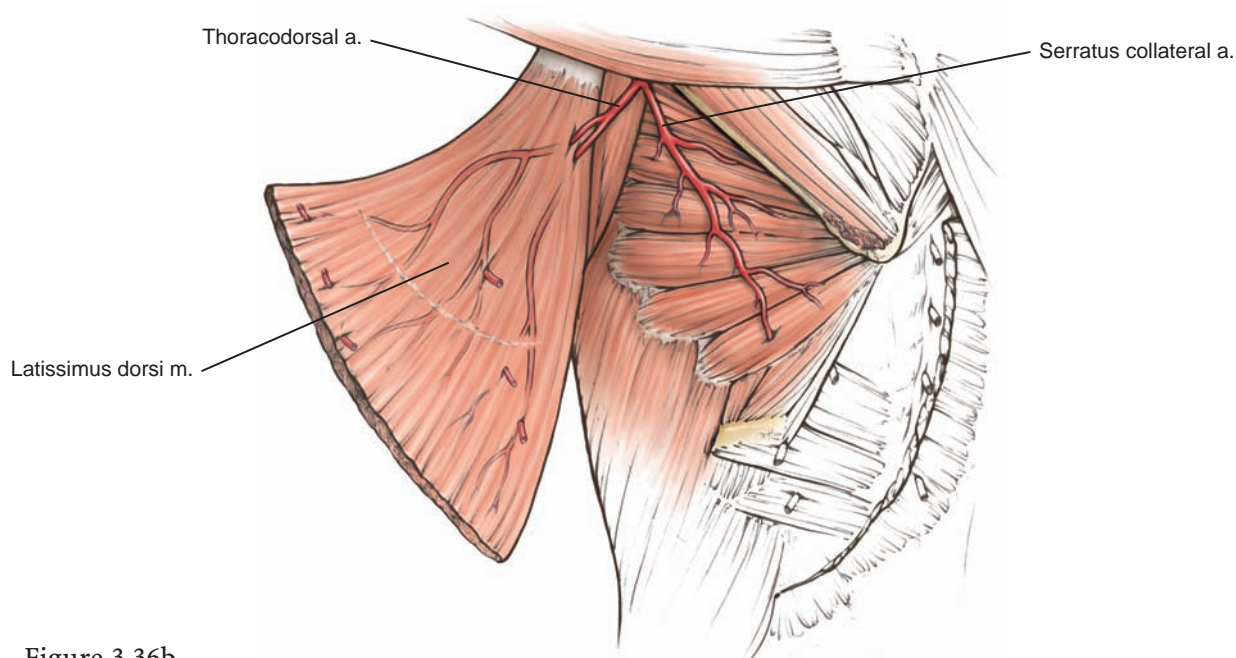


Figure 3.36b

The patient is marked preoperatively in the standing position. The limits of the entire latissimus dorsi muscle are marked, as well as the IMF and lateral breast border. The skin island can be oriented in almost any direction depending on the soft tissue requirements and defect location. The most favorable scar is orienting the skin island as an ellipse within the relaxed skin tension lines located in the center of the muscle.

After completion of the skin-sparing mastectomy, the dissection is started anteriorly with the patient supine. The latissimus dorsi muscle is then identified high up in the axilla, staying at first on top of the muscle. The thoracodorsal pedicle is then dissected just deep to the muscle, and protected. The submuscular plane is then opened inferiorly to make the flap harvest easier. It is important at this point to preserve the lateral breast border, and not undermine the skin bridge between the anterior border

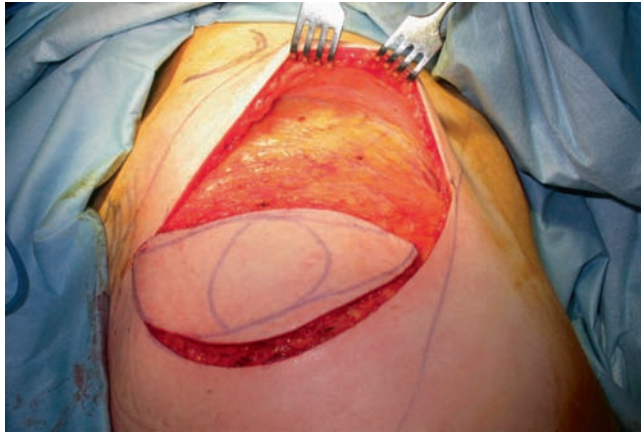


Figure 3.36c

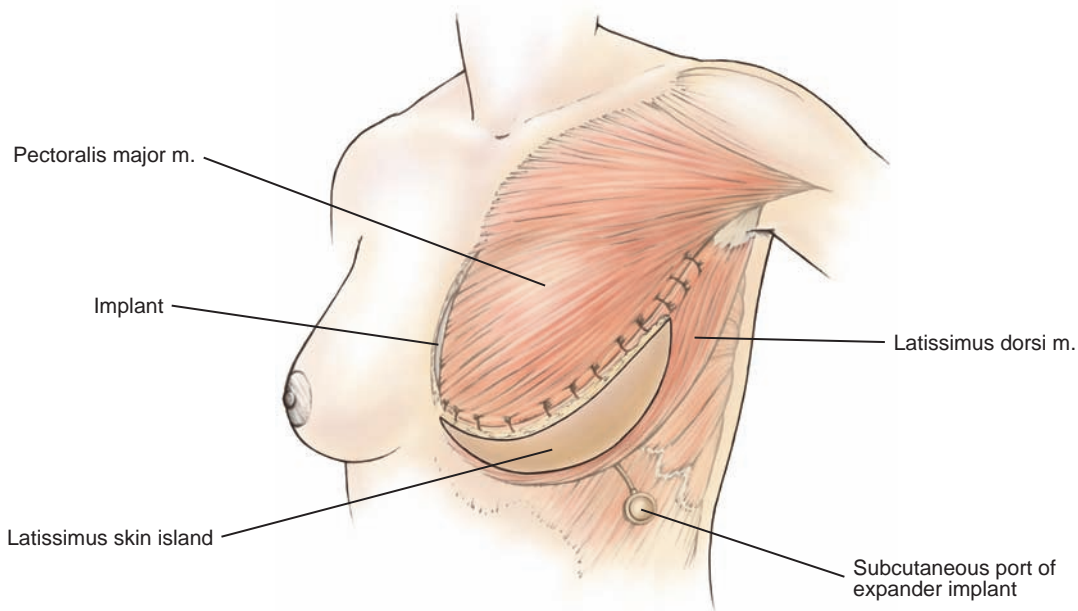


Figure 3.36d

of the muscle and lateral breast boundary. The skin is then covered anteriorly with a dressing, and the patient is repped and draped in either the lateral decubitus or prone position. Posterior dissection begins by incising the skin island and dissecting down to and through the deep thoracic fascia. Preserving the subfascial or deeper fat on top of the muscle will provide an additional layer of protection between the implant and the skin. This volume added latissimus dorsi flap also allows for a smaller implant to be used and providing a more natural-appearing breast.

Once the flaps have been developed appropriately, the deep layer of fat is divided exposing the latissimus muscle. The superior border of the latissimus is divided, separating the fibers from the teres major muscle. The muscle is then elevated off the chest wall keeping the serratus muscle down. The flap is passed into the breast pocket, and the back is closed over suction drains. The patient is then repositioned, and in a supine position the humeral insertions is taken down about 90%. A contoured tissue expander is placed above the pectoralis muscle, and the latissimus dorsi flap is

draped over the expander and sutured circumferentially. The additional coverage on the muscle will soften the peripheral margins of the mastectomy defect. The flap is inset by suturing a shaped skin island (usually circular) to the mastectomy flaps.

The second stage occurs following completion of expansion and typically includes expander removal, placement of a permanent implant and nipple reconstruction.

Results

This is a 36-year-old woman who presented with a T2 N1 left-sided breast cancer, who underwent bilateral skin-sparing mastectomies. She was interested in relatively small natural looking breasts and a decision was made to perform immediate reconstruction using bilateral latissimus dorsi myocutaneous flaps with expanders. The

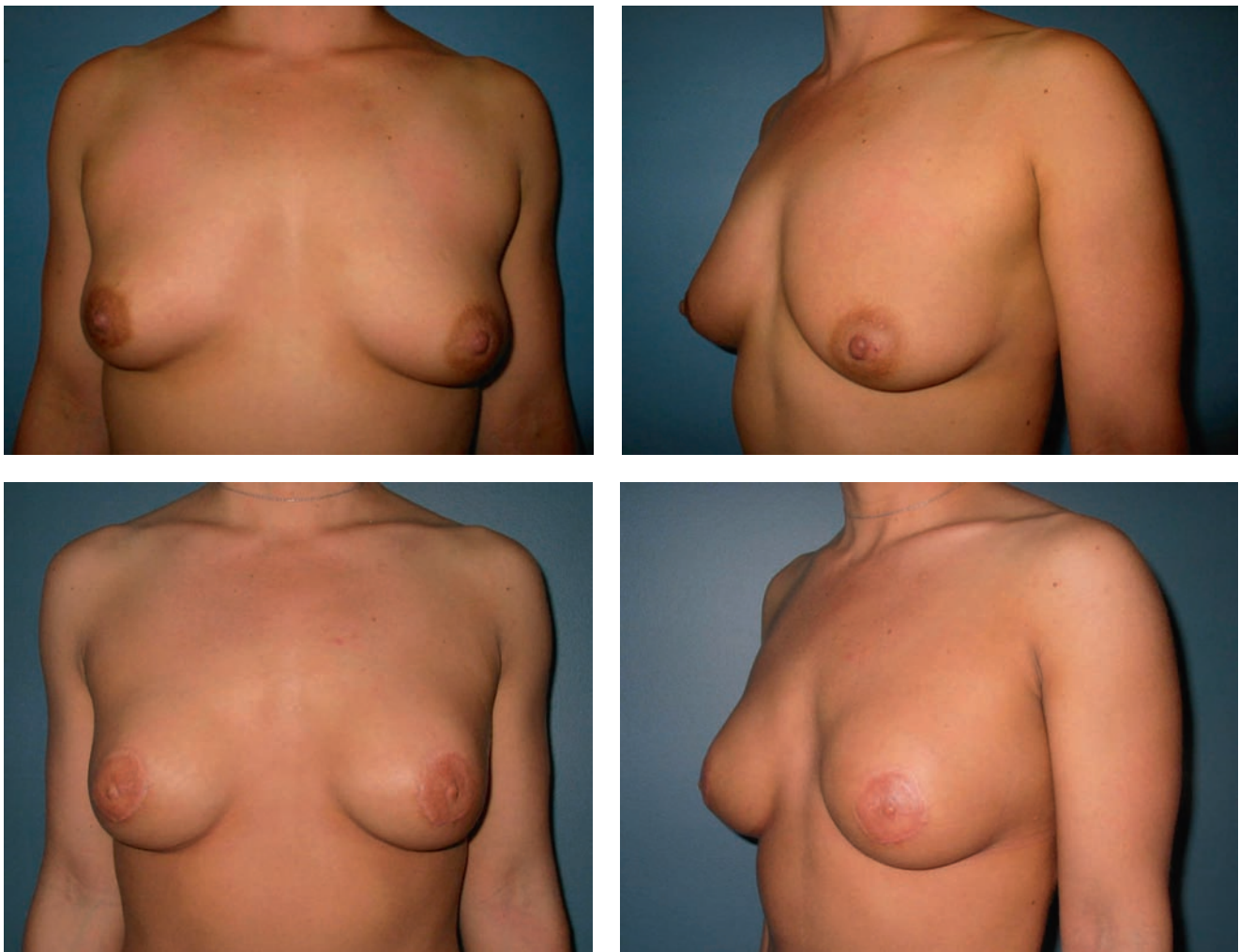


Figure 3.37

expanders were sized appropriately and eventually exchanged for 175 mL smooth, round, moderate profile plus gel-filled implants at the time of nipple reconstruction. Her result at 4 years following mastectomy demonstrates favorable symmetry and shape.

Transverse Rectus Myocutaneous (TRAM) Flap

The lower abdominal flaps are still a very popular autologous option for breast reconstruction. Since introduced by Hartrampf in 1982, these flaps have undergone numerous refinements made possible in part due to better understanding of the surgical and vascular anatomy. The pedicle transverse rectus abdominus myocutaneous (TRAM) flap in patients without risk factors (smoking, obesity, abdominal scars, HTN, radiation therapy) is able to reliably support two zones. Additional options available that might improve the reliability of the pedicled TRAM flap options include adding a second pedicle (bipedicle TRAM flap), adding flow through the inferior epigastric system (“supercharged” TRAM flap), incorporating more periumbilical perforators (midabdominal TRAM), or improving blood supply through vascular delay (TRAM flap with preoperative delay). These techniques improve perfusion to the flap, reducing the incidence of fat necrosis and partial flap loss in high-risk patients, or in situations where more than two zones are required. However, there has been a recent trend toward taking less abdominal tissue in an attempt to improve donor morbidity, while maximizing perfusion to the flap. Studies have shown that the dominant blood supply to the rectus abdominus muscle came from the deep inferior epigastric artery (Boyd and Taylor 1984). Using the inferior epigastric system requires microvascular transfer, however, improves the vascularity of the skin island allowing for a larger more reliable flap. The free TRAM flap became a useful option for high-risk patients, and has become the procedure of choice in some institutions where microsurgery has been embraced, where flap failure rates are as low as 1–2%.

The main drawback to free TRAM flap is the microsurgical expertise required, longer operating times, as well as the risk of complete flap loss. However, in addition to improved flap perfusion, proponents of free TRAM surgery report improved donor site morbidity as well as preservation of the IMF. In an attempt to further reduce the risk of abdominal hernia, bulge, weakness, or loss of function related to full muscle harvest, the introduction of muscle-sparing free TRAM flaps and then rectus muscle and anterior rectus fascial-sparing perforator flaps (deep inferior epigastric perforator flap DIEP, and superficial inferior epigastric perforator flap SIEA). These perforator flaps have a relatively steep learning curve, longer dissection times, and require that the perforators coming through the abdominal wall be of adequate size to support the flap.

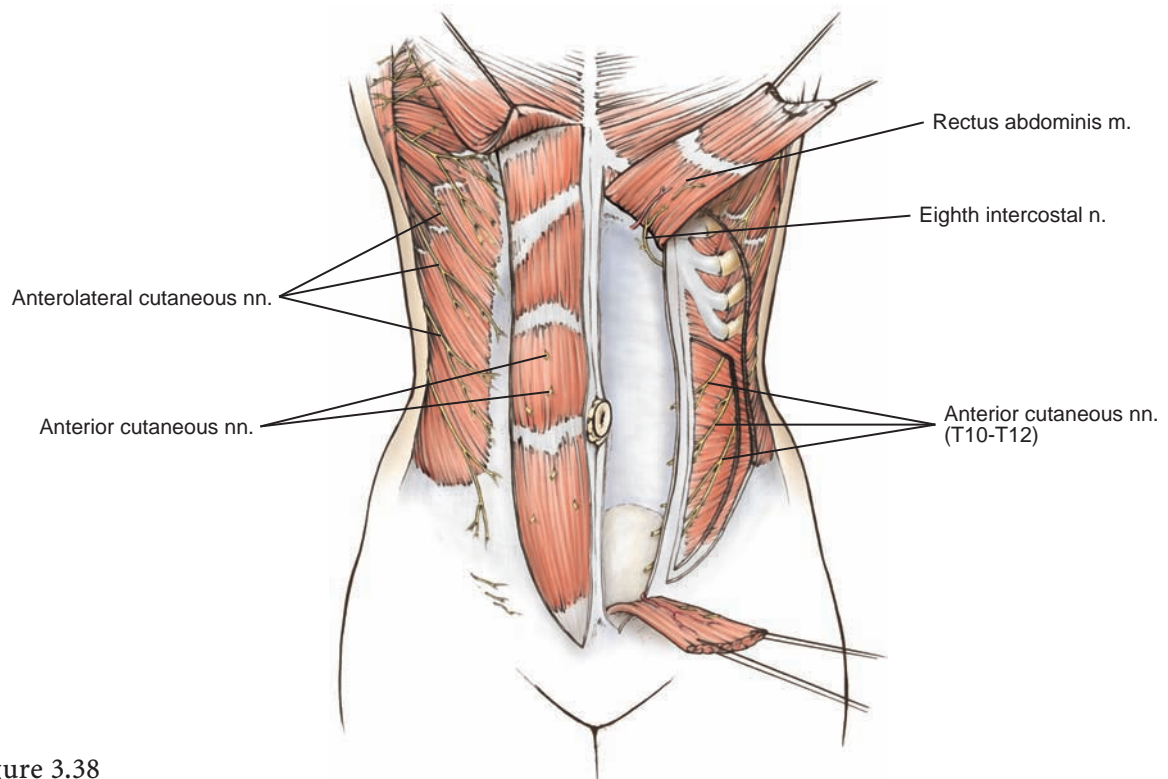


Figure 3.38

Surgical Anatomy

The lower abdominal skin and fat is well-perfused by perforators from the vertical epigastric system. Successful TRAM flap harvest requires attention to anatomic details, careful patient selection, and appropriate perioperative management. This vertical epigastric vascular system provides the major source of blood supply to the rectus abdominis muscle and the overlying musculocutaneous territories of the anterior abdominal wall.

The superior epigastric artery, a terminal branch of the internal mammary artery, nourishes the superiorly based (pedicled) TRAM flap. Musculocutaneous perforating arteries extend from the vertical epigastric system within the rectus abdominis muscle and pass through the anterior rectus sheath, providing nourishment for the skin and subcutaneous tissue of the anterior abdominal wall. These perforating vessels branch into axially coursing vessels that are primarily located above the superficial layer of the abdominal wall fascia and are especially concentrated in the subdermal plexus. In the upper abdomen these vessels supply the primary flow into the thoracoepigastric flap, with the subdermal plexus providing significant collateral flow. The inferior epigastric system is dominant and provides increased flow through these perforators since the angiosomes (skin territories) are closer to the source.

Axial vessels branching from the direct periumbilical rectus abdominis muscular perforators nourish the lateral extensions of the TRAM flap that are not directly over the rectus abdominis muscle. A rich vascular network and interconnected vessels branch in the subcutaneous tissues across the midline of the abdomen. The vascular network is present primarily at the level of the subdermal plexus and communicates

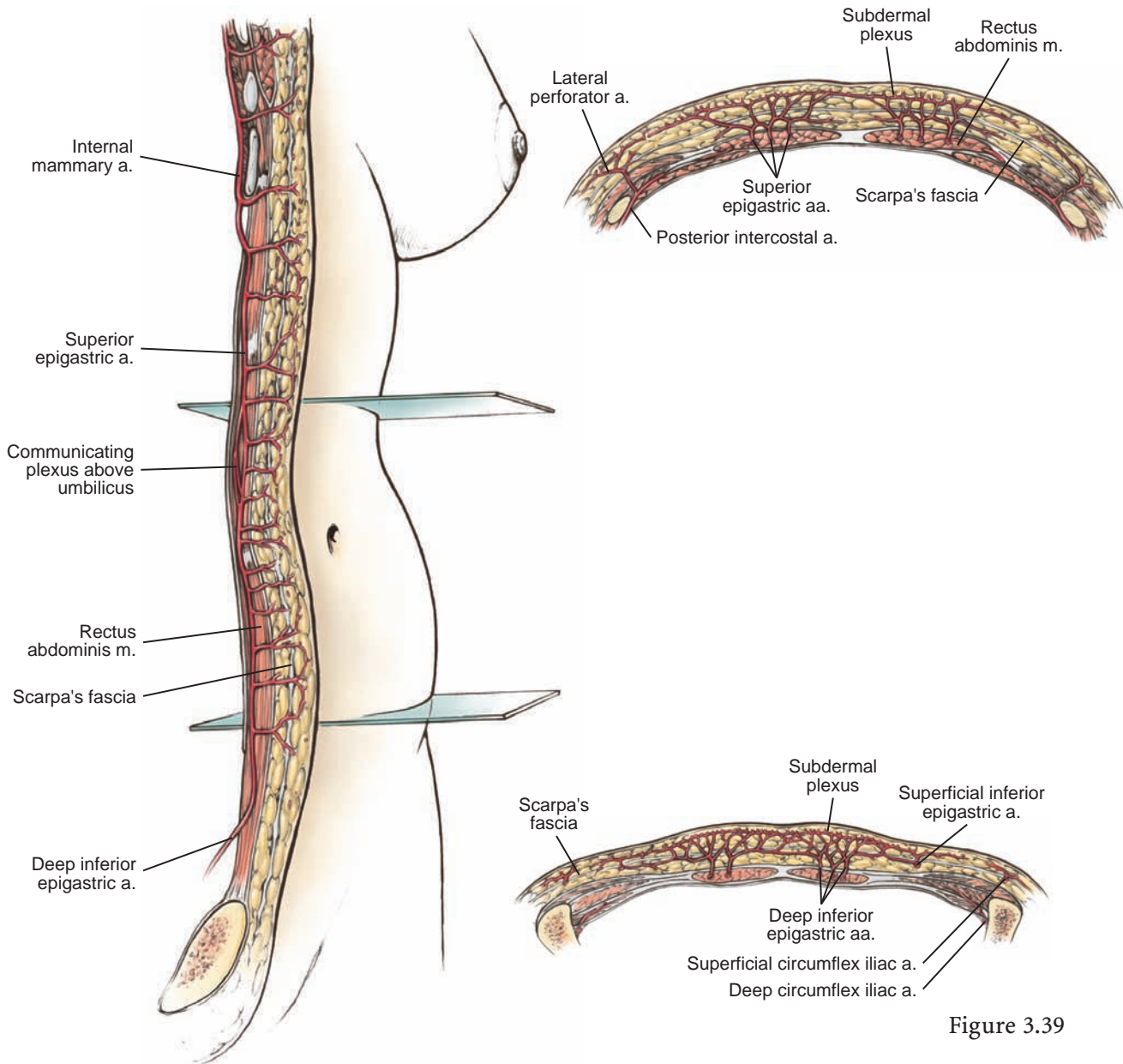


Figure 3.39

with the axial vascular system and subdermal plexus of the contralateral anterior abdominal wall, providing flow to the skin on the contralateral side. TRAM flap elevation across the entire anterior abdominal wall laterally to the anterior axillary line is dependent on this collateral flow and that of the subdermal plexus across the midline into the opposite sides of the abdominal wall subcutaneous vascular network.

The TRAM flap procedure provides autologous tissue for breast reconstruction. With this procedure, a woman's breasts can be restored with her own, sometimes abundant abdominal tissues, with the added benefit of abdominoplasty. The lower abdominal wall skin replaces large portions of missing breast skin, and autogenous lower abdominal wall fat is used for the missing breast parenchyma, obviating the need for breast

Surgical Applications

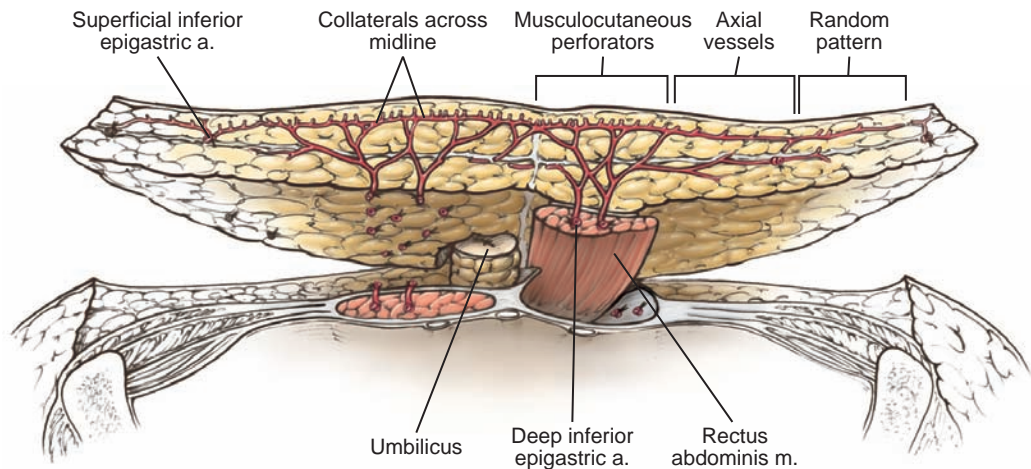


Figure 3.40

implants with their associated concerns. Many patients need autologous tissue breast reconstruction for a satisfactory result; others choose this approach to avoid breast implants. In addition to a thorough knowledge of the surgical anatomy of the TRAM flap and abdominal wall, this procedure takes an aesthetically experienced eye and judicious shaping of the flap to produce the expected result.

Pedicle TRAM

Following completion of the mastectomy, the transverse abdominal is made above the umbilicus, and the abdominal flap is elevated over the costal margin toward the area of the tunnel. If flap closure is too tight, the lower incision can be moved upward on the abdominal wall. The dissection extends 3–4 cm above the costal margin through the center of the IMF to create the tunnel. The ipsilateral TRAM island flap seems to have improved venous drainage and preserves the central IMF anatomy. The myocutaneous perforators are identified and a strip of fascial is preserved over the rectus muscle. The deep inferior epigastric vessels are ligated, and the flap is elevated either using the entire rectus muscle, or in a muscle-sparing fashion using only the area with the vascular pedicle. Flap inset is either vertical or horizontal depending on the breast size and shape. The unreliable zones and subcarpas fascial are excised when possible. The breast is shaped with the vertical-mound-shaping technique. The upper flap is buried and de-epithelialized to give upper breast fill. A small portion of the flap is turned under and de-epithelialized to give some lower projection and ptosis.

The rectus sheath is closed with a running Prolene stitch, with care taken below to arcuate line to ensure closure of both anterior and posterior layers of the rectus sheath laterally. Mesh reconstruction is often required for bilateral muscle harvest or when closure is too tight.

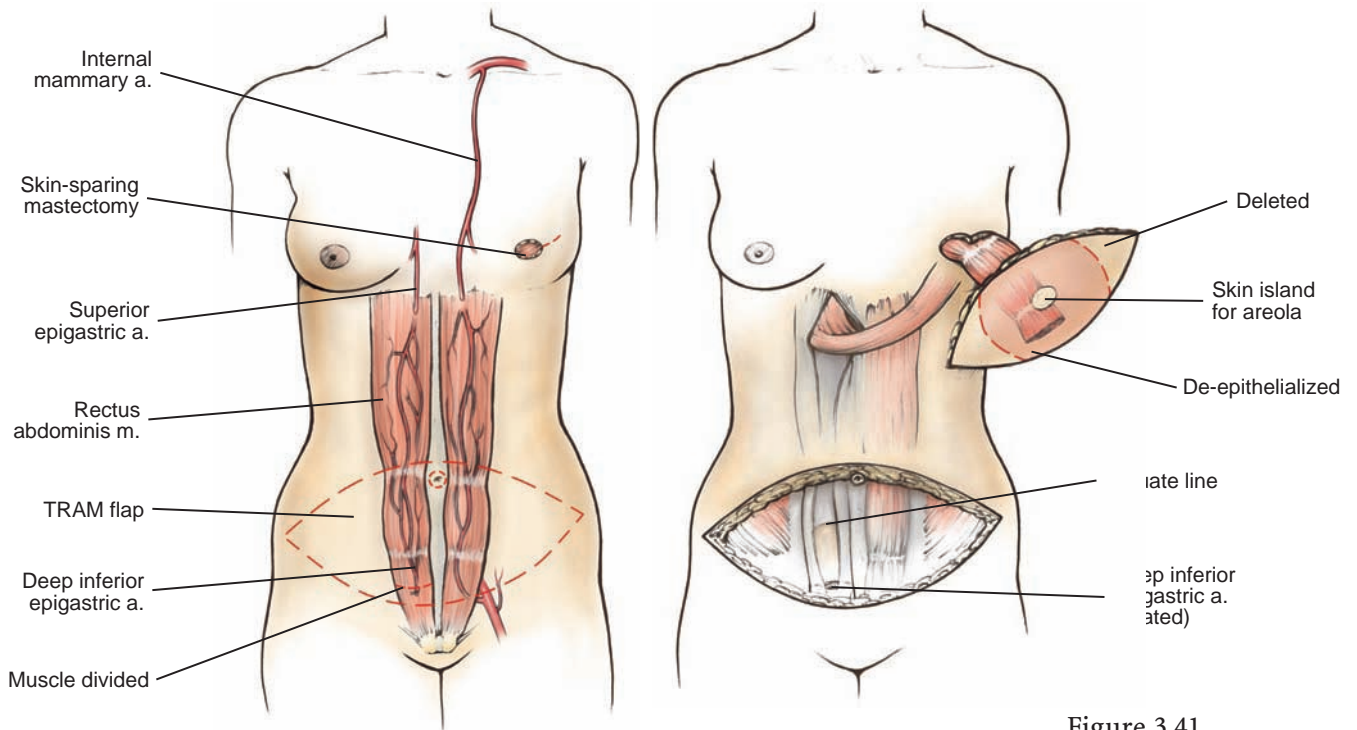


Figure 3.41

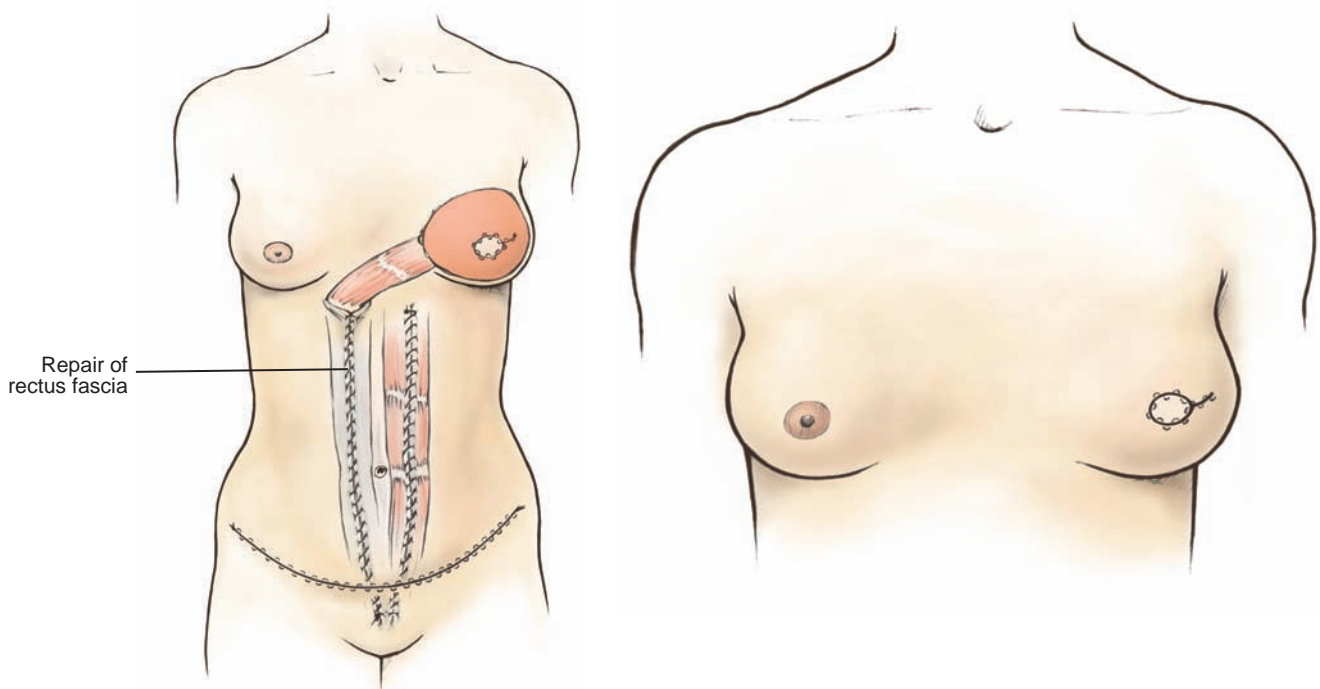


Figure 3.42

An opposite plication vertically over the rectus fascia further tightens the abdominal wall, flattens the umbilicus, and gives better abdominal symmetry.

Free TRAM

The free TRAM flap is elevated in the usual fashion until the perforators are identified. The dissection then differs based on technique and size of perforators. Various amounts of muscle and fascial can be harvested, as classified by Nahabedian:

Muscle-sparing technique	Definition (rectus abdominus)
MS-0	Full width, partial length
MS-1	Preservation of lateral segment
MS-2	Preservation of medial and lateral segment
MS-3 (DIEP flap)	Preservation of the entire muscle

Adapted from Nahabedian MY, Tsangaris T, Momen B. Breast reconstruction with the DIEP flap or the muscle-sparing (MS-2) free TRAM flap: Is there a difference? *Plast Reconstr Surg.* 2005 Feb;115(2): 436–444; discussion 445–456.

With the muscle-sparing procedure the lateral intercostal nerves are often preserved along with as much muscle and fascia as possible contributing to a lower incidence of abdominal wall deformity and dysfunction. The deep inferior epigastric

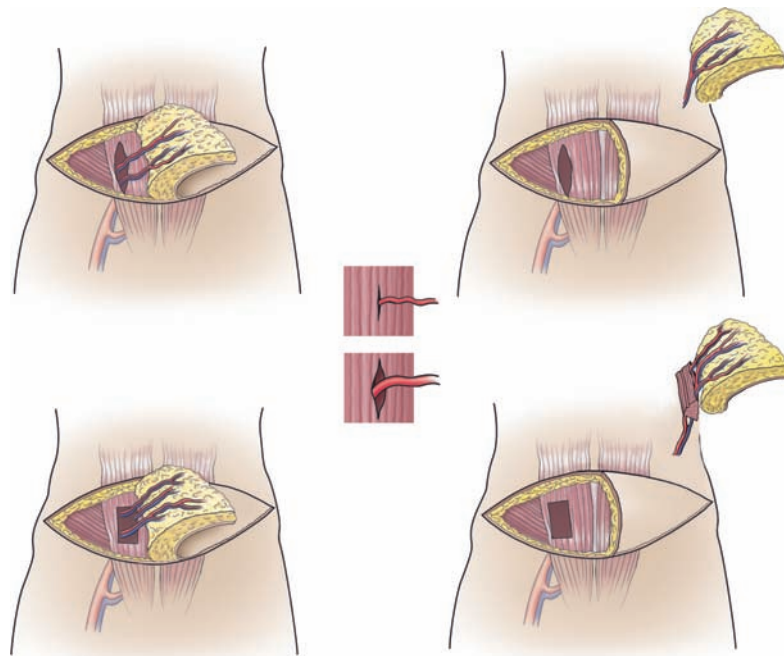


Figure 3.43

artery and vein are then dissected and cleaned. Once the recipient vessels have been prepared under the microscope using either the internal mammary artery and vein, or the thoracodorsal system, the flap is ready for anastomosis. Use of the vein coupler has simplified the process.

Secondary breast procedures typically occur 2–3 months following the initial reconstruction and often include revision of the reconstruction, contralateral symmetry procedure, and nipple reconstruction.

Results

This 58-year-old woman with stage 1 invasive lobular carcinoma was treated with chemotherapy followed by partial mastectomy. Due to positive margins she required a skin-sparing mastectomy and was reconstructed immediately using a pedicled

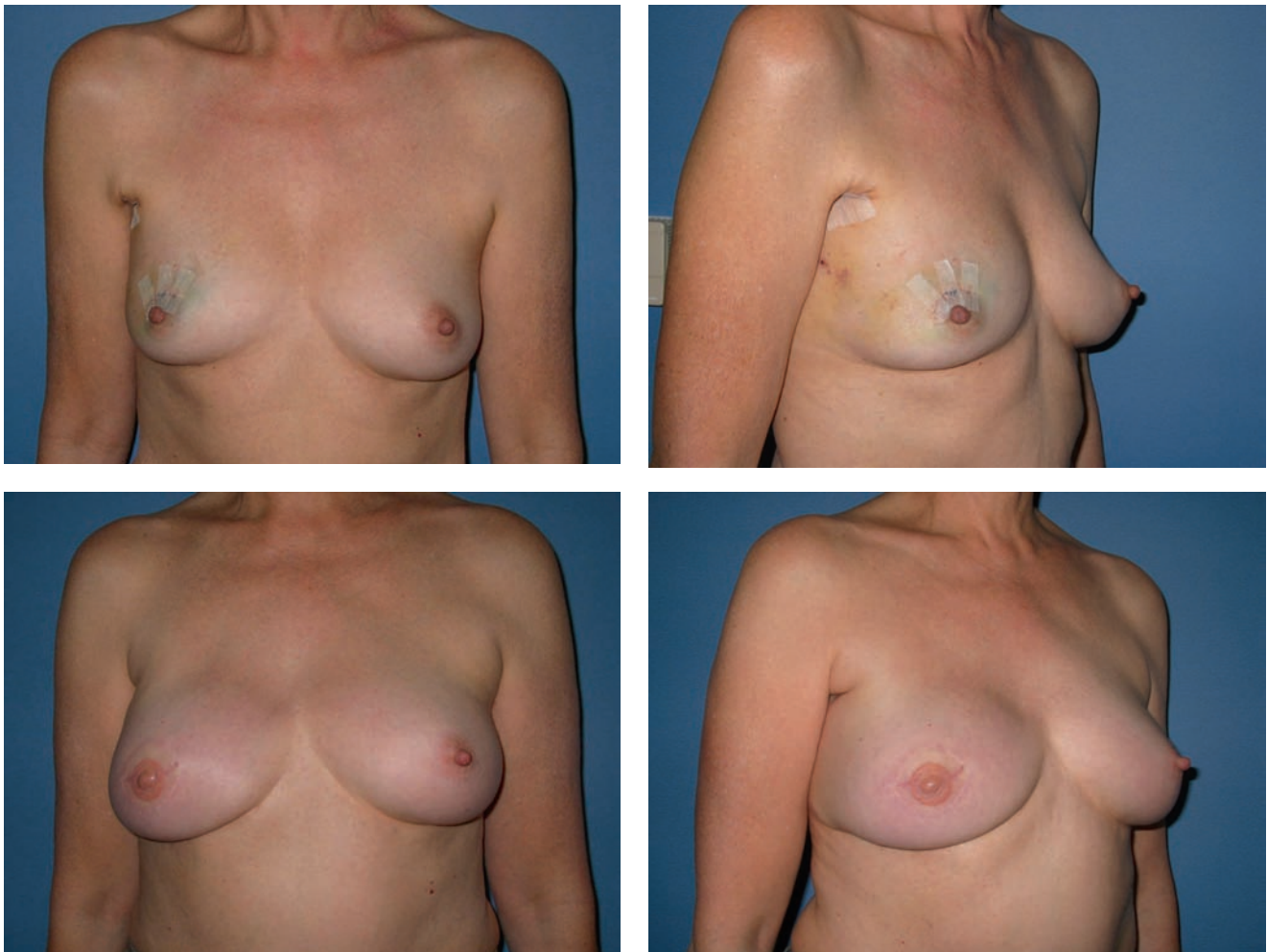


Figure 3.44

TRAM flap. The tissue from her abdomen was used to replace the breast tissue and a small area of abdominal skin was used to fill the defect left after the nipple areola was removed. She is shown 1 year following completion of nipple reconstruction using local skin flaps, and areola tattoo.

This 43-year-old woman with stage 3 breast cancer previously underwent a mastectomy followed by radiation therapy. She presented 2 years later requesting breast reconstruction. Given her history of radiation therapy, and her lower abdominal anatomy, she was a good candidate for resection of the irradiated chest wall skin and free muscle-sparing TRAM flap breast reconstruction. Her final result is shown 1 year following nipple reconstruction with good shape, symmetry, and a soft breast.



Figure 3.45

Anatomic Basis of Complications

- Injury to long thoracic nerve results in a winged scapula.
- Too extensive resection of brachial lymphatic vessels results in increased risk for arm lymphedema.
- Abdominal wall bulge, weakness or hernia when closed under excessive tension, following denervation of the muscle.
- Flap necrosis when perforators are too small to adequately perfuse skin flaps.
- Injury to the thoracodorsal nerve weakens the latissimus dorsi muscle.
- Injury to the medial pectoral nerves results in partial atrophy of the pectoralis major muscle.
- Total division of the intercostobrachial nerve results in numbness and dysesthesia under the arm.
- Retraction of the latissimus muscle following transfer for reconstruction when the thoracodorsal nerve is not divided or the humeral insertion is not released.
- Necrosis of native mastectomy skin flaps when perforators are violated or when skin flaps are too long or when flaps are too thin.
- Recurrent back seroma following harvest of the entire latissimus dorsi muscle.

Major

Minor

Partial Breast Reconstruction

In order to support the complex nature of ever-expanding criteria for breast conservation, there has been a recent surge of reconstructive techniques for the partial mastectomy defect. Up to 30% of women will have a residual deformity that may require surgical correction, the secondary correction of which is often difficult. The original papers on partial breast reconstruction focused on recognizing the post-BCT following radiation therapy. The shift has now focused more on recognizing the potentially unfavorable partial mastectomy defect, and reconstructing this defect in an attempt to prevent the deformity. Such immediate reconstruction of the partial mastectomy defect has been referred to as oncoplastic techniques by Werner Audrestsch in Europe where this has been adopted for quadrantectomy defects. The word oncoplastic is derived from the Greek words “onco” (tumor) and “plastic” (mould), the combination of which for breast conservation defects allow removal of larger amounts of breast tissue with safer margins, without compromising the cosmetic outcome. Women with breast cancer no longer need to accept significant deformities in order to preserve their breasts. The wider the margin of resection, the lower the risk of local recurrence; it often becomes a dilemma for the surgeon to meet both these endpoints. Breast shape becomes compromised and significant contour deformities, breast asymmetry, and poor aesthetic outcomes are not uncommon.

The two main indications for reconstruction include (1) recognizing the potential for poor cosmetic results or (2) to broaden the indications for breast conservation. In the past women with large breasts, central or lower quadrant tumors, and a large tumor to breast ratio were deemed poor candidates for BCT because of unfavorable results and often required mastectomy. The tumor to breast ratio is one of the most important factors when predicting the potential for a poor outcome. Studies have shown a decline in cosmetic scores for patients with parenchymal resection greater than 70–100 cm³ (Mills, Taylor), or when the specimen weight to breast volume ratio exceeds 10 (Cochrane). In general when more than 20% of the breast is excised with partial mastectomy, the cosmetic result is likely to be unfavorable. Other indications included concerns regarding not being able to achieve negative margins without a generous resection. Partial breast reconstruction is indicated whenever the potential for a poor cosmetic result exists such as patients with tumors in whom a standard lumpectomy would lead to breast deformity or gross asymmetry, or in patients without which would preclude them from breast conservation.

The timing is either immediate (at the time of lumpectomy), delayed immediate (once confirmation of negative margins 1–2 weeks following lumpectomy), or delayed (following completion of radiation therapy). In patients where there is concern regarding obtaining negative margins at the time of lumpectomy (i.e., age <40 years, extensive DCIS, prior chemotherapy, infiltrating lobular carcinoma) it is often safer to proceed with reconstruction once margins have been confirmed. When the reconstruction is performed immediately, every effort should be made to minimize negative margins through intraoperative margin assessment (macroscopic, radiographic evaluation, frozen section or cytology), and separate intraoperative cavity sampling which render negative margin status in 60% of patients who were otherwise considered positive on initial resection (Cao). The cavity is clipped intraoperatively for postoperative surveillance, as well as radiation boost if needed. The options for managing positive margins include re-excision or completion mastectomy and reconstruction. The extent of the disease will often dictate the latter in these situations where a generous oncoplastic resection has already been performed.

Partial mastectomy defects represent an anatomic variety that ranges from small defects to larger ones involving skin, nipple–areolar complex, and a significant amount of glandular tissue. There are two fundamental types of procedures – volume displacement and volume replacement. The decision as to which is more appropriate depends on breast size, tumor (or defect) size, location, and patient desires. Large or moderate-sized breasts or ptotic breasts with sufficient parenchyma remaining following resection are amenable to reshaping procedures. When additional tissue (volume and skin) is required to maintain the desired breast size or shape, i.e., smaller or non-ptotic breasts, volume replacement procedures are required.

Volume Displacement Procedures

The breast reshaping procedures all essentially rely on advancement, rotation, or transposition of a large area of breast to fill a small or moderate-sized defect. This absorbs the volume loss over a larger area. In its simplest form, it entails mobilizing

the breast plate from the area immediately around the defect in a breast flap advancement technique as proposed by Anderson et al. The dissection is over the pectoralis muscle and essentially involves a full-thickness segment of breast fibroglandular tissue advanced to fill the dead space, to preserve shape and appearance. These procedures are indicated in small-to-medium-sized breasts where the resection does not lead to any significant volume alteration that might cause breast asymmetry. A contralateral symmetry procedure is typically not required. Perhaps the most popular and versatile breast reshaping options are the mastopexy or reduction techniques, referred to in the past as oncoplastic reduction or therapeutic reduction. The ideal patient is one where the tumor can be excised within the expected breast reduction specimen, in medium-to-large or ptotic breasts where sufficient breast parenchyma remains following resection to reshape the mound.

In women with large or ptotic breasts, the numerous reduction patterns or pedicle designs will invariably allow remodeling of a defect in any location and any size, as long as sufficient breast tissue and skin is available. Creative mammoplasty designs can be made for complete removal of the lesion and reshaping of the mound. Preoperative markings are important, and a decision is made on pedicle design depending on tumor location. Typically if the pedicle points to or can be rotated into the defect it can be used (i.e., inferior pedicle reduction techniques for upper pole tumor defects).

Communication with the resective surgeon is crucial, ensuring that their approach is within your planned skin takeout pattern if possible. If the tumor is located outside the proposed skin takeout pattern, it can be excised through a separate incision as long as vascularity of the skin flaps will not be compromised. The Wise pattern markings are more versatile allowing tumor resection in any breast quadrant. Once the resection is performed, the cavity is inspected paying attention to the defect location in relation to the nipple, as well as the remaining breast tissue. Additional cavity samples are taken and the cavity is clipped. The reconstructive goals include (1) preservation of nipple viability, (2) reshaping of breast mound, and (3) closure of dead space. The nipple and dermatoglandular pedicle is dissected, and remaining tissue is resected if necessary for completion of the reduction. Occasionally, additional dermatoglandular or glandular pedicles can be created from tissue that might otherwise have been resected, and rotated to autoaugment the defect if it is peripheral on the breast. The contralateral procedure is performed using a similar technique. The ipsilateral side is typically kept about 10% larger to allow for radiation fibrosis. Drains are used if extensive nodal dissection is performed.

Additional mastopexy options exist for oncoplastic breast conservation. The donut mastopexy allows a breast segment to be removed through a periareolar incision, and is useful for segmentally distributed cancers in the upper or lateral portion of the breast. The batwing mastopexy involves a full thickness excision of lesions deep within the breast centrally or adjacent to the nipple–areolar complex. The two similar half-circle incisions with angled wings on either side of the areolar allow advancement of the fibroglandular tissue to close the defect. Since it removes sufficient breast tissue and skin to alter the size of the breast and nipple position, a similar contralateral lift is occasionally required to achieve symmetry.

Results

This 33-year-old woman with stage III breast cancer had excellent response to pre-operative chemotherapy, and desired breast conservation. In order to minimize the potential for a poor cosmetic result with a defect in the upper pole, she underwent a right wire-guided lumpectomy (100 g) with simultaneous bilateral breast reduction (total volumes 250 g left, and 150 g right). The nipple was moved based on an inferiorly based dermatoglandular pedicle. Her result is shown at 1 year following completion of right breast radiation therapy.

Volume Replacement Techniques

These techniques are typically required in small non-ptotic breasts, where insufficient tissue is left following resection for remodeling, or when quadrantectomy-type

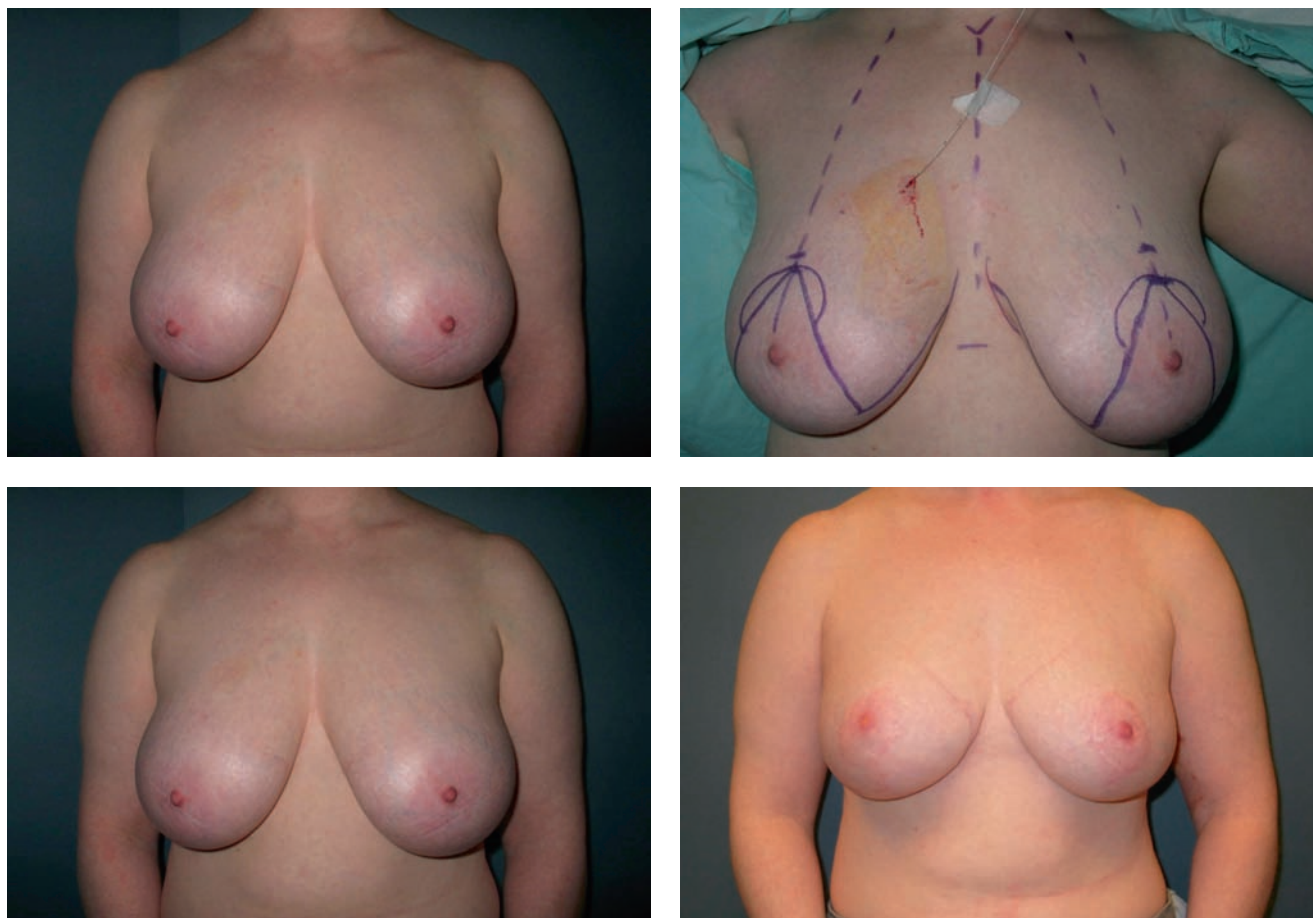


Figure 3.46

resections including skin and parenchyma are resected from outside the Wise pattern markings. The concept involves replacing the volume of tissue removed with autologous tissue from an extramammary region. It is of paramount importance that if autologous flaps are to be used for partial breast reconstruction that confirmation of negative margins be determined prior to flap transfer. The potential employment of a reconstructive option should always be considered in case complete mastectomy and reconstruction are required.

Small lateral defects (less than 10% of breast size) can be closed with local fasciocutaneous flaps from the lateral thoracic region. Lateral thoracodorsal or subaxillary flaps are essentially rhomboid-type flaps ideal for lateral defects, or upper outer, especially in obese patients. The latissimus dorsi musculocutaneous flap is a common local option for lateral, central, and even medial defects. It has excellent blood supply and provides both muscle for filling of glandular defects and skin for cutaneous deficiencies. Avoiding a scar on the back can be achieved by harvesting the LD without skin through the lateral breast incision. The use of an endoscope can assist in raising the muscle. A deinnervated and radiated LD will undergo postoperative atrophy. To compensate for the expected loss in muscle volume, a flap much larger than the defect should be harvested, possibly preserving subscapular fat on the muscle. A similar skin island to the classical LD musculocutaneous flap can be raised as a pedicled perforator flap either from the thoracodorsal or intercostal vessels. The thoraco-dorsal artery perforator (TDAP) Flap can easily reach defects in the lateral, superolateral, and central regions of the breast. If no suitable perforators are found, the flap is easily converted to a muscle-sparing – TDAP or muscle-sparing – LD flap. The lateral intercostal artery perforator (LICAP) flap is another alternative to the TDAP flap for lateral and inferior breast defects. The LICAPs are found at 2.7–3.5 cm from the anterior border of the LD muscle. The anterior intercostal artery perforator (AICAP) flap is based on perforators originating from the intercostal vessels through the rectus abdominis or the external oblique muscles. Since it has a short pedicle, the AICAP flap is suitable to cover close defects that extend over the inferior or medial quadrants of the breast. The superior epigastric artery perforator (SEAP) flap is based on perforators arising from the superior epigastric artery or its superficial branch. It has the same indications as the AICAP flap, however, the SEAP flap has longer pedicle and therefore it can cover more remote defect in the breast. Large medial defects are more difficult to reconstruct, and often are best avoided by completion mastectomy and reconstruction.

The benefits of using the oncoplastic approach with breast conservation therapy have been well-demonstrated, and will continue to gain popularity and acceptance in the future. The options for women with breast cancer are numerous, and this provides an additional, often favorable one. We need to critically evaluate results measuring functional, oncological, and aesthetic outcomes in an attempt to establish safe and effective practice guidelines to maximize oncological safety.

Anatomic Basis of Complications

- Major**
 - Violation of the aesthetic units to the breast creating a patch-like appearance.
 - Skin necrosis when incisions are designed without respect for perforating vessels and the subdermal plexus.
 - Flap loss when unable to support the skin island on limited perforating vessels, or pedicle trauma/tension.
 - Secondary breast deformity with skin retraction when defect is not adequately reconstructed using volume replacement or volume displacement techniques.
- Minor**
 - Breast asymmetry when radiation fibrosis further reduces volume of the ipsilateral breast.
 - Nipple necrosis when blood supply is interrupted or through over-resection of the breast parenchyma around the nipple.

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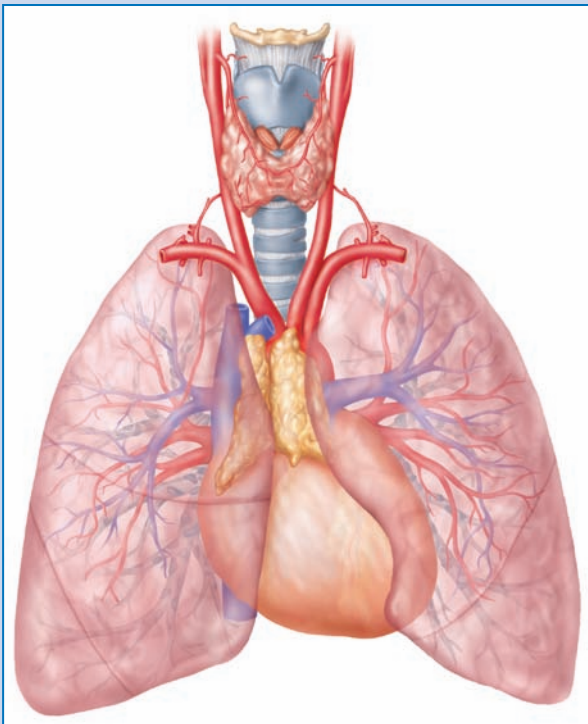
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Mediastinum, Thymus, Cervical and Thoracic Trachea, and Lung

Daniel L. Miller

Robert B. Lee



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Mediastinum

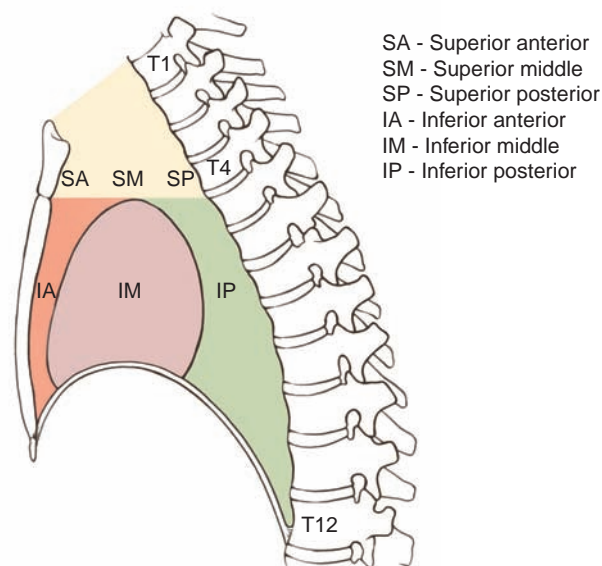
The mediastinum exists by definition as an area defined by arbitrary anatomic boundaries within which many intrathoracic organs reside. The mediastinum's existence by definition has led not only to confusion but also to controversy regarding its anatomic subdivisions. This in turn has led to confusion in the radiologic, medical, and surgical literature reporting frequency of different tumors within the mediastinum. The organs and tumors within the mediastinum are many. This section defines the mediastinum and its compartments, the contents within, surgical procedures for diagnosis, and representative surgical techniques within each compartment.

Surgical Anatomy

The mediastinum is that anatomic compartment defined as the intrathoracic region, bounded laterally by the parietal pleura, superiorly by the thoracic inlet, inferiorly by the superior surface of the diaphragm, anteriorly by the sternum (jugular notch to xiphoid), and posteriorly by the anterior longitudinal spinal ligaments, which run along the first through the eleventh thoracic vertebrae. Although the costovertebral regions (paravertebral sulci) are not by definition within the mediastinum, it has been commonly accepted that masses here are considered within the mediastinum. A mass lesion may arise and predominate within a given region; however, extension into another division as the mass enlarges is common. The site in which the greatest bulk of a given lesion resides defines its compartment of origin.

Divisions of Mediastinum

Figure 4.1



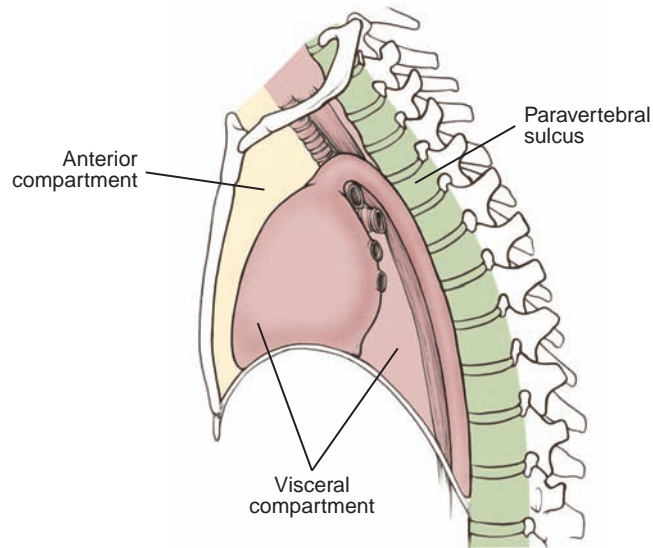


Figure 4.2

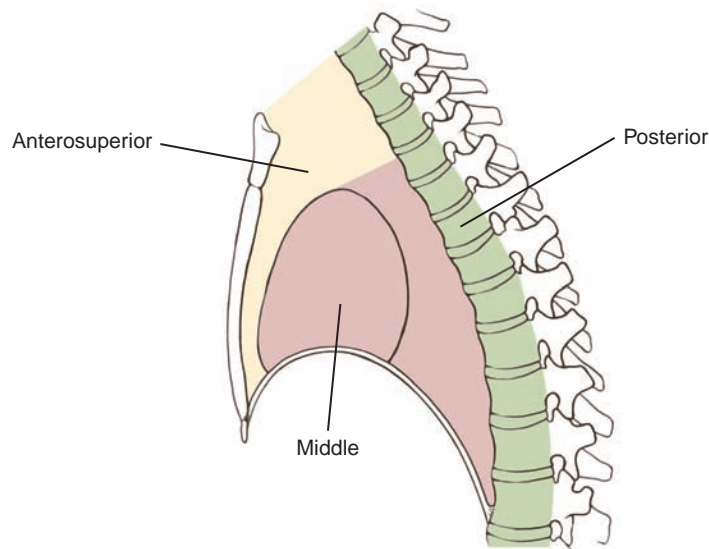


Figure 4.3

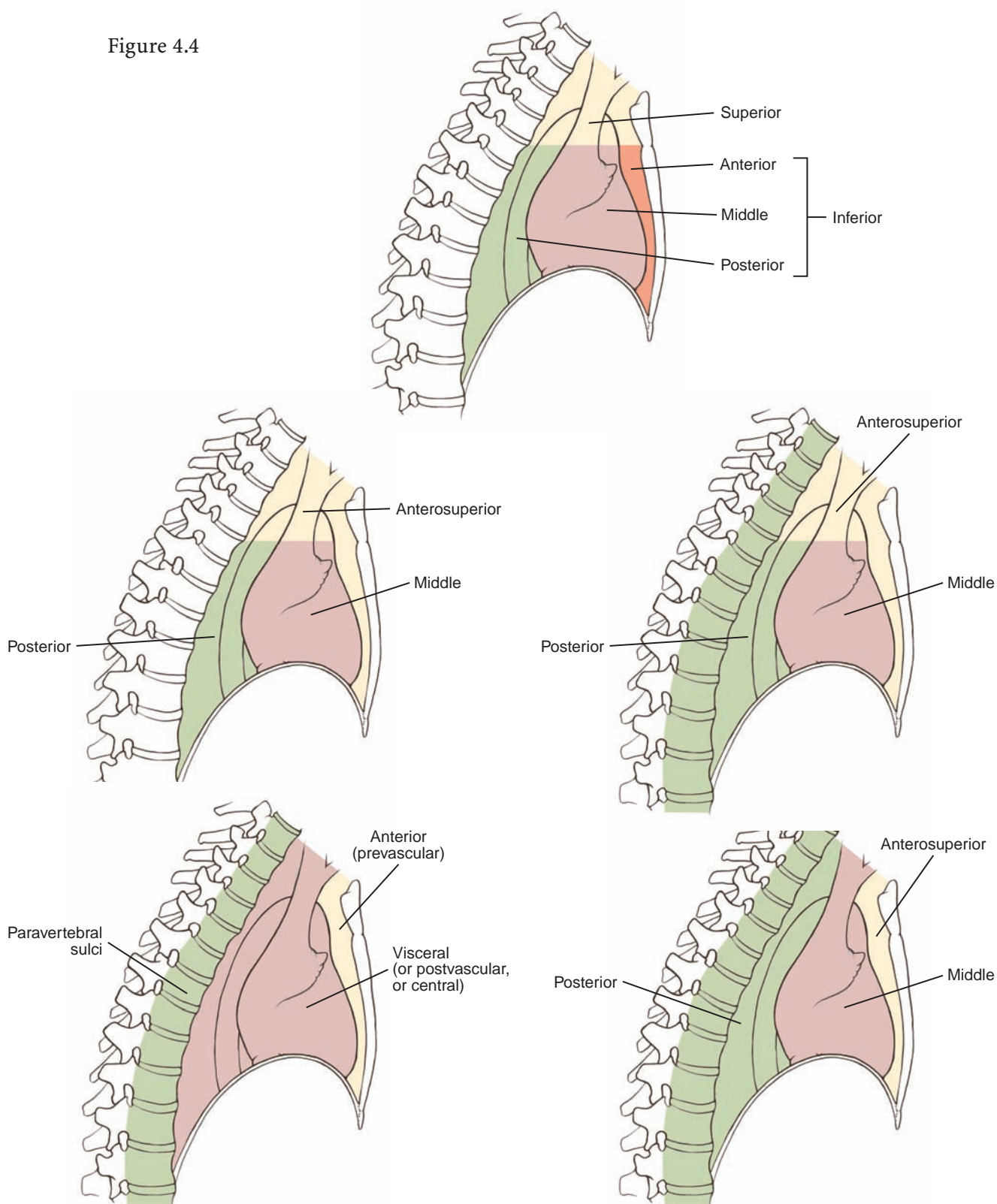
The arbitrary division of the mediastinum into compartments has led to confusion. Traditionally, anatomists divided the mediastinum into a superior and an inferior section, with anterior, middle, and posterior sections within each. Shields suggested a simplified division in 1972.

Using Shield's definition, the superior anterior, middle, and posterior sections are the anterior and visceral compartments and the bilateral paravertebral sulci.

This schema closely corresponds to the division that thoracic surgeons have found most clinically useful, which combines the anterior and superior compartments into one anterosuperior mediastinal compartment.

The other compartments are the middle and posterior. Walsh gives the clearest description of the different nomenclatures used to compartmentalize the mediastinum. His fourth diagram (in the lower left) is similar to that of Shields, and is used for the present discussion.

Figure 4.4



The anatomy of the mediastinum by definition is the boundaries of its compartments and the organs within. An in-depth discussion of each structure is beyond the confines of this text. A more detailed anatomic description of the thymus, trachea, main stem bronchi, and esophagus will follow.

The anterior, or prevascular, compartment is bounded posteriorly by an arbitrary plane along the anterior surface of the great vessels and the pericardium, anteriorly by the inner table of the sternum, and laterally by the mediastinal parietal pleura. The superior extent is the thoracic inlet and the inferior extent is the diaphragm. The visceral or middle compartment originates anteriorly at the imaginary plane forming the posterior extent of the anterior compartment. The posterior extent is the anterior aspect of the vertebral bodies. The lateral and superoinferior boundaries are the same as for the anterior compartment. The posterior compartment, or costovertebral sulci, begins at the dorsal aspect of the vertebral bodies and extends posteriorly to the transverse vertebral processes. Superior and inferior boundaries are the same as for the previous vertically oriented compartments.

Structures and Lesions

The anterior (prevascular) compartment may contain the thymus, retrosternal thyroid, and parathyroid glands, fat, germ cell rests, and lymph nodes. The only organs rightfully residing in the anterior compartment are the thymus and anterior mediastinal lymph nodes. When present, the thyroid and parathyroid glands and germ cell rests are ectopic. In adults 54% of mediastinal tumors develop in the anterior space, 20% in the visceral (central) space, and 26% in the posterior (paravertebral) space. In children 63% of mediastinal tumors develop in the posterior (paravertebral) space, compared with 11% in the visceral (middle) space and 26% in the anterior (anterosuperior) space.

The true incidence and prevalence of masses within each compartment will remain unclear and debatable as long as no single definition of the compartments is uniformly accepted as standard. At present it is accurate to say that there is a recognized increase in lymphoproliferative diseases and increased recognition of thymic tumors in myasthenia gravis patients screened with chest computed tomography (CT). The anterior compartment is the “hot zone” in which abnormal lesions are most frequently found.

Because in adults the thymus is the site of most mediastinal masses, and specifically, anterior mediastinal masses, the thymus and thymic resection are discussed separately. Thyroid goiter extending into the mediastinum, with or without malignancy, and ectopic parathyroid glands are addressed in Chap. 2. Germ cell tumors, which constitute approximately 15% of masses in the adult anterior mediastinum, are discussed in detail by Allen et al.

The most frequent challenge for thoracic surgeons when masses are detected in the anterior mediastinum is the distinction between thymoma, a surgically treated disease, and lymphoma, a medically treated disease. Although thymomas usually predominate in this region, lymphoma occurs 22% of the time in adults and 45% of

Anterior Compartment

Table 4.1 Structure and lesions in the anterior superior mediastinum

Structure	Tumor
Thymus	Thymoma Thymolipoma Thymic carcinoid Thymic cyst Thymic hyperplasia Thymic carcinoma
Thyroid	Substernal goiter Ectopic thyroid without connection to neck
Parathyroid	Ectopic parathyroid adenoma Parathyroid carcinoma
Fat	Lipoma Liposarcoma
Lymph nodes	Malignant diseases Hodgkin's lymphoma Non-Hodgkin's lymphoma Metastatic carcinoma Benign processes Castleman's disease (nodal hyperplasia) Infectious mononucleosis Granuloma Lymphangioma Fungal diseases Histoplasmosis Coccidioidomycosis Tuberculosis Sarcoidosis Wegener's granulomatosis
Germ cell rests	Benign processes Teratoma (dermoid) Malignant lesions Seminoma Nonseminomatous germ cell tumors Embryonal carcinoma Choriocarcinoma Endodermal sinus tumor (yolk sac) Teratocarcinoma

From Walsh GC. General principles and surgical considerations in the management of mediastinal masses. In: Roth JA, Ruckdeschel JC, Weisenburger TH, editors. Thoracic oncology. Philadelphia: WB Saunders; 1995. p. 448

the time in children. Many of the lymphomas in this region are not primary lesions but part of a systemic lymphoproliferative disorder (Hodgkin's lymphoma, 67% and non-Hodgkin's lymphoma, 43%). Fever, night sweats, weight loss, anorexia, and the "B" symptoms of lymphoma are useful in distinguishing lymphoma from thymoma. Generalized weakness, easy fatigability with repetitive motion, and oculobulbar

symptoms suggest the diagnosis of myasthenia gravis and associated thymoma. Contrast-enhanced CT evaluation of the chest is absolutely essential prior to any invasive diagnostic procedure. The diagnosis is more dependent on the expertise of your cytopathologists than the amount of tissue. Today, thoracoscopy has become the most common diagnostic procedure to differentiate thymoma vs. lymphoma. Lymphomas tend to be bilateral and more diffuse, whereas thymomas often predominate on one side, as seen on chest CT scans. Fine-needle aspiration biopsy has previously been discouraged in differentiating lymphoma from thymoma, for fear of disrupting the thymic capsule and disseminating thymic carcinoma. I used to routinely perform fine-needle aspiration biopsy, when lymphoma is suspected to obtain tissue, for flow cytometry and cytology.

These techniques have a high rate of specificity in differentiating lymphoma from thymoma, thus averting a more invasive surgical procedure. The superior posterior mediastinum is the home of neurogenic tumors. The most common are neuroblastomas, benign (70%) and malignant (30%).

The visceral (middle) compartment contains the trachea, proximal main stem bronchi, thoracic esophagus, pericardium, heart and great vessels, lymph nodes, phrenic, vagus, and sympathetic nerves, and thoracic duct. Tracheobronchial and esophageal tumors are discussed subsequently. Although containing the greatest number of “true organs,” the visceral compartment contains the least number of tumors (20%) in the adult population if esophageal and tracheobronchial malignancies are excluded.

Cardiac tumors are rare. Metastases to the heart are 20–30 times more frequent than primary cardiac tumors. Benign tumors of cardiac origin account for 75% of cardiac tumors. Of the benign cardiac tumors, myxomas primarily of the atria constitute the vast majority. Malignant cardiac tumors are most often sarcomas (rhabdomyosarcoma and angiosarcoma), which rapidly progress to death within weeks, and most often (80% of the time) associated with systemic metastasis at the time of diagnosis. Both primary and metastatic cardiac tumors can be resected with cardiopulmonary bypass and reconstructive surgery. Cardiac transplantation has made right-sided endomyocardial biopsy safe and commonplace. Thus, in any patient with a known prior malignancy and newly found right chamber cardiac mass, biopsy should be attempted and diagnosis made prior to surgical resection. In most cases resection of a metastatic cardiac neoplasm without assured control of the original primary lesion is contraindicated. Bronchogenic carcinoma extending into the cardiac chamber without lymph-node metastasis can be resected by the experienced cardiothoracic surgeon with acceptable morbidity and mortality and at least 30% 5-year survival. Transesophageal echocardiography and MRA can be used to evaluate bronchogenic carcinoma for resection. It accurately allows exclusion of unresectable tumors and guides the approach in attempts at resection.

Pericardial tumors are uncommon. As with cardiac tumors, metastasis to the pericardium or direct involvement by nearby primary malignancies is more common than primary tumors arising from the pericardium. In fact, as patients with breast and lung primary tumors survive longer, malignant pericardial effusion associated with pericardial involvement is becoming more common. Bronchogenic carcinoma is the most

Middle Compartment

Table 4.2 Structures and lesions in the middle (visceral) mediastinal compartment

Structure	Tumor
Trachea	Bronchogenic cyst Adenocystic carcinoma Carcinoid tumor Mucoepidermoid Bronchial mucous gland adenoma Mixed salivary gland tumor Squamous cell carcinoma
Esophagus	Primary malignancies Adenocarcinoma or squamous cell carcinoma Small-cell carcinoma Mesenchymal tumor Leiomyosarcoma Rhabdomyosarcoma Lymphoma Melanoma Benign lesions Duplication cyst Leiomyoma Esophageal diverticulum (pulsion or traction)
Pericardium	Pericardial cyst Pericardial diverticulum Hemangiopericytoma
Heart	Fibroma Rhabdomyosarcoma
Aorta and arch vessels	Aneurysm (saccular or diffuse) Coarctation Arch anomalies Double aortic arch Right arch with left ligamentum Left arch with aberrant right subclavian artery Leiomyosarcoma, Leiomyoma Angiosarcoma
Veins	Ectasia and aneurysm formation Venous anomalies Persistent left superior vena cava Anomalous pulmonary venous drainage Azygous continuation of the inferior vena cava Leiomyoma, leiomyosarcoma
Lymph nodes	Sarcoidosis Lymphoma Metastatic carcinoma
Phrenic and vagus nerves	Nerve sheath tumors
Sympathetic nerves	Paraganglioma (chemodectoma)
Thoracic duct	Cysts
Lymphatic vessels	Lymphangioma (cystic hygroma) Lymphangiopericytoma

From Walsh GC. General principles and surgical considerations in the management of mediastinal masses. In: Roth JA, Ruckdeschel JC, Weisenburger TH, editors. Thoracic oncology. Philadelphia: WB Saunders; 1995. p. 448

frequent tumor metastatic to the pericardium (33%), followed by breast carcinoma (25%) and hematologic malignancies (15%). The most frequent primary pericardial malignant tumor is mesothelioma. Extremely rare, it was found in 0.0022% of 500,000 autopsies in one series. Other primary pericardial tumors include angiosarcoma and tetratomas, most commonly seen in children, which are also extremely rare.

Within the visceral compartment are several lymph-node groups. The paratracheal, tracheobronchial, subcarinal, and subaortic lymph nodes are well known to the thoracic surgeon as sites of metastasis of primary bronchogenic carcinoma. Most frequently, enlargement of these lymph nodes is due to metastases; however, granulomatous disease, reactive lymphadenopathy, and sarcoidosis may produce profound asymptomatic nodal enlargement and require differentiation from primary lymphoma and metastasis before initiation of treatment. A less well-known group of mediastinal lymph nodes is described by Shields as located around the pericardial attachments to the diaphragm, draining the diaphragm and liver. They may on occasion be involved by lymphoma.

The posterior compartment (paravertebral or costovertebral sulci) contains peripheral intercostal nerves, sympathetic ganglia, and paraganglia. Owing to its contents this area is the most common site of mediastinal neurogenic tumors. The majority of posterior compartment tumors are benign; the incidence of malignancy is low in adults (0.5%), but is slightly increased in children. Tumors in this compartment tend to enlarge, but generally remain asymptomatic and are identified on chest radiographs obtained for other purposes. Most authors recommend excision without prior tissue diagnosis because these lesions are well-characterized on CT and nuclear magnetic resonance imaging (MRI).

Mediastinal paragangliomas are highly vascular and frequently chemically active. Miller and I discuss the diagnosis and treatment of these uncommon mediastinal tumors in the text of Wood and Thomas text.

Posterior Compartment

Table 4.3 Structures and lesions in the posterior (costovertebral sulcus) compartment

Structure	Tumor
Peripheral intercostal nerve	Benign processes
	Neurofibroma
	Neurilemmoma (schwannoma)
	Malignant lesions
Sympathetic ganglia	Neurosarcoma
	Benign
	Ganglioneuroma
	Malignant
	Ganglioneuroblastoma
Paraganglia	Neuroblastoma
	Pheochromocytoma
	Chemodectoma (paraganglioma)

From Walsh GC. General principles and surgical considerations in the management of mediastinal masses. In: Roth JA, Ruckdeschel JC, Weisenburger TH, editors. Thoracic oncology. Philadelphia: WB Saunders; 1995. p. 449

Surgical Procedures

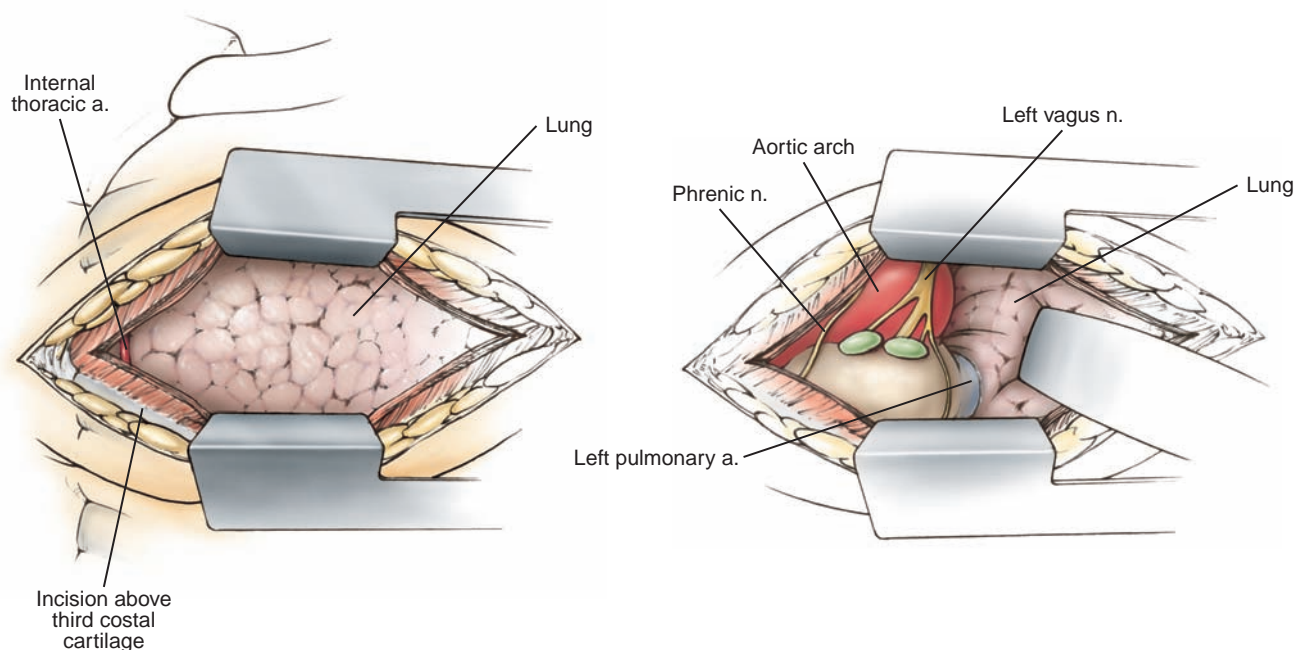
Diagnosis and Resection of Mediastinal Tumors

Anterior Compartment

Thymectomy is the most frequent resection performed in the anterior mediastinum and is detailed in length in the subsequent section. Before embarking on resection of an anterior mediastinal mass, noninvasive diagnostic techniques (e.g., CT, MRI, ultrasonography, serum tumor markers), and clinical examination should be performed and the results scrutinized. PET scanning can be used but in the setting of an anterior mediastinal mass it is usually used to find extrathoracic disease. Even after exhaustive investigation, differentiation between thymoma and lymphoma may be a challenge. Fine-needle aspiration biopsy with a 20-, 22-, or 25-gauge needle or the preferred core needle biopsies, with fluoroscopic or CT guidance, should be performed if the clinical history and imaging studies support the diagnosis of lymphoma. The use of flow cytometry has made subtyping of lymphoma increasingly accurate. Fine-needle aspiration biopsy is also sensitive (90%) in diagnosing metastatic carcinoma in the mediastinum.

Extended or substernal mediastinoscopy, as described by Ginsberg et al., can be used to access the anterior compartment. Through the same 2 cm cervical incision used for standard mediastinoscopy, the strap muscles are mobilized and retracted laterally. The scope is advanced anterior to the thymus and thus anterior to the innominate vein. Great care must be taken not to produce excessive traction on the innominate vein to prevent a tear. Further advancement of the scope permits entrance into the prevascular space anterior to the great vessels, allowing biopsy of anterior mediastinal masses and aortopulmonary lymph nodes. Because of the proximity of

Figure 4.5



the great vascular structures, this procedure is somewhat more risky than standard mediastinoscopy and should be performed only by the seasoned thoracic surgeon. More recently, Leschber and colleagues discussed the advantages of the new video mediastinoscope of reduced complications, improved sampling, and improved teaching of the traditional one operator procedure.

Anterior or parasternal mediastinotomy (Chamberlin procedure) is the more frequently performed procedure for access to the anterior compartment. A 2–5-cm incision is made from the lateral sternal border laterally over the third or fourth costal cartilage depending on the location of the tumor. The incision is deepened with the electrocautery through the overlying pectoralis muscle. The intercostal muscles are detached from a superior edge of the rib as far laterally as practical and medially to the internal thoracic vessels. The internal thoracic vessels should be avoided and preserved. The pleura may be dissected and retracted laterally or entered. As originally described, the third cartilage was excised. I have not found this uniformly necessary and it leads to more postoperative discomfort. This approach allows access to hilar and aortopulmonary lymph nodes and anterior compartment masses. The surgeon should identify clearly the surrounding vascular structures prior to any incisional or excisional biopsy. I have found it useful to use the video mediastinoscope, which has expedited the procedure, improved teaching of residents, and decreased postoperative pain. This same approach can be used on the opposite side for anterior compartment masses predominating on the right.

Of late, thoracoscopy has been used more frequently. The advantages have been multiple which includes improved assessment of involvement of the tumor in relation to mediastinal structures, detection of intrathoracic metastatic disease, and ability to perform the procedure as an outpatient.

Middle Compartment

Operations within the middle compartment mandate precise planning and diagnosis prior to embarkation. Contrast-enhanced chest CT is mandatory, and on occasion aortic arch aortography should be performed before any attempt at fine-needle aspiration or excisional biopsy to prevent any catastrophic biopsy of aneurysmal vascular structures. Surgery of the trachea and esophagus are detailed subsequently. With the exclusion of vascular lesions, tracheal lesions, and esophageal lesions, surgery of the middle mediastinum is performed to resect pericardial and cardiac lesions.

The pericardium is approached via a full median sternotomy or unilateral thoracoscopy. This allows excision of pericardial cysts or tumors. On occasion a pericardial mass will involve the phrenic nerve or be posterior to the phrenic nerve. In this situation the approach should be transthoracic through a standard posterior lateral thoracotomy or thoroscopically on the affected side. In cases of tumor, excision of the phrenic nerve is acceptable but usually unnecessary. The mass should be excised with sharp and electrocautery dissection with at least 2 cm margins verified negative for tumor on frozen section analysis. On the left side a wide excision should be performed to avert herniation or entrapment of the left ventricle. When wide excision is not indicated the defect may be closed with bovine pericardial patch. When right-sided lesions

are excised, the defect should be reconstructed with bovine pericardium to prevent herniation of the right atrium or torsion and herniation of the entire heart through the defect. This unlikely occurrence is extremely rare if a pneumonectomy has not been performed in conjunction with the pericardial resection. Excision of metastatic pericardial lesions may be performed for diagnosis. The anterior and lateral pericardium down to the phrenic nerve should be excised and the pleura entered to avert later constrictive processes or accumulation of malignant pericardial effusion.

The heart and cardiac chambers are usually approached through a full median sternotomy. This allows the best exposure and control of vascular structures. Cardiopulmonary bypass may be instituted through this incision or femorally. Resection of intracardiac tumors is most often performed through the right atrium and across the intra-atrial septum or through the tricuspid valve. Such resections are generally performed by cardiac surgeons or thoracic surgical oncologists who also perform cardiac surgery. Proper planning by the experienced cardiothoracic surgeon allows resection of primary and metastatic cardiac tumors not previously thought possible. Kirklin and Barratt-Boyes' text provides further in-depth discussion of the management and resection of intracardiac tumors.

Mediastinoscopy is frequently performed to diagnose masses and stage lymph-node involvement in the middle (visceral) compartment. With the patient under general anesthesia, a 2-cm transverse incision is made one finger breadth above the sternal notch. The underlying strap muscles are retracted laterally in the midline, the pretracheal fascia is bluntly or sharply opened, and the pretracheal space entered. The pretracheal space is then gently examined with the surgeon's index finger. This permits not only detection of masses but gentle mobilization of the areolar tissue surrounding the trachea. The video mediastinoscope is then gently placed within the pretracheal space and advanced underneath the innominate vessels under direct vision. The right paratracheal space, precarinal, subcarinal, and left paratracheal space are then examined in that order. Areas of intended biopsy should be aspirated with a needle prior to biopsy to avert biopsy of a vascular structure. Great care should be exercised in the area of the azygos vein and pulmonary artery, the structures most frequently inadvertently injured during mediastinoscopy. Injury to the trachea and esophagus has also been described. However, with the use of the video mediastinoscope this uncontrolled procedure has not become less anxiety provoking especially in a training center. EBUS and EUS are now being used more frequently to diagnose mediastinal and hilar lymphadenopathy. Long-term follow-up will be necessary to see which modality should be used. The most important issue for the thoracic surgeon is to have available all of these diagnostic modalities so that the patient can get the diagnosis the least invasively but most accurately that can expedite treatment.

Posterior Compartment

Resection of tumors in the posterior mediastinum involves excision of tumors arising from peripheral intercostal nerves or sympathetic ganglia. Often a diagnosis cannot be confirmed by preoperative fine-needle aspiration biopsy. The surgeon is justified in

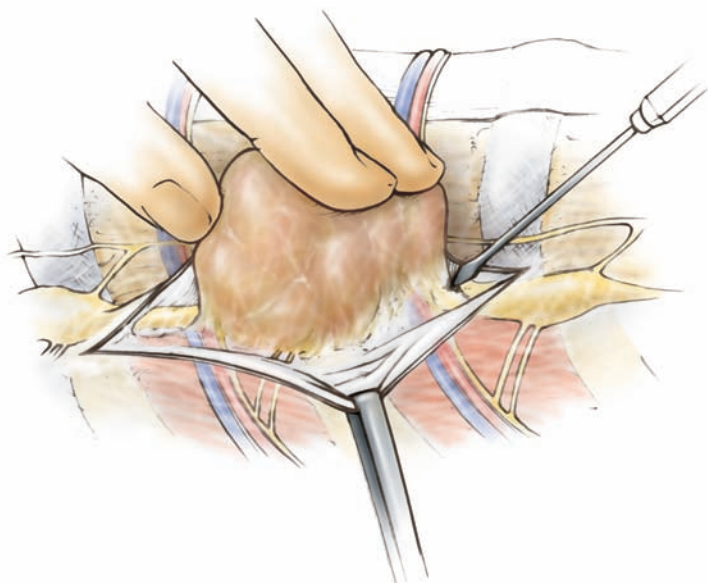


Figure 4.6

proceeding with excision because these lesions will continue to enlarge at varying rates, ultimately producing pain or pressure due to compression of nearby structures. Neurofibromas, neurolemmomas (schwannoma), and ganglioneuromas are the most frequently seen posterior mediastinal neurogenic tumors. Both neurofibromas and neurolemmomas have a malignant potential (2–3%). They are often associated with von Recklinghausen's disease. Paragangliomas are frequently vascular and vasoactive. Resection is justified and should be aggressive. Complete resection is associated with alleviation of symptoms and cure, whereas other therapeutic modalities are ineffectual.

All neurogenic tumors should be approached through an ipsilateral approach either a posterolateral thoracotomy or thoracoscopically. The lung is retracted anteriorly and the parietal pleura incised circumferentially 2 cm around the mass. Those tumors not entering the vertebral neural foramina may be easily excised with sharp scissors and electrocautery. As the dissection approaches closer to the vertebral column, the electrocautery should be abandoned in favor of the scissors and ligating clips to prevent possible transmission of electrical current into the spinal cord. Accurate preoperative workup with MRI may allow resection of these tumors thoracoscopically if there is no foramen involvement.

Neurogenic tumors of the posterior mediastinum with intravertebral foraminal extension deserve additional planning and neurosurgical consultation. Extension into the vertebral column is suggested when widening of the foramina or vertebral body erosion is suggested on plain chest radiographs. Chest CT with fine (3–5 mm) sections through the tumor and adjacent vertebral column gives a more definitive image. When these neurogenic “dumbbell” tumors are suspected, nuclear MRI of the thorax with sagittal, coronal, and cross-sectional images is highly desirable if not essential. Nuclear MRI has all but replaced thoracic spinal column myelography. Once the tumor is confirmed to be a dumbbell tumor with extension into the vertebral column, inclusion of a neurosurgical oncologic surgeon on the surgical team is appropriate.

A posterior non-thoracotomy approach has been described by the Japanese, but the standard approach is through an ipsilateral thoracotomy or thoracoscopy. This approach allows excellent visualization for excision and control of the vascular structures feeding the tumor, as well as laminectomy if indicated. The inner space entered is dependent on the level of the lesion, but generally is within the fourth, fifth, or sixth inner space. The parietal pleura is incised and the previously collapsed lung retracted anteriorly. A nasogastric tube should be in place to aid in identifying the esophagus. The extent of rib, vertebral body, and nerve involvement is assessed. With scissors and the electrocautery, the dissection is begun inferiorly and proceeds laterally and superiorly, leaving the medial aspect attached. This allows the area of the intervertebral foramina to be approached last. Traction should be avoided and the electrocautery abandoned to avert inadvertent injury to the spinal cord. At this point the neurosurgeon is involved to perform a laminectomy and intradural excision of the tumor. This allows en bloc removal of tumor while minimizing possible injury to the spinal cord. The aorta and lung are rarely invaded unless the tumor is a malignant infiltrative type. The tumor blood supply is from segmental intercostal vessels, which can be ligated. The neurosurgeon will assist in confirming absence of a cerebrospinal fluid leak. If a cerebrospinal fluid leak is identified, a pedicled intercostal muscle flap may be used to seal the leak. Absorbable hemostatic agents should not be used because of the risk of associated swelling and neurological injury. A single-tube thoracostomy drain is usually all that is required. Closure of the thoracotomy is standard.

Anatomic Basis of Complications

- Poor preoperative imaging studies lead to poorly planned diagnostic attempts. No structure in the anterior, middle, or posterior mediastinum should be biopsied (fine-needle aspiration or incisional biopsy) without confirmatory studies to eliminate the possibility that the lesion is of vascular origin.
- Video mediastinoscopy should be performed only by those familiar with the anatomic position of the trachea, superior vena cava, azygos vein, and right and left pulmonary arteries as seen through the mediastinoscope. Needle aspiration should always be performed prior to biopsy. Compression of the innominate artery by overzealous upward lifting of the scope may tear the artery or dislodge atheromatous debris distally.
- Intracavitary cardiac masses should be biopsied preoperatively in patients with history of prior malignancy to prevent unnecessary and possibly harmful surgical procedures.
- Posterior neurogenic tumors must be assumed to have vertebral foraminal extension until conclusively ruled out to prevent incomplete excision or spinal cord injury. Neurosurgical consultation is mandatory.

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Thymus

The thymic gland lies within the superior anterior mediastinum. The frequency of both benign and malignant tumors of the thymus and the association with myasthenia gravis mandates additional in-depth and separate discussion of the thymus. The most common tumor of the anterior superior mediastinum, thymoma, is unusual in that mitotic figures are infrequent and malignancy is determined not by histology but clinically by depth of invasion. Even when judged malignant, thymic tumors follow a relatively benign course.

The thymus contains several cell types. The term thymoma has been reserved for tumors arising from its epithelial components. Originally proposed by Bell in 1917, “a thymoma may now be defined as a tumor, benign or malignant, probably derived from thymic epithelium.” This restriction was reiterated by Rosai and Levine, who stated that the definition of thymoma be limited to “neoplasms of thymic epithelial cells regardless of presence or absence of a lymphoid component.”

Histologically, thymomas consist of varying degrees of thymic epithelial cells and lymphocytes. This has resulted in various classifications based on ratios of the cell types. The following schema has been proposed based on the most prevalent epithelial cell type and the pattern of lymphoid infiltration:

1. Cortical thymoma: Lymphocytes are the predominate cell types, and many are blastic.
2. Medullary thymoma: Predominant cell types are medullary epithelial cells, with lymphocytes.
3. Mixed thymoma: Have cortical and medullary epithelial cells, and lymphocytes vary in number; therefore, subtypes are mixed common type, mixed cortical predominant, and mixed medullary predominant.

Medullary (epithelial cell predominant) and mixed types are more frequently benign (noninvasive), with good long-term survival and prognosis. The cortical (lymphocyte cell predominant) and predominant cortical types are generally malignant (invasive), with poor long-term prognosis.

Tumor staging has evolved based on clinical assessment at the time of operation by the thoracic surgical oncologist and less so based on histology. No staging system has been adopted by the official bodies that have defined staging systems for most cancers. The first staging system, proposed by Bergh and colleagues, classified non-invasive thymomas as stage I, those invading the mediastinal fat as stage II, and those invading surrounding organs or those with metastases as stage III. In 1981 Masaoka et al. originally proposed and updated in 1991, the classification most often used and accepted as the standard staging system for thymomas. As it is currently used, this system takes into account both macroscopic as well as microscopic evidence of tumor invasion into other mediastinal structures. A slight modification of this system has been proposed, namely, to divide stage I into Ia and Ib subclasses. A staging

classification system based on T, N, and M categories has been proposed for thymomas. However, only series has reported results using this TNM system.

Masaoka Staging Classification	
Stage I	Macroscopically, completely encapsulated; microscopically, no capsular invasion
Stage II	Macroscopic invasion into surrounding fatty tissue, or microscopic capsular invasion
Stage III	Macroscopic invasion of adjacent organs (pericardium, great vessels, lung)
Stage IV	A: Pleural or pericardial dissemination B: Lymphatic or hematogenous metastasis
From Masaoka A, Monden Y, Nakalara K, et al. Follow-up study of thymomas with special reference to their clinical stages. <i>Cancer</i> 1991;68:1984–1987. Copyright © 1991 American Cancer Society. Reprinted by permission of Wiley-Liss, a subsidiary of John Wiley & Sons.	

The Thymic Tumor Study Group modified Masaoka's classification to account for completeness of resection. This is an important modification because most authors of large series report that extent of tumor invasion and completeness of resection are the most important prognostic factors.

Thymic Tumor Study Group Staging System	
Stage IA	Encapsulated, noninvasive tumor; total excision
IB	Apparently encapsulated tumor; total excision but adhesions to mediastinal structures, indicating microscopic invasiveness seen at surgery
Stage II	Invasive tumor; total excision
Stage IIIA	Invasive tumor; incomplete excision
IIIB	Simple biopsy (when performing mediastinoscopy, thoracoscopy, or thoracotomy)
Stage IVA	Subpleural metastasis
IVB	Extrathoracic metastasis
From Bretel JJ. Staging and preliminary results of the Thymic Tumor Study Group. Thymic tumors. In: Sarragin R, Vroussos C, Vincent J, editors. Fourth cancer research workshop. Basel: Karger; 1989. p. 156–64. Reproduced with permission of S. Karger AG, Basel.	

Table 4.4 Data from thymoma review

Stage	Actuarial Survival (%)			
	No. of cases	Recurrence (%)	5 Years	10 Years
I	133	1.5	89.2	86.9
II	34	12.5	71.9	59.9
III	53	29.7	71.3	64.3
IVA	21	25.0	59.4	39.6

Modified from Maggi G, Casadio C, Cavallo A, et al. Thymoma: results of 241 operated cases. *Ann Thorac Surg.* 1991;51:152–6. Reprinted with permission from the Society of Thoracic Surgeons

The widespread use of chest CT for evaluation of myasthenia gravis has revealed an increasing number of previously undetected early thymomas. Approximately 20% of patients with myasthenia gravis have a thymoma. Forty to sixty percent of patients with thymomas have myasthenia when examined. Thus, most thymomas are seen as stage I or stage II tumors.

One third of thymomas will be classified as “malignant” due to invasion of nearby structures (stage III or stage IV). Pleural and pericardial implants constitute stage IV disease. This is a somewhat unusual and infrequent finding. Even less common is extrathoracic metastasis to bone, supraclavicular lymph nodes, liver, and spleen.

Recurrence is more common than metastasis and is most likely related to unrecognized and incomplete resection or understaging. Benign thymomas (stage I) recur at a rate less than 2%, usually in the mediastinum. Recurrence may also be due to unrecognized dissemination at the time of surgery or from tumor implants during operative manipulation. The recurrence rate for stage II tumor is approximately 10%, and 15% for totally resected stage III tumors. Patients with recurrence may undergo successful repeat operations, with expected actuarial survival of 66% at 5 years and 49% at 10 years.

The mean patient age at diagnosis is within the fourth decade; thymomas in children are uncommon. There is no geographic or race distinction. Males are affected slightly more often than females, but the difference is not statistically significant. When myasthenia gravis is known to exist, the patient is more often female. Approximately

Table 4.5 Conditions associated with thymoma

Condition	Percentage of patients
Myasthenia gravis	30–60
Cytopenia	15
Other non-thymic malignancies	12
Systemic lupus erythematosus	1
Rheumatoid arthritis	1
Pemphigus	1
Hemolytic anemia	1

Data from Levasseur P, Mesestrier M, Gaud C, et al. Thymomes et maladies associées. *Rev Mal Respir.* 1988;5:173–8; Souadjian JV, Enriquez P, Silverstein MN, et al. The spectrum of disease with thymoma. Coincidence or syndrome? *Arch Intern Med.* 1974;134:374–9

one-third of patients have no symptoms. The remainder may complain of pain in the chest or back (24%) or cough (20%). More than 50% of patients without myasthenia gravis have no symptoms. Autoimmune diseases are commonly associated with thymoma, with myasthenia gravis being the most common, occurring in 60% of patients.

Surgical Anatomy

The thymus is a glandular bilobed structure with an isthmus, composed of an epithelial cell stroma and varying amounts of lymphoid cells. It occupies a position in the anterosuperior mediastinum. Beginning in the third week of fetal development, the thymus evolves as a portion of the third pharyngeal pouch along with the parathyroid glands and descends into the anterior mediastinum to rest on the anterior surface of the aortic arch. Thus, in adult life aberrant thymic tissue may be found anywhere

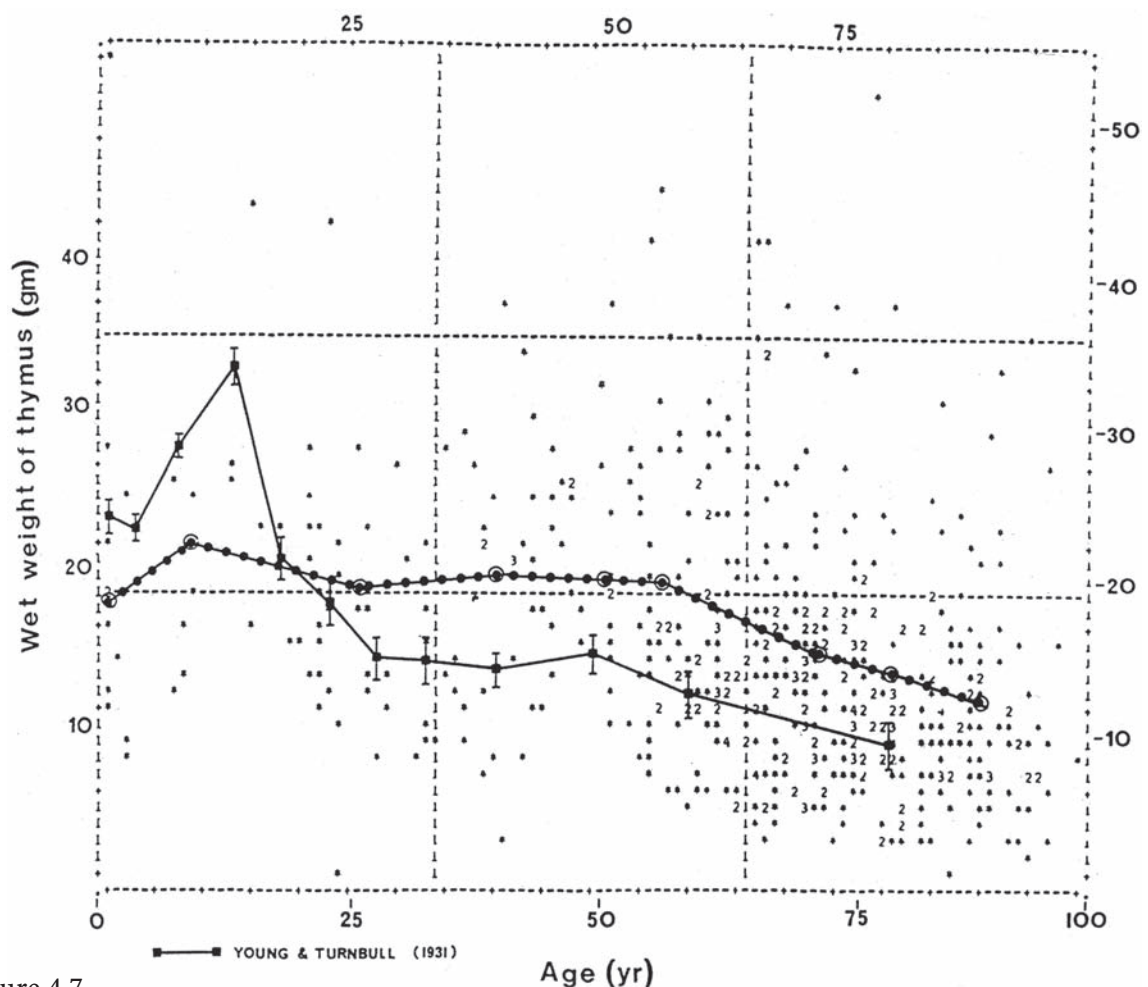


Figure 4.7

along this path of descent, particularly near the parathyroid glands, and infrequently at other sites, including neck, eardrum, pulmonary hilum, or posterior mediastinum. I have excised a thymoma from the inferior pulmonary ligament as well as the posterior mediastinum. The cells arising from the third pharyngeal pouch are epithelial cells and form the reticular framework, or medulla, to which the lymphoid cells migrate. During the third month of fetal life lymphocytes arising from the totipotent stem cells migrate to this epithelial stroma and undergo differentiation into T lymphocytes under the influence of thymic hormones. Thymus-derived lymphocytes, or T cells, are responsible for the cell-mediated portion of the immunologic defense system. The thymus is a large organ at birth and continues to grow into adolescence, reaching a volume of 40 g. Thereafter it undergoes fatty infiltration, termed involution.

Congenital absence of the thymus may occur as part of DiGeorge syndrome, leading to profound immunosuppression and early death. The adult thymus is located posterior to the sternum, beginning superiorly at the lower aspect of the inferior thyroid poles and extending through the thoracic inlet to the level of the fourth costal cartilage.

Blood Supply

The arterial blood supply is derived from five sources. The major blood supply is from branches of the inferior thyroid artery and internal thoracic arteries. Smaller

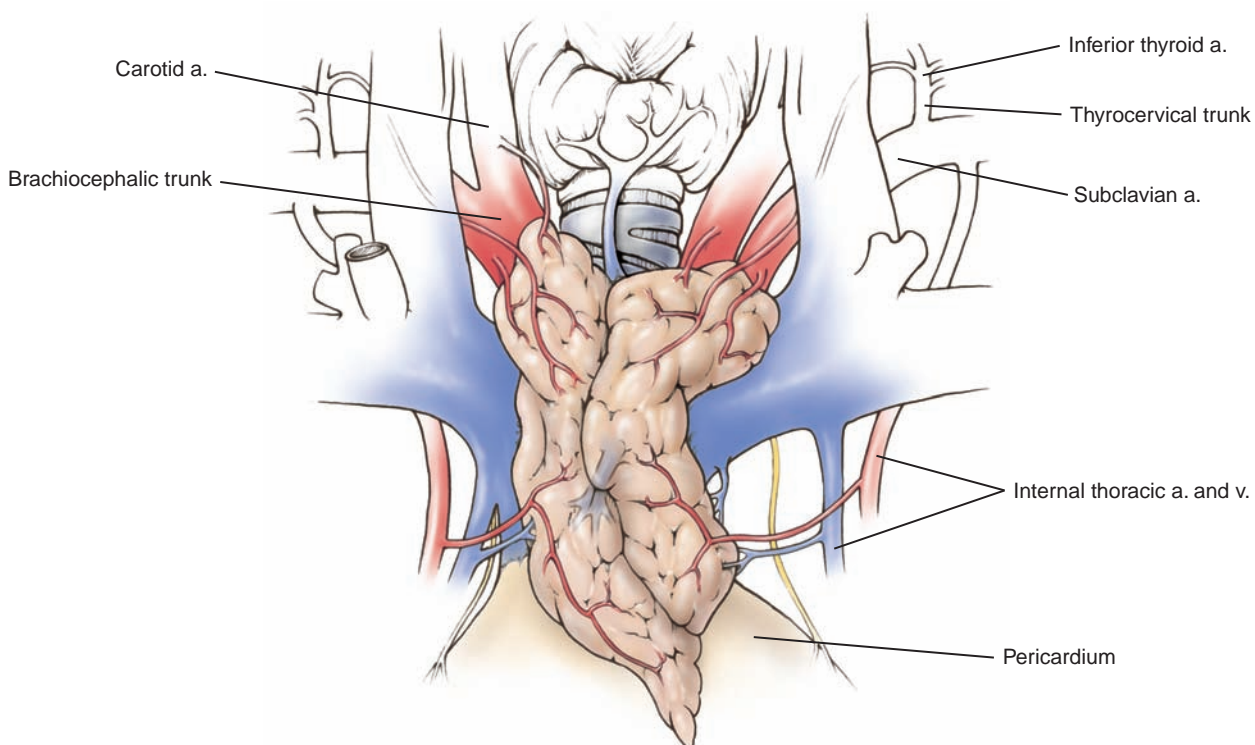


Figure 4.8

branches from the superior thyroid, subclavian, and carotid arteries constitute the remainder of the blood supply. These are easily controlled by ligation or clipping during resection.

The venous drainage of the thymus, like that of most other organs, is variable. The medial aspects of the right and left lobes are drained by separate 2–3 mm veins that join posteriorly and superiorly to form the great vein of Keynes. The vein of Keynes is a short, wide vein that travels superiorly and joins the anteroinferior surface of the left brachiocephalic vein. The lateral aspect of the right lobe drains directly into the superior vena cava, with the left lateral side draining into the left brachiocephalic vein. Smaller, short, friable veins drain the isthmus and posterior aspect of the gland. These veins drain directly into the innominate vein, and often cause problems during resection. Other unnamed and inconsistent branches drain the gland and flow into the internal thoracic veins, thyroid ima, and inferior thyroid veins.

Lymphatic Drainage

The lymphatic drainage of the thymus has been studied and discussed by multiple anatomists. The thymus lacks afferent lymphatic vessels. Efferent lymphatic vessels originate from the medulla and corticomedullary junction and travel superiorly through the supporting stroma to drain into the brachiocephalic, tracheobronchial, and internal mammary lymph nodes. The thymus derives innervation from the autonomic nervous system, the phrenic nerve, and the ansa hypoglossi. The sympathetic supply runs with the vasculature and originates from the stellate ganglion. The vagus nerve also sends out nerve trunks to the thymus.

Surgical Applications

Resection of Thymic Gland Tumors

Access to the thymus is attained through four primary approaches: transcervical, partial median sternotomy (upper split), complete median sternotomy, and thoracoscopically. The transcervical approach is advocated as most applicable in patients undergoing thymectomy for myasthenia gravis with a small (2 cm) thymoma or no tumor at all. A partial sternotomy, upper split, is a vertical incision below the sternal notch to the fourth costal cartilage. This allows a partial vertical sternotomy, which exposes the entire thymus and superior mediastinum. This is the approach utilized popularized by the Mayo Clinic when performing thymectomy for myasthenia gravis. This incision allows excellent exposure of the entire thymus and underlying vasculature for resection of moderate sized tumors if necessary. Tumors larger than 5–10 cm and those believed to be invasive should be resected through a complete median sternotomy to allow resection of the lateral-most aspects of the tumor. I have on occasion resected thymomas exceeding 10 cm through a right or left thoracotomy. This is not the preferred approach, because resection of the left lobe across the anterior mediastinum through a right thoracotomy is difficult, and it can be challenging to control the vascular supply of the left lobe. A transthoracic approach should be

entertained only when the tumor is large, bulky, and predominantly on one side of the mediastinum. All thymic tissue must be resected. Bilateral injury to the phrenic nerves must be avoided; however unilateral resection of an involved phrenic nerve by an invasive thymoma is accepted. If there is a question of preoperative involvement of the phrenic nerve a sniff test is required to determine if the contralateral nerve is intact thus avoiding ventilatory dependence if bilateral phrenic injury occurs.

Several basic principles of the surgical management of thymic tumors have been outlined by Wilkins:

1. Use of contrast-enhanced chest CT for characterization of tumor
2. Avoidance of needle or open biopsy to decrease risk for tumor implantation and spread
3. Complete median sternotomy for approach
4. Incision and opening of both pleural cavities for examination of the extent of tumor
5. Total thymectomy encompassing all thymic tissue
6. Extended radical resection for invasive tumors, including pericardium, pleura, lung parenchyma, phrenic nerve, and innominate vein when invaded
7. Partial pleurectomy (stripping) when pleural implants are noted

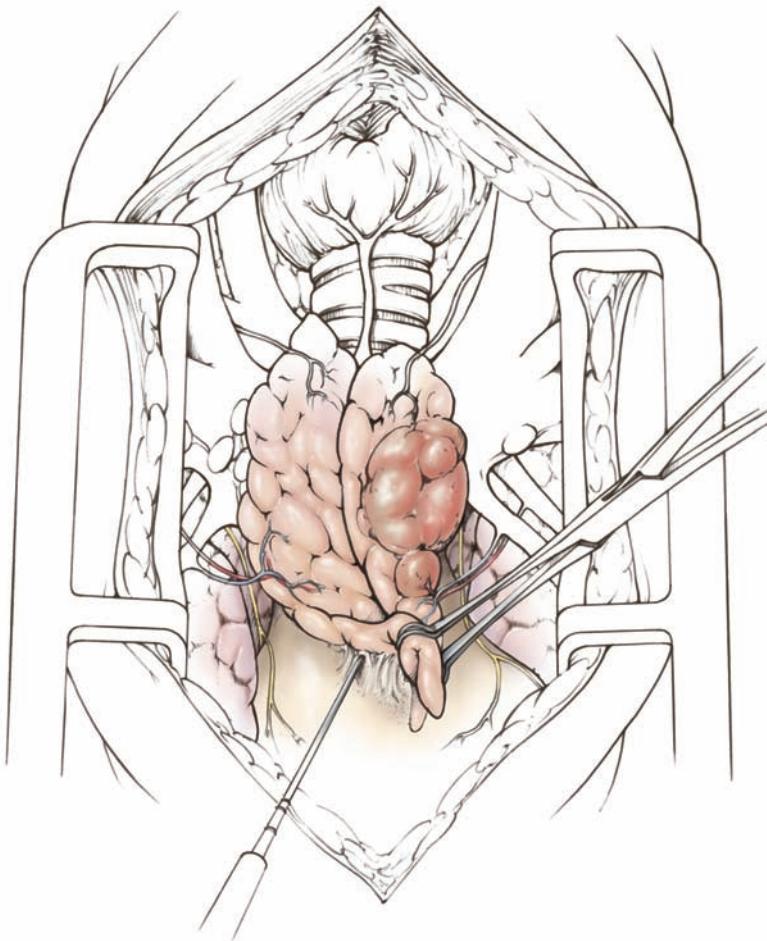


Figure 4.9

After complete median sternotomy, dissection is begun at the lower aspect of the uninvolved pole or the inferior margin if structural anatomy is distorted by tumor. Sharp and blunt dissection with scissors and cautery begins inferiorly and progresses superiorly and laterally.

Tissue planes are usually easily separable. Dense adhesions imply probable extension of tumor through the capsule into pleura or pericardium (invasive thymoma). Either or both should be excised with the tumor en bloc. The opposite pole is dissected similarly, so that the entire mass is elevated superiorly as the innominate vein is approached. The great vein of Keynes may be encountered and should be ligated. Generally two to five veins directly enter the innominate vein. Each should be ligated or clipped.

The dissection proceeds superiorly into the thoracic inlet and lower cervical region. The upper poles usually end inferior to the lower thyroid poles. The supporting ligamentous cord and the arterial supply should be ligated and divided. It is essential for all thymic tissue to be excised. All surrounding adipose and superior mediastinal lymph nodes should be excised, and an involved phrenic nerve should be resected when necessary. Care should be taken in patients with myasthenia gravis, which can contribute to respiratory insufficiency. It is justifiable and essential to resect all involved structures, based on low recurrence rate and extended survival with complete and total resection. The recurrence rate is less than 2% for stage I thymomas. In Wilkins' series, 20-year actuarial survival for stage I was 78%, for stage II 75%, and for stage III 21%. Other recurrence and survival data, as reported by Maggi et al., are equally favorable.

I have resected the phrenic nerve, lung parenchyma, innominate vein, and superior vena cava when indicated, without consequence. The innominate vein can usually

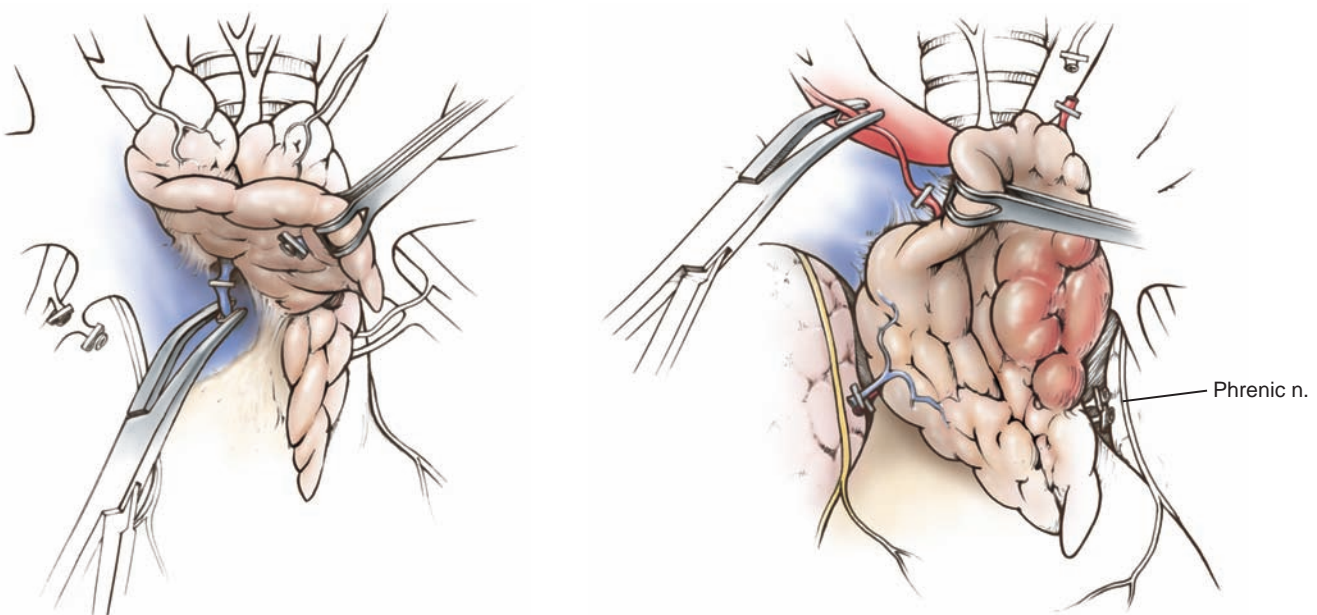


Figure 4.10

be ligated without sequelae. The superior vena cava should be reconstructed. Patients with large invasive tumors should undergo induction treatment with chemotherapy and radiation prior to resection. Survival advantage has been documented with this trimodality treatment plan by Wright and colleagues at Massachusetts General Hospital.

Anatomic Basis of Complications

- **Phrenic nerves:** Due to their lateral location on the pericardium superior to the pulmonary hilum, the phrenic nerves are not infrequently involved by thymic tumors. It is unusual for both phrenic nerves to be involved. A single nerve can and should be resected if necessary for complete resection. Care should be taken in patients with myasthenia gravis.
- **Recurrent laryngeal nerves:** The recurrent laryngeal nerves are usually well lateral in the chest and posterior in the neck. Care should be taken if the thymic tumor involves the left lobe and extends down near the aortic arch.
- **Innominate vein:** The innominate vein is the vascular structure most often injured during thymectomy. Great care should be employed when ligating venous tributaries entering the innominate vein from the thymus, to prevent possible catastrophic bleeding. Caution should also be used when opening the sternal retractor so as not to create a stretching or traction tear of the innominate vein.

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Cervical and Thoracic Trachea

The trachea and main stem bronchi, although not anatomically distinct from the remainder of the respiratory system, are less often affected by malignant processes, but lesions in this area present a considerably more formidable surgical challenge than malignancies of the lung parenchyma. Thoracic surgical pioneers such as Grillo, Pearson, and Mathisen have defined tracheal anatomy and formulated surgical approaches that are anatomically based. It is from their early work and from my own experience that this section is based.

Unlike the more commonly seen parenchymal bronchogenic carcinoma, tracheal tumors are relatively rare, occurring at an estimated rate of 2.7 new cases per million per year. Tracheal lesions may be categorized into three groups: primary malignant, primary benign, and secondary malignant. The presentation of tracheal tumors is often insidious and delayed. The most frequent complaint is dyspnea. Wheezing often develops and frequently leads to the mistaken diagnosis and treatment of adult-onset asthma. Stridor occurs as a relatively late sequelae, when at least 75% of the tracheal circumference is affected. Cough is a frequent complaint, and hemoptysis occurs in 33% of patients. When present at the carina or main stem bronchus level, the only symptoms or signs may be recurrent pneumonia. All of these subtle findings lead to delay in diagnosis if a high index of suspicion is not maintained.

Evaluation is radiographic and endoscopic. Posteroanterior and lateral chest radiographs often do not elucidate tracheal tumors. Over-penetrated cervical and upper thoracic views are frequently more revealing and may lead to more sophisticated radiologic endeavors. Conventional tracheal tomograms give additional information, but are of more historical interest, having been replaced by the ever-increasing sophisticated techniques of CT with three-dimensional reconstruction and virtual bronchoscopy.

The radiographic technique I favor is the three-dimensional reconstruction helical CT. Scans can be obtained at sections as small as 3 mm, beginning at the vocal cords and extending to the takeoff of the upper lobe bronchi. This technique allows accurate determination of the proximal, distal, and lateral extent of a lesion. The degree of circumferential narrowing and extratracheal mediastinal spread can be determined. Invasion of nearby structures is also revealed. Relevant mediastinal lymph nodes may also be assessed. Our current method allows computer-generated three-dimensional reconstruction of the trachea. Utilization of these techniques allows an accurate operative strategy to be formed. MRI allows coronal and capital images to be produced, but these images are not superior to those obtained with helical CT and are certainly more costly. I have rarely used MRI. Tracheobronchial barium contrast studies are of historical importance, but are not being performed in most centers doing tracheal surgery.

Endoscopic evaluation should follow radiographic imaging of the tumor. The surgical oncologist must be facile with both flexible and rigid bronchoscopy. Many patients will have nearly obstructing lesions, and therefore flexible bronchoscopy outside the operative theater may be inadvisable. One must be able to protect the potency of the airway at all times and be prepared to intubate the patient with the rigid bronchoscope or endotracheal tube if compromise occurs due to bleeding, swelling, or secretions. The flexible scope allows passage beyond a tumor in the trachea or major bronchi to obtain distal mucosal biopsy specimens and thereby determines the extent of distal resection or defines unresectability. This is most important when the tumor is of an adenoid cystic histologic type, because this tumor extends submucosally beyond visible gross tumor.

Video-assisted rigid bronchoscopy is my preferred endoscopic method. This allows more precise measurement of distances from the vocal cords to the proximal aspect of the tumor, the distal aspect of the tumor, and the carina. Length of the tumor and degree of circumferential narrowing can be determined. Photographic documentation is also performed. Carinal and main stem bronchial lesions may require both methods, because navigating around lesions to determine distal extent and margins is essential. I often use the neodymium:ytterium-aluminum-garnet (Nd:YAG) laser

Table 4.6 Frequency of tracheal tumors

	Boston Grillo, Mathisen (<i>n</i> = 198)	Moscow Perelman (<i>n</i> = 144)
Malignant tumors		
Adenoid cystic	80	66
Squamous cell	70	21
Spindle cell squamous	2	–
Adenocarcinoma	1	1
Adenosquamous carcinoma	1	–
Small cell carcinoid	1	3
Melanoma	1	–
Atypical carcinoid	1	–
Plasmacytoma	–	3
Intermediate tumors		
Carcinoid	10	20
Mucoepidermoid	4	1
Benign processes		
Squamous papilloma	5	2
Pleomorphic adenoma	2	–
Granular cell tumor	2	–
Chondroma	2	–
Neurilemoma	–	5
Hemangioma	1	4

Data adapted from Mathisen DJ. Tracheal tumors. *Chest Surg Clin N Am.* 1996;6:875–98; Perelman MI, Koroleva N, Birjukov J, et al. Primary tracheal tumors. *Semin Thorac Cardiovasc Surg.* 1996;8:400–02

to temporarily palliate the airway until definitive open-surgical resection can be performed. The jet ventilator is also on standby for oxygenation issues if necessary.

Primary malignant tumors of the trachea are more common than benign tumors. The two largest series of surgically resected primary tracheal tumors are from Massachusetts General Hospital (MGH) (198 patients) and the Center for Surgery, Moscow (144 patients). Adenoid cystic carcinoma was the most frequently encountered primary tumors (and primary malignant tumors) in both series: MGH series, 80 of 198 patients (40.4%); Moscow series, 66 of 144 patients (45.8%). Squamous cell carcinoma was the second most common malignant tumor in each series: MGH, 70 of 198 (35.4%); Moscow, 21 of 144 (14.6%). Carcinoid tumors were the third-most frequently seen tumors. Primary benign tumors were far less common: MGH, 10.6%; and Moscow, 16.6%. Many of these tumors are very rare and have been noted only one time, making meaningful statements somewhat superficial. In each series, resection of these benign tumors was curative and was accomplished with low mortality.

Secondary malignant tumors are those malignant processes involving anatomically adjacent organs that invade the trachea by extension of the primary tumor. Those tumors arise from the lung, larynx, esophagus, and thyroid gland.

Surgical Anatomy

The adult trachea is 10–12 cm long, depending on patient age, sex, and race. Beginning at the cricoid cartilage (C6 in the supine patient), it extends to the carina (T4 in the supine patient). The area from the undersurface of the vocal cords to the superior aspect of the cricoid is considered the subglottic area. The trachea is composed of C-shaped cartilages anteriorly and laterally. The posterior aspect of the trachea, the membranous trachea, is flat and pliable, opposed to and therefore directly anterior to the esophagus. The anterior cartilages and posterior membranous trachea are in a unique configuration that provides strength and patency while allowing dynamic physiologic changes during respiration. The trachea is composed of 20–22 of these C rings, with approximately 2.1 rings per centimeter. The tracheal length may vary as much as 1.5–2.5 cm during respiration and swallowing.

The cervical trachea is relatively unprotected and vulnerable from the cricoid cartilage to the sternal notch. It parallels the vertebral column more so than the sternum, traveling posteriorly to lie deep within the posterior mediastinum posterior to the cardiac structures. The angle between the sternum and trachea approaches 90° at the thoracic inlet and increases with age as kyphosis progresses. This has significant operative ramifications as the cervical trachea (50% of the tracheal length) may be exposed through a properly placed transverse cervical collar incision. The proximal cervical trachea is posterior to the thyroid isthmus, inferior thyroid veins, and thyroid ima artery when present. The sternothyroid and sternohyoid muscles, cervical fascia, and inconsistent crossing branches of the anterior jugular veins are superficial

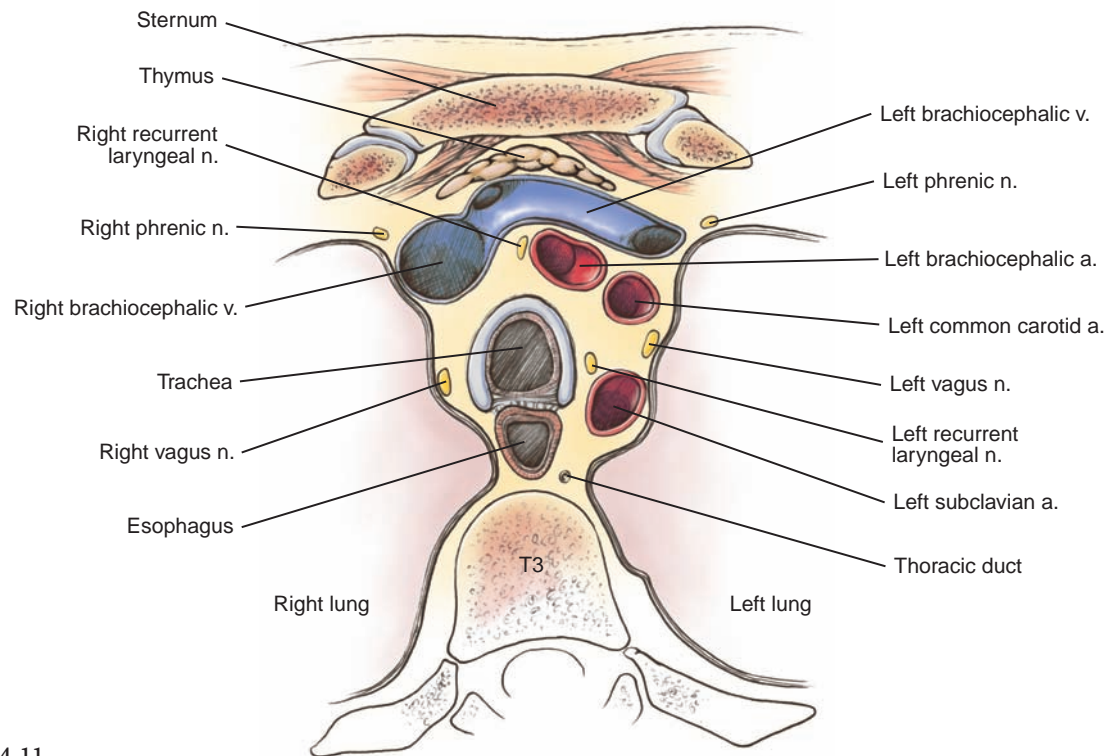


Figure 4.11

to these structures. The right and left lobes of the thyroid gland cover the lateral aspects of the proximal cervical trachea. The cervical esophagus is directly posterior to the membranous trachea. One of the vital structures in this area is the recurrent laryngeal nerves. The recurrent nerves are small cord-like structures found in the tracheoesophageal groove. They are difficult to identify, and therefore the area of the tracheoesophageal groove should be avoided during dissection.

The second part of the trachea begins at or below the sternal notch. This is an arbitrary division used in planning a surgical approach for resection. At the level of the sternal notch the trachea begins to dive posteriorly and deep as it follows the vertebral column. Access for resection is better obtained through a partial median sternotomy (upper split), full median sternotomy, or right posterolateral thoracotomy.

Anteriorly and to the right laterally are the innominate artery and left innominate vein. The left carotid and subclavian arteries and the left vagus and phrenic nerves are to the left and lateral of the proximal thoracic trachea. Two centimeters more distal, the anterior surface of the thoracic trachea is crossed by the aortic arch. The superior vena cava comes to oppose the right lateral aspect of the trachea at this point, and the esophagus begins to deviate from the midline to the left posterolateral aspect of the thoracic trachea. As the trachea travels deeper into the chest and emerges from underneath the aortic arch, the azygos vein is encountered on the right as it travels anteriorly to empty into the superior vena cava. Great caution should be exercised in this area during resection or mediastinoscopy, because the azygos vein is easily injured by traction tears or inadvertent biopsy. Finally, the most distal aspect of

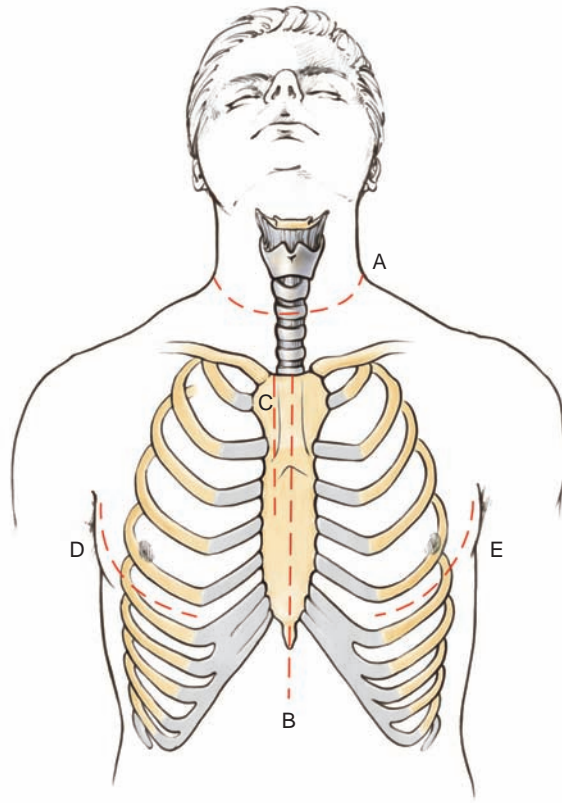


Figure 4.12

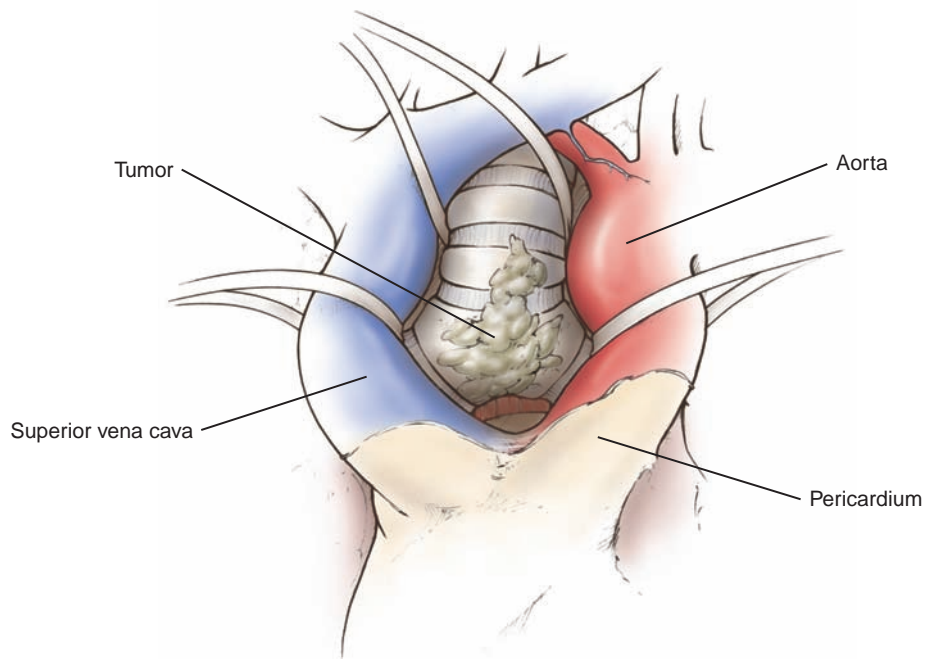


Figure 4.13

the thoracic trachea passes posterior to the bifurcation of the main pulmonary artery. The trachea ends at the carina, which is deep to the posterior pericardium. The area may be approached anteriorly by mobilizing the superior vena cava and ascending aorta laterally and incising the posterior pericardium.

Blood Supply

The major arterial supply to the cervical trachea is the inferior thyroid artery. Grillo and Miura are credited with defining the upper vascular supply in 1966 when they injected barium sulfate into the inferior thyroid artery. They revealed that the inferior thyroid artery gives rise to three branches, which travel medially to the lateral wall of the trachea where they coalesce to form a lateral longitudinal artery just anterior to the tracheoesophageal groove. This finding was substantiated when Salassa et al. performed a cervical dissection in 21 human cadavers. They documented several anatomic patterns of the inferior thyroid artery. Most commonly, the artery arose from the thyrocervical trunk of the subclavian artery and traveled posteriorly to the common carotid artery, then divided into three branches. These branches coalesced to form a longitudinal artery that gave off small branches to the membranous portion of the trachea between cartilages. This pattern of three branches occurred more than half of the time. The next most common patterns consisted of two branches in 35% and one branch in 12%. The first branch typically supplies the lower cervical trachea;

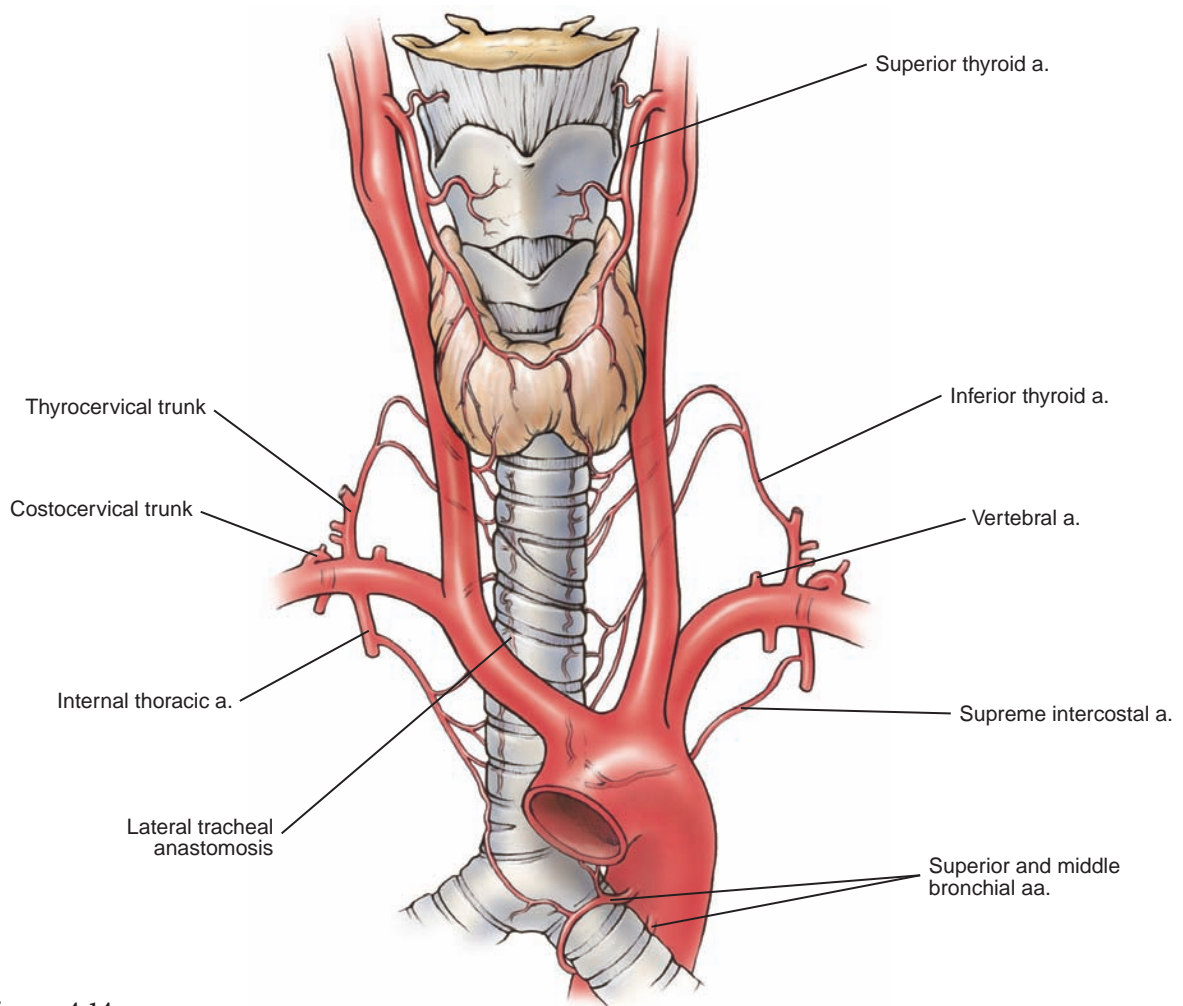


Figure 4.14

the second branch supplies the area of the trachea between the first and third arterial branches, and a portion of the cervical esophagus; and the third, most superior of the three branches, supplies the cervical trachea underlying the thyroid gland.

The thoracic tracheal arterial supply is much more inconsistent and involves more arterial sources. The innominate and subclavian arteries remain the parent source. The supreme intercostal artery was revealed by Salassa et al. to be the main source of arterial supply in 38% of their cadavers. Branches originating from the subclavian proximal to the vertebral artery ostia were the major sources in 31% of cadavers. As in the cervical region, these arteries arrive on the lateral aspect of the trachea from their superior origin and form the lateral longitudinal artery of the trachea. Finally, the right internal mammary artery was the main arterial supply in 13% and the innominate artery in 19% of cadavers. All cervical and thoracic tracheal supply sources approach the trachea laterally and form lateral longitudinal anastomoses about 0.5 cm anterior to the tracheoesophageal groove. These vessels of the longitudinal network are 1–2 mm in diameter. This network gives off two branches, the anterior and posterior transverse intercartilaginous arteries. These vessels enter between the cartilage rings and form a capillary plexus in the submucosa. The posterior membranous trachea is supplied by small tracheal branches from primary esophageal vessels. The cartilaginous rings receive their blood supply by diffusion of nutrients via the submucosal plexus. The posterior membranous portion of the trachea is composed of fibroelastic tissue and smooth muscle that is responsible for the changing diameter of the trachea and is sometimes called the trachealis muscle.

Venous drainage is from the submucosa through ever enlarging channels that eventually reach the inferior thyroid veins. Tracheal lymphatic vessels drain into cervical, peritracheal, and tracheobronchial lymph-node chains. The trachea is supplied by sympathetic and parasympathetic fibers.

Histologically the tracheal mucosa is composed of pseudostratified ciliated columnar epithelium and mucus-producing goblet cells. Microvilli containing brush cells are also present.

Surgical Applications

The general surgical oncologist and thoracic surgical oncologist must be knowledgeable regarding both flexible and rigid bronchoscopy. Each has its advantages and may often complement the other.

An advantage of flexible fiberoptic bronchoscopy is that it can be performed in the awake patient after application of topical lidocaine administered by nebulizer. Intravenous sedation with short-acting benzodiazepines and synthetic narcotics is advantageous because the cooperative patient is more easily examined. Each of these agents may be reversed at the completion of the procedure by administration of flumazenil (Romazicon) and naloxone (Narcan), respectively.

Bronchoscopy

The bronchoscope may be attached to a video system for magnification and photographic documentation or used for standard direct vision. The bronchoscope may be introduced through the nares or orotracheally. I find it easier to pass the scope through the nares, thus avoiding the posterior tongue and thereby reducing the gag reflex.

The first structures visualized are the epiglottis and the laryngeal complex. Both form and movement of the vocal cord should be analyzed. The scope is passed down through the vocal cords into the subglottic area, noting the diameter. Advancement to the carina is then accomplished, noting any endotracheal tumor or deformity and documenting its length, reduction of tracheal diameter, and distances from the vocal cords and carina. The right and left bronchi are then examined. The flexible scope may be passed all the way down to the lobar and segmental bronchi. The flexible scope may be used to visualize anatomic details or obtain biopsy specimens or for laser destruction of airway tumors.

Rigid bronchoscopy requires a general anesthetic and paralysis. The surgeon should be prepared to intubate with the rigid scope should the airway collapse during relaxation. A video-assisted bronchoscope is far superior to the traditional, poorly lit direct vision scope. I use the Dumon-Harrell ventilating bronchoscope (Bryan Corp., Worcester, MA). The patient is placed in the supine position with the neck hyperextended, eyes shielded, and upper teeth protected. The scope is introduced posterior to the base of the tongue and advanced forward into the posterior pharynx to view the epiglottis. The epiglottis is lifted anteriorly with the tip of the scope to allow vocal cord examination. Passage through the vocal cords is facilitated by rotation of the scope 90°. The subglottic area and proximal, middle, and distal trachea may then be examined. The experienced endoscopist can pass the scope to the level of the segmental bronchi. The rigid scope can be used for both mechanical and Nd:YAG laser destruction of tumor as a temporizing maneuver to open the airway prior to resection or as palliation in the high-risk surgical candidate. On occasion, the flexible scope may be introduced through the rigid scope to reach the more distal airway.

Incisions for Tracheal and Major Bronchial Resections

The trachea can be approached through a multitude of incisions. It is best to divide the trachea into cervical and thoracic divisions to plan the surgical approach. Fully half of the trachea, the cervical trachea, can be adequately exposed through a cervical collar incision with the patient supine. When a transverse roll is placed underneath the shoulders and the head hyperextended, an additional 2–4 cm of upper thoracic trachea may be visualized. A partial or complete median sternotomy may be added for further exposure of the upper or middle thoracic portions of the trachea. The cervical trachea is usually defined as that portion above the arch of the aorta. If the site of resection begins below the aortic arch then the trachea should be exposed via a right thoracotomy.

A complete median sternotomy allows access to the carina. It is unusual and generally unnecessary to approach the carina from an anterior direction for oncologic purposes. This approach is most often used for management of carinal trauma or closure of a postoperative bronchopleural fistula after pneumonectomy when a transthoracic approach is not possible.

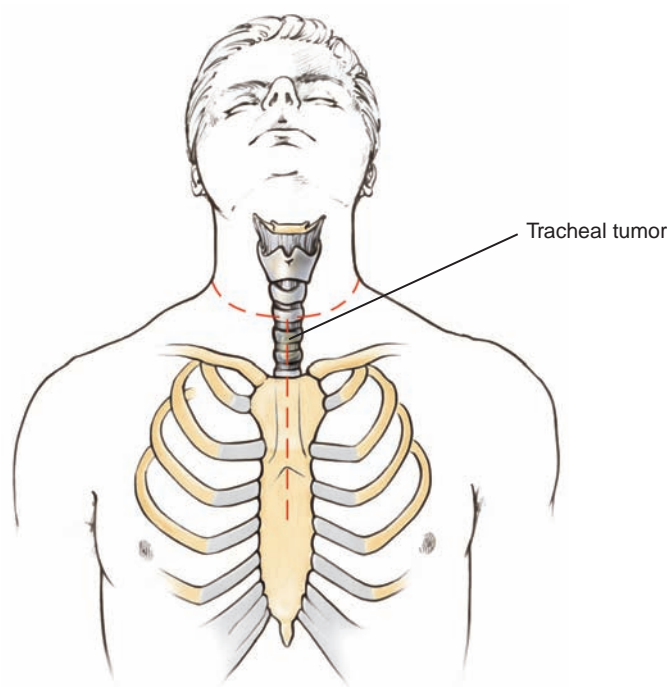


Figure 4.15

Through a complete median sternotomy the anterosuperior aspect of the pericardium is opened. The reflections of the pericardium are removed from the great vessels with the electrocautery. The superior vena cava is released from its pericardial attachments and freed from the underlying right main pulmonary artery and retracted with tapes laterally to the right. The ascending aorta is freed from pericardial reflections and the underlying right main pulmonary artery and retracted with tapes laterally to the left. The right main pulmonary artery may need to be mobilized and retracted inferiorly. The posterior pericardium is then incised to reveal the carina. Mobilization maneuvers can also be performed through this incision.

A traditional right posterior lateral thoracotomy is the incision of choice for exposure of distal thoracic trachea, the carina, and both main stem bronchi. This approach allows excellent exposure of the lower half of the trachea and carina. Vertebral kyphosis increases with age, bringing more of the cervical trachea below the thoracic inlet into the chest. Allen has shown that large differences in the amount of extrathoracic trachea occur between flexion and extension. Thus, with profound flexion in the younger patient, the cricoid cartilage may be brought very near the thoracic inlet, making more of the lower cervical and upper thoracic trachea accessible through a posterolateral thoracotomy. When this approach is utilized, a standard skin incision is made, the latissimus muscle is mobilized and divided, and the serratus anterior muscle is mobilized, reflected anteriorly, and spared. I have not chosen to perform tracheal resection and reconstruction through a vertical muscle-sparing incision. The fifth intercostal space is usually utilized, but the fourth intercostal space is preferred if the lesion is in the upper thoracic trachea.

The left posterolateral thoracotomy is infrequently utilized for tracheal and carinal resection because of the limited exposure related to the presence of the aortic

arch and descending aorta. Occasionally this incision and approach are utilized for a sleeve resection involving the left main stem bronchus.

Resection and Reconstruction of Cervical Trachea

Primary and secondary tumors involving the upper half of the trachea are most easily approached through a collar incision. The patient is prepared and draped for a median sternotomy in case additional exposure of the upper thoracic trachea is required. Through the collar incision, superior and inferior subplatysmal flaps are formed. The midline of the sternohyoid and sternothyroid is identified and incised and the muscles retracted laterally with stay sutures or neuro hooks. The thyroid isthmus is divided as necessary. The anterior and lateral aspects of the trachea are now exposed from the cricoid to the sternal notch.

Mobilization of the trachea is essential for achieving a tension-free anastomosis after resection. All fascial and areolar tissue attachments are freed from the anterior surface down to and including the anterior surface of the carina and main stem bronchi. Great care must be exercised in the region of the innominate vessels to avert vascular injury. The posterior mobilization is more easily performed after proximal transection. The lateral attachments, or “tissue stalks,” should be left undisturbed to prevent injury to the longitudinal tracheal artery and recurrent nerves. The site of proximal transection should have been previously determined via bronchoscopy and CT; thus the site of the proximal incision on the trachea and the length of the resection should be predetermined. Final determination is now performed by having the first assistant pass a fiberoptic bronchoscope proximal to the tumor. The surgeon then passes an 18-gauge needle through the anterior wall of the trachea at the incision site. The bronchoscopist will determine the correctness of the chosen site and adequacy of the margin.

The trachea is divided anterior to posterior. The distal transection site is determined by direct inspection. A sterile malleable wire–reinforced endotracheal tube is passed into the remaining distal trachea for cross-field ventilation during the reconstruction.

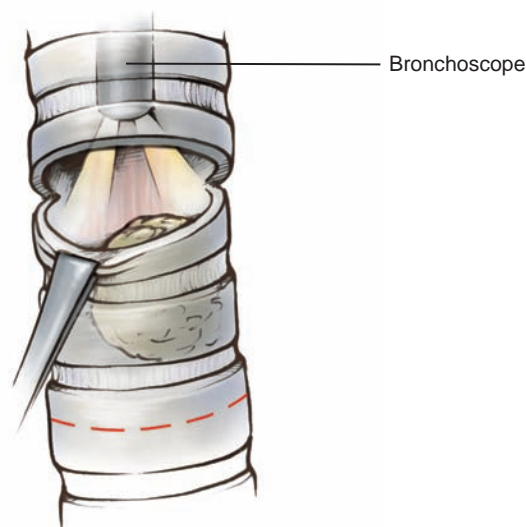


Figure 4.16

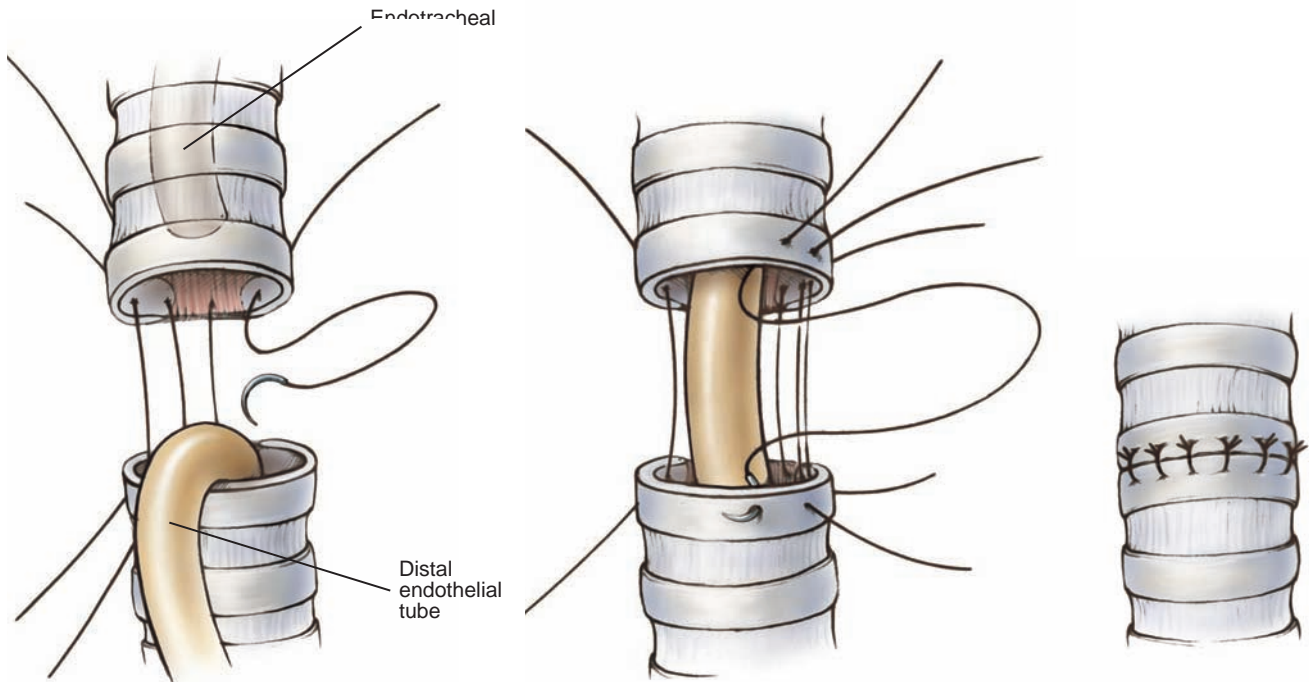


Figure 4.17

When proper ventilation is ensured, the membranous portion of the remaining tracheal segment is sharply and bluntly separated from the underlying esophagus. The reconstruction may now be performed. It is essential that the end-to-end tracheal anastomosis be performed with no tension, which on occasion will require additional release maneuvers such as the hilar and laryngeal release described by Heitmiller. When the tumor is an adenoid cystic carcinoma, frozen-section analysis of multiple areas proximally and distally must be performed, because this tumor has the propensity to extend in the submucosa far beyond grossly recognizable tumor. After confirming free margins, the anastomosis is begun.

Two 0 silk sutures are placed through the lateral cartilage of the proximal and distal segment 2 cm from the cut end. Hemostats are placed on these “traction sutures,” which are then crossed and used to pull the segments toward each other. The membranous trachea is brought together utilizing a running 4-0 PDS suture with the ends secured with straight hemostats. Periods of apnea are used for this portion of the anastomosis. All cartilaginous sutures are then placed using interrupted 3-0 PDS with the knots tied on the outside first, and then tied in order to be under the least possible tension. The distal endotracheal tube is removed prior to tying the anterior suture line, and the original endotracheal tube, which was left in place in the proximal trachea, is advanced through the partially completed anastomosis into the distal trachea. The endotracheal tube placement is confirmed and ventilation resumed. The lateral and anterior portions of the anastomosis are completed in similar fashion, utilizing interrupted sutures with knots tied on the outside. The lateral stay sutures are now tied to further reduce the tension. The strap muscles are reapproximated, the platysma is reapproximated, and the skin is closed. The patient’s neck is brought

to maximal flexion. Historically, the chin was sutured to the anterior chest wall for 5 days to prevent extension of the neck and undue tension on the anastomosis. More recently, less than 25% of the time a chin stitch is placed, especially in first-time cases and when less than three rings are removed. All attempts are made at extubation to prevent suture line disruption by the endotracheal tube.

Resection and Reconstruction of Thoracic Trachea

Tumors in the thoracic portion of the trachea, not including the carina, are most easily approached through a right posterolateral thoracotomy. A left double-lumen endotracheal tube and single-lung ventilation should be utilized. Mediastinoscopy should be performed immediately prior to the anticipated resection. This accomplishes two objectives. First, paratracheal lymph nodes are sampled. When the tumor is parenchymal in origin, this nodal group remains an N2 group and should preclude further resection except under investigational multimodality protocol situations for stage IIIA bronchogenic carcinomas. When the tumor is primary to the intrathoracic trachea, positive paratracheal lymph nodes are a relative contraindication to resection, depending on the overall clinical situation. Second, mediastinoscopy also serves the purpose of dividing tissue in the pretracheal plane down to the carina and left main stem bronchus. This maneuver enhances mobilization. The parietal pleura overlying the trachea is identified and incised. The right vagus nerve is mobilized posteriorly and the superior vena cava anteriorly. The azygous vein is occluded with a suture at its entrance into the superior vena cava and divided at the chest wall after ligation. The length of the intervening section is maintained in this fashion and allows the vein to be used as an inlay tissue graft covering of the

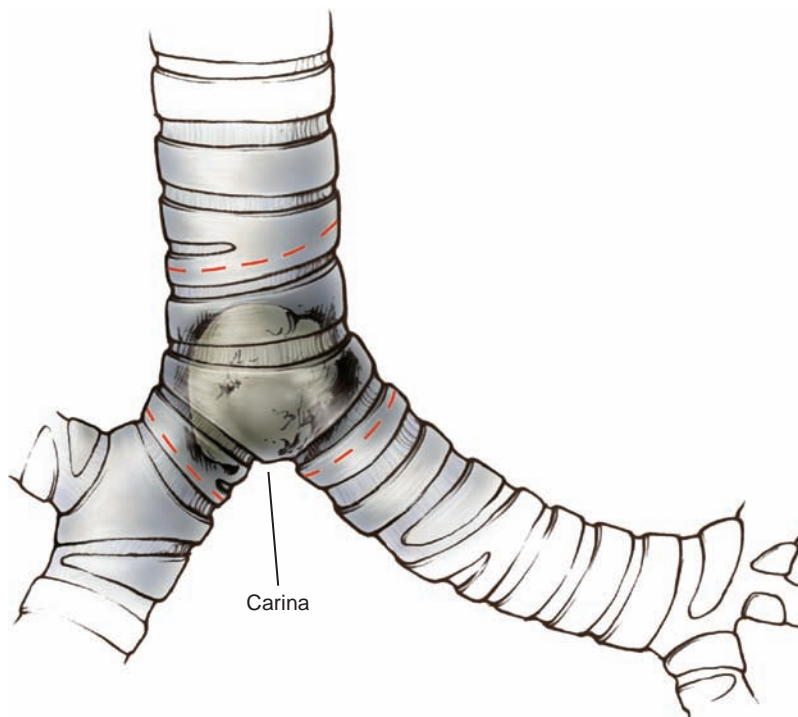


Figure 4.18

tracheal anastomosis. The proximal trachea, carina, and right and left main stem bronchi are further mobilized and encircled with cotton tapes. Division of the right inferior pulmonary ligament and right hilar release allows additional mobilization. The lateral aspects of the trachea are once again avoided.

The sites of proximal and distal division are determined as described for cervical resection. The tracheal anastomosis in the thorax is sometimes facilitated by placement of sutures first in the left lateral wall, because this is now the deepest aspect. The membranous portion, anterior aspect, and finally the right lateral aspect are running and interrupted PDS sutures with knots tied on the outside. The endotracheal tube is managed as previously discussed. An “azygous vein flap” may be sutured over the anastomosis to separate it from the surrounding structures thus preventing a fistula. A longitudinal pericardial flap or pleural flap may also be used for the same purpose.

Tumors at the carina or proximal main stem bronchi without involvement of the lung parenchyma are uncommon. Those tumors that are relatively small and endobronchial may be resected utilizing a carinal resection or sleeve pneumonectomy. Such resections require great experience and clinical judgment, and must be approached on an individual basis.

The right main stem bronchus is anastomosed end to side to the distal thoracic trachea. The end of the left main stem bronchus is then anastomosed to the distal end of the thoracic trachea. Resection and reconstructive techniques are beyond the scope of this text. Mathisen provides an excellent description of these techniques in his work “Carinal Reconstruction: Techniques and Problems.”

Reconstruction After Carinal Resection

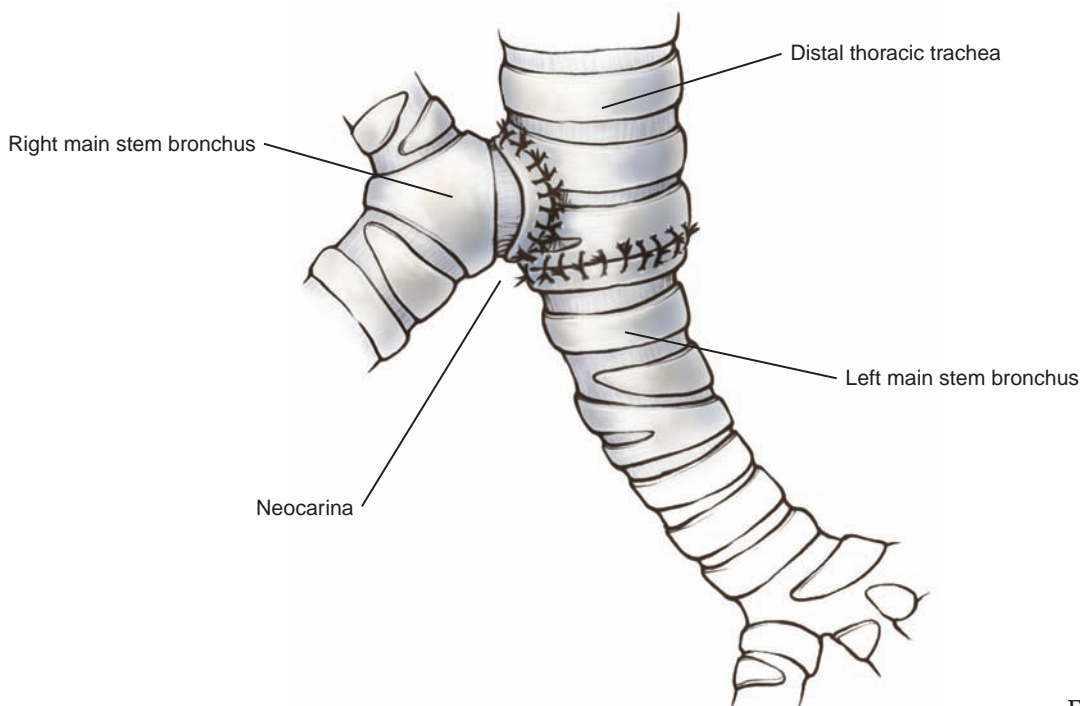


Figure 4.19

Anatomic Basis of Complications

- The surgical oncologist must recognize that the longitudinal tracheal artery is present laterally and is the vital blood supply of the trachea. Disruption will lead to possible anastomotic failure.
- The recurrent laryngeal nerves run laterally in the tracheoesophageal groove. Failure to avoid this area may lead to unilateral or bilateral vocal cord paralysis.
- When a lower cervical tracheal resection is performed, the reconstruction may lie in close proximity to the transversely running innominate artery. A muscle or pericardial flap should be interposed between the tracheal anastomosis and the innominate artery to prevent trachoinnominate artery fistula.

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Lung

In 2008, 1,500,000 new lung cancer cases will be diagnosed worldwide; while in the United States over 215,000 patients will be diagnosed. Smoking is the most common cause of lung cancer in the United States. It is estimated that over 90% of these cancers are caused by smoking. Currently, there are over 95 million current or former smokers in the United States.

Lung cancer is the most common cause of cancer death in both, men and women, far exceeding the next three most common causes combined death rates of colon, prostate, and breast cancer. Lung cancer deaths in women surpassed death due to breast cancer more than a decade ago, in 1987. In 2008, lung cancer was responsible for 25% of all cancer deaths in women.

The expected 5-year survival rate for all patients in whom lung cancer is diagnosed is 16% compared to 65% for colon, 89% for breast and 99% for prostate. The overall 5-year survival rate is 50% for cases detected with localized disease. However, only 25% of lung cancer cases are diagnosed at an early stage. Patients with distant disease have a 5-year survival, which is usually less than 3%.

Lung cancer is a relatively new disease, a disease of the twentieth century, due to environmental pollution from industry and more commonly tobacco use. The first recognized correlation between the environment and pulmonary malignancies occurred in 1879 when Haerting and Hesse reported that 75% of deaths among the Schneeberg miners of the Black Forest in Germany were due to pulmonary tumors. The first clinical report of a primary pulmonary malignancy was authored by G.H. Bayle in 1810, who described a left hilar pulmonary mass with lymph-node, liver, and subcutaneous tissue metastases.

The motivational causes prompting the development of thoracic surgery were trauma and infection (i.e., tuberculosis and empyema). Development of thoracic surgical oncology was delayed by the slow development of endotracheal intubation, positive pressure ventilation, and inhalation anesthetics. The first successful lobectomy for malignancy in which there was anatomic dissection and ligation of the hilar structures was by H.M. Davies, an English surgeon who resected the right lower lobe. Prior to this, mass ligation of the hilar structures was performed. The first successful pneumonectomy for lung cancer was performed by Ewerts A. Graham in a 48-year-old fellow physician. The hilar structures were mass ligated and the bronchus closed with catgut. The year was 1933, and the patient survived 30 years despite metastasis to regional lymph nodes. The reader is referred to Kittle's description of the history of thoracic surgical oncology for an excellent in-depth discussion.

Significant improvements have been made in cardiorespiratory assessment, perioperative staging, and perioperative care. Belief that removal of the entire lung, pneumonectomy, was superior to lobectomy led to mortality rates of 40–50% from the 1930s to the late 1950s. By 1983 Ginsberg et al. were reporting a 30-day operative mortality of 3.9% in a series of 2,500 consecutive resections for lung cancer. In 1998, Wada et al. reported a 30-day operative mortality of 1.3% in 7,099 consecutive resections for

lung cancer and in 2008 Boffa et al. reviewed the data from the Society of Thoracic Surgeons General Thoracic Surgery database and reported a 30-day operative mortality of 2.5% in 9,033 consecutive resections for lung cancer.

Despite the marked improvements in perioperative care and marked reduction in operative mortality, there has been no statically significant improvement in overall 5-year survival for resectable non-small-cell lung cancer in the last 40 years. Currently, 5-year survival approximates 40%, not significantly different from Pearson's report in 1985, in which he pointed out that 5-year survival at the beginning of his career was 23%. Our failure to progress is largely due to inaccuracy of preoperative clinical staging, lack of uniform performance of operative staging, lymph-node dissection, and largely ineffective postoperative adjuvant therapy. Introduction of neo-adjuvant chemotherapy and chemotherapy plus radiation therapy holds true promise for improving 5-year survival for lung cancer patients with locoregional lymph-node metastasis from primary lung cancer. Only continued vigilance in perioperative care, improved accuracy of perioperative and intraoperative staging, and institution of multimodality protocols as treatment strategy will lead to meaningful improvement in 5-year survival.

Staging of Lung Cancer

Early classification and categorization of the different histologic types of lung cancer evolved and culminated in the classification scheme proposed by the World Health Organization in 1981. Clinically the thoracic surgical oncologist is faced with a more practical division of these various lung cancers into two biologically diverse subgroups: small-cell lung carcinomas and non-small-cell lung carcinomas. Small-cell lung carcinomas are believed to be biologically aggressive, frequently having locoregional nodal metastasis and distant organ metastasis at the time of discovery. The role of surgery in small-cell lung carcinoma is often limited to diagnosis and staging, and chemotherapy plus radiation therapy is considered the best therapeutic option. The role of surgery is somewhat controversial but distinctly present. Urschel and Kohman have discussed the surgical management of peripheral and central small-cell lung carcinomas, respectively.

The thoracic surgeon is most often called on to intervene and manage pulmonary malignancy due to non-small-cell lung carcinomas. The most frequently encountered non-small-cell lung carcinomas are (1) squamous cell carcinoma, (2) adenocarcinoma, (3) large cell carcinoma, (4) adenosquamous carcinoma, and (5) carcinoid tumors; the first three are the most common. All authors note a decrease in the predominance of squamous cell carcinoma and an increased number of adenocarcinomas.

Accurate radiologic and surgical invasive staging is essential to determine operability in patients with apparently favorable and resectable lesions. Computed tomography (CT) has been the modality of choice for staging. With the introduction of positive emission tomography (PET) scanning extrathoracic staging has improved, but false

positives still exist up to 30%, especially in the mediastinum. Tissue biopsy is mandatory to accurate stage patients who present with advanced disease. Accurate staging allows prognostic determination of 5-year survival for patients with stage I and stage II disease, identifies patients with stage IIIA disease who might benefit from neoadjuvant chemotherapy and radiation therapy trials prior to resection, and eliminates patients with stage IV disease with distant metastasis who generally will not benefit from surgical resection. Accurate staging determines the extent of disease within the individual patient, allowing the patient to be grouped with patients with similarly staged disease for purposes of providing conventionally proved therapeutic options or providing access to experimental multimodality therapeutic protocols when effective therapeutic options have not been established for that patient's lung cancer stage.

World Health Organization Classification of Lung Tumors

- Epithelial tumors
 - Benign
 - Papillomas
 - Squamous cell
 - "Transitional"
 - Adenomas
 - Pleomorphic ("mixed tumor")
 - Monomorphic
 - Other
 - Dysplasia
 - Carcinoma in situ
 - Malignant
 - Squamous cell carcinoma
 - Variant: Spindle cell (squamous) carcinoma
 - Small-cell carcinoma
 - Oat cell
 - Intermediate cell type
 - Combined oat cell
 - Adenocarcinoma
 - Acinar
 - Papillary
 - Bronchoalveolar
 - Solid carcinoma with mucus formation
 - Large-cell carcinoma
 - Giant cell
 - Cleaved cell
 - Adenosquamous carcinoma
 - Carcinoid tumor
 - Bronchial gland carcinoma
 - Adenoid cystic
 - Mucoepidermoid
 - Other
 - Other

TNM Description

Primary Tumor (T)

TX Primary tumor cannot be assessed, or tumor proved by the presence of malignant cells in sputum or bronchial washings but not visualized at imaging or bronchoscopy

T0 No evidence of primary tumor

Tis Carcinoma in situ

T1 Tumor ≤ 3 cm in greatest dimension, surrounded by lung or visceral pleura, without bronchoscopic evidence of invasion more proximal than the lobar bronchus^a (i.e., not in the main bronchus)

T2 Tumor with any of the following features of size or extent:

>3 cm in greatest dimension

Involves main bronchus, ≥ 2 cm distal to the carina

Invades the visceral pleura

Associated with atelectasis or obstructive pneumonitis that extends to the hilar region but does not involve the entire lung

T3 Tumor of any size that directly invades any of the following: chest wall (including superior sulcus tumors), diaphragm, mediastinal pleura, parietal pericardium; or tumor in the main bronchus, <2 cm distal to the carina, but without involvement of the carina; or associated atelectasis or obstructive pneumonitis of the entire lung

T4 Tumor of any size that invades any of the following: mediastinum, heart, great vessels, trachea, esophagus, vertebral body, carina; or tumor with a malignant pleural or pericardial effusion,^b or with satellite tumor nodule(s) within the ipsilateral primary tumor lobe of the lung

Regional Lymph Nodes (N)

NX Regional lymph nodes cannot be assessed

N0 No regional lymph-node metastasis

N1 Metastasis to ipsilateral hilar lymph nodes, and intrapulmonary nodes involved by direct extension of the primary tumor

N2 Metastasis to ipsilateral and/or subcarinal lymph node(s)

N3 Metastasis to contralateral mediastinal, contralateral hilar, ipsilateral or contralateral scalene, or supraclavicular lymph node(s)

Distant Metastasis (M)

MX Presence of distant metastasis cannot be assessed

M0 No distant metastasis

M1 Distant metastasis present^c

From Mountain CF. Revisions in the international system for staging lung cancer. Chest 1997;111:1710–17.

^a The uncommon superficial tumor of any size with its invasive component limited to the bronchial wall, which may extend proximal to the main bronchus, is also classified T1.

^b Most pleural effusions associated with lung cancer are due to tumor. However, in a few patients multiple cytopathologic examinations of pleural fluid show no tumor. In these cases, the fluid is non-bloody and is not an exudate. When these elements and clinical judgment dictate that the effusion is not related to the tumor, the effusion should be excluded as a staging element and the patient's disease should be staged T1, T2, or T3. Pericardial effusion is classified according to the same rules.

^c Separate metastatic tumor nodule(s) in the ipsilateral nonprimary tumor lobe(s) of the lung are also classified M1.

Stage Grouping TNM Subsets ^a	
Stage	TNM Subset
0	Carcinoma in situ
IA	T1 N0 M0
IB	T2 N0 M0
IIA	T1 N1 M0
IIB	T2 N1 M0
IIIA	T3 N0 M0
	T3 N1 M0
	T1 N2 M0
	T2 N2 M0
IIIB	T3 N2 M0
	T4 N0 M0
	T4 N1 M0
	T4 N2 M0
	T1 N3 M0
	T2 N3 M0
	T3 N3 M0
	T4 N3 M0
IV	Any T, Any N M1
From Mountain CF. Revisions in the international system for staging lung cancer. Chest 1997;111:1710–7.	
^a Staging is not relevant for occult carcinoma, designated TX N0 M0.	

The TNM system for staging lung cancer is based on anatomic criteria, as are most other malignancies (T – tumor size, N – presence or absence of regional lymph-node metastasis, and M – presence or absence of distant metastasis). Originally staging proposals for lung cancer were formed in the middle to late 1950s by the American Joint Committee for Cancer Staging and End Results Reporting (AJCC) and the International Union Against Cancer (UICC). Over the years, differences in survival were noted among some of the subset groups, leading the AJCC and the UICC to form a single system in 1985, which was presented at the Fourth World Congress on Lung Cancer by the task force chairman, Clifton F. Mountain, M.D. This universally accepted system was recently revised and published in June 1997. This system is the presently accepted staging system for lung cancer. The revised international system for staging lung cancer was formulated to address the heterogeneity of end results (i.e., survival) within the stage groupings and to provide for greater specificity in stage classification while disrupting the current system as little as possible. A new revised staging system led by Peter Goldstraw M.D. will be coming out in 2009 to address changes in stage I in regards to tumor size and satellite lesions.

Clinical staging is accomplished by noninvasive means (plain chest radiography, computerized tomography, MRI, radionuclide scanning, positron emission tomography) and invasive means (fine-needle aspiration biopsy, rigid and fiberoptic bronchoscopy, endoscopic bronchoscopy, endoscopic ultrasound, mediastinoscopy, mediastinotomy, video-assisted thoracoscopy, thoracotomy). Detailed descriptions and virtues of these various investigational maneuvers are not within the format of this text but are contained in texts by Roth et al. and by Aisner et al.

Stage-Based Treatment of Lung Cancer

Surgical therapy remains the mainstay of treatment for stage I and stage II bronchogenic carcinoma. Neoadjuvant chemotherapy and chemotherapy–radiation therapy followed by surgical resection have improved survival in patients with stage IIIA disease, but the chemotherapeutic agents and sequencing of chemotherapy, radiation therapy, and surgical resection remain controversial. More recently patients with stage IB (tumors greater than 4 cm), stage II, and stage IIIA have shown improved survival with cisplatin-based adjuvant chemotherapy and should be offered to all patients. Stage IIIB lung cancer has been treated largely with chemotherapeutic agents and radiation therapy. Rarely is stage IIIB disease on the basis of T4 involvement curable by surgery alone unless T4 status is done to a satellite lesion in the same lobe as the primary tumor. Stage IV disease has an overall poor prognosis with treatment options usually only for palliation.

Stage I non-small-cell lung carcinomas are tumors less than 3 cm in diameter not invading the visceral pleura, with no nodal metastasis or stage IB tumors are larger than 3 cm, invading the visceral pleura or involving the main stem bronchus 2 cm distal to the carina. If postobstructive atelectasis or pneumonitis develops, the tumor is considered stage IB. These tumors should be resected by lobectomy with a mediastinal lymphadenectomy. Lobectomy results in superior survival, compared with wedge resection or segmental resection. Five-year survival for pathologically staged IA non-small-cell lung carcinomas is 75%, and for IB is 60%.

Stage II non-small-cell lung carcinomas consist of stage IIA (T1 N1 M0) and IIB (T2 N1 M0 and T3 N0 M0) tumors. The N1 designation is defined as metastasis to ipsilateral peribronchial or ipsilateral hilar lymph nodes and intrapulmonary nodes involved by direct extension of the primary tumor. This stage is defined by the presence of N1 nodal metastasis, which has significant implications for survival. Stage IIA (T1 N1 M0) has a pathologic 5-year survival rate of 55%, and stage IIB (T2 N1 M0) has a 5-year survival rate of 39%. Also, added to stage IIB in the revised staging system are T3 N0 tumors. T3 tumors are any size tumors that invade the chest wall, diaphragm, mediastinal pleura, or parietal pericardium, and tumors are within 2 cm of the carina without involving the carina. Tumors causing complete atelectasis or obstructive pneumonitis of the entire lung are T3. T3 N0 M0 tumors have a similar pathologic

survival rate of 38%. Surgical treatment is generally lobectomy with en bloc resection of chest wall, diaphragm, or pericardium. Pneumonectomy or sleeve resection is performed for tumors of the hilum or tumors of the main stem bronchus.

Stage III non-small-cell lung carcinoma designates those tumors with metastasis to N2 lymph nodes, ipsilateral mediastinal, or subcarinal lymph nodes, or N3 lymph nodes contralateral mediastinal, contralateral hilar, ipsilateral or contralateral scalene, or supraclavicular lymph nodes. This stage also includes T4 tumors: tumors of any size that invade the vital structures such as the heart, great vessels, trachea, esophagus, vertebral body, or carina. Tumors producing pleural or pericardial effusions or those with satellite tumor nodules within the ipsilateral primary tumor lobe are T4 lesions. Five-year survival for this stage is 20%. Improved survival up to 35–40% has been seen with the addition of neoadjuvant chemotherapy for stage IIIA, N2 disease. Surgical management requires lobectomy, pneumonectomy, or complex radical resection with extensive lymphadenectomy. Note the poor survival of T3 lesions when there is local lymph-node metastasis. Stage IIIB tumors are defined as T4 tumors with N0–N3 nodal status. Five-year survival is poor less than 10%, although some small series have reported better survival for carefully selected T4 N0 M0 lesions. Stage IIIB also includes tumors with N3 metastasis (T1–T4). Survival is an abysmal 3%. Surgical resection is not an option for N3 disease, and only an option for very select T4 N0 lesions.

Stage IV non-small-cell lung carcinoma is defined as lesions with distant metastasis. Five-year survival is poor at 1%. Occasionally a patient with solitary brain metastasis or adrenal metastasis may be a surgical candidate. Reported series are small and anecdotal, with 5-year survival approximating 15%.

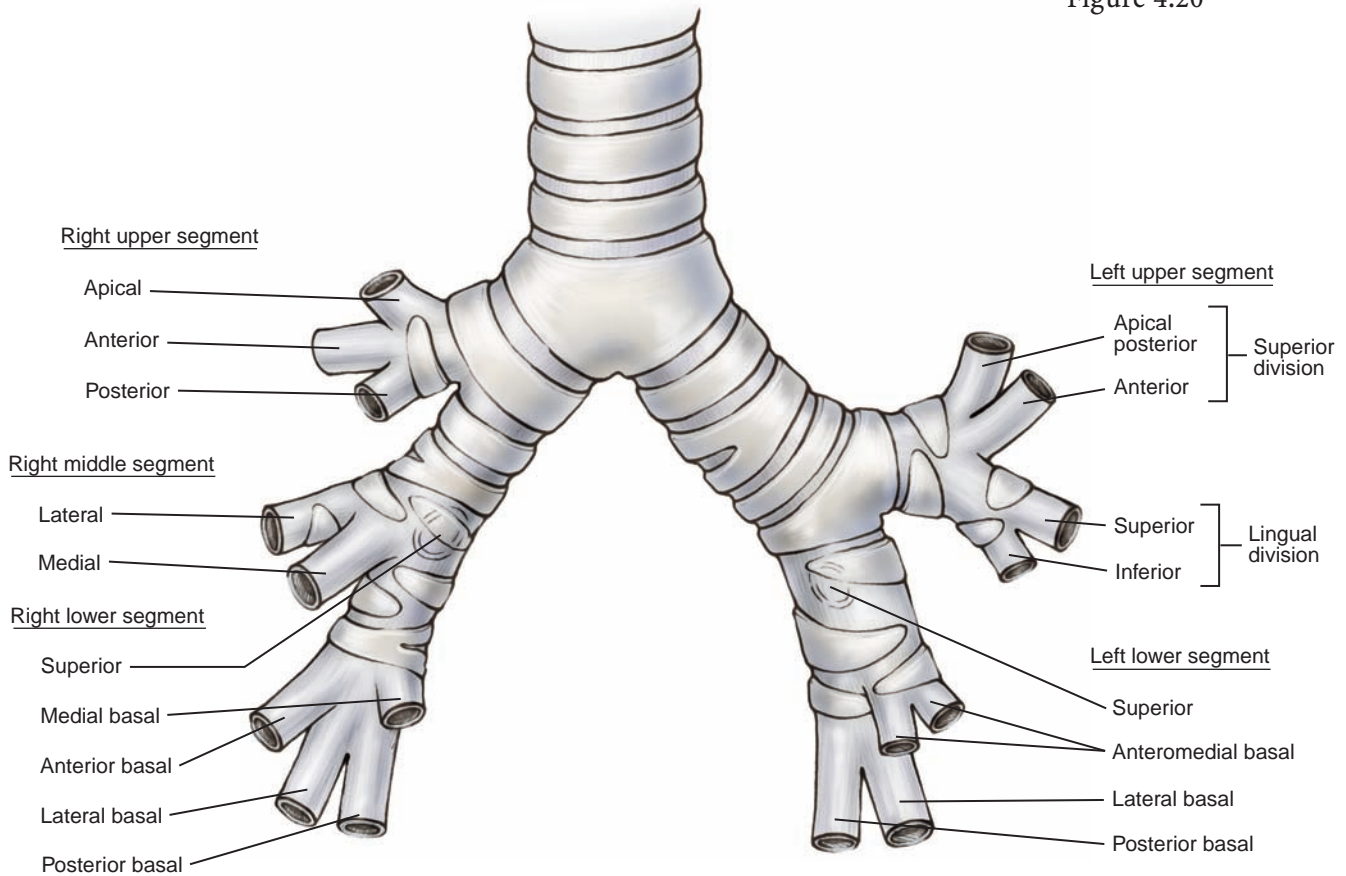
Surgical Anatomy

Bronchopulmonary Segments

Early surgical endeavors to resect pulmonary malignancies involved mass ligation of the hilum and pneumonectomy, as described by Graham. This technique quickly was abandoned as careful identification of the arterial and venous structures of the hilum were appreciated and understood, thereby allowing development of techniques of lobectomy to preserve lung parenchyma unaffected by tumor. The anatomic unit of the lung is termed the bronchopulmonary segment, defined as that portion of the lung that can function independently, a segmental branching of a major lobar bronchus with its own pulmonary arterial supply and venous drainage.

The lung is generally composed of 18 segments (10 on the right, 8 on the left). The right lung has more parenchymal mass (55%) and is composed of three lobes: the upper, middle, and lower lobes, which are separated by two fissures. The major fissure runs obliquely from posterior to anterior, beginning at the level of the fifth rib posteriorly, following the course of the sixth rib, and ending at the diaphragm near the sixth costochondral junction. The horizontal fissure separates the upper lobe from the

Figure 4.20



middle lobe, beginning in the oblique fissure in the midaxillary line at the level of the sixth rib and running anteriorly to the fourth costochondral junction. Within the right upper lobe are three bronchopulmonary segments: apical, posterior, and anterior. The right middle lobe is composed of a medial and lateral segment. The right lower lobe is composed of five segments: superior, medial basal, anterior basal, lateral basal, and posterior basal. Within the segments the course of the bronchus is most consistent. The segmental pulmonary artery follows the course of the bronchus but is more variable. The bronchus and pulmonary artery are centrally located within the segment, but the pulmonary veins course along the plane formed by adjacent segments, draining those adjacent segments. The pulmonary veins form the boundaries of the segments.

The left lung is composed of eight bronchopulmonary segments, four in the upper lobe and four in the lower lobe. The left upper lobe consists of an apical posterior, anterior, and two lingular segments (the superior and inferior segments). The upper lobe is separated from the lower lobe by a single obliquely running fissure that starts at about the level of the fourth rib and proceeds anteriorly and inferiorly to end near the sixth or seventh costochondral junction. The lingular segments of the upper lobe are anatomically equivalent to those of the right middle lobe. The left lower lobe is composed of the remaining four segments: superior, anteromedial basal, lateral basal, and posterior basal.

Accessory fissures do occur, producing unusual or anomalous lobulations. These fissures usually are found where the planes separating bronchopulmonary segments are located. Such lobes have been termed the posterior accessory, inferior accessory, and left middle lobe. Rarely an accessory segmental bronchus arises from the trachea. This bronchus usually goes to the apical segment of the right upper lobe.

Right Hilum

Knowledge and familiarity of the anatomic spatial relationships between the bronchus, pulmonary artery, and pulmonary veins is essential for pulmonary resection. Centrally located tumors may require intrapericardial control of the vascular structures. The most superior and posterior structure of the right hilum is the right main stem bronchus, which emanates from the carina (at the level of the T4 vertebra) and travels inferior to the azygous vein before dividing into the right upper lobe lobar bronchus approximately 1–2 cm from the origin of the right main stem bronchus and the bronchus intermedius. The bronchus intermedius is 1.5–2 cm long and terminates in the right middle lobe bronchus anteriorly and the right lower lobe bronchus posteriorly and slightly inferiorly. Each of the lobar bronchi give rise to segmental bronchi named for the bronchopulmonary segments.

The main pulmonary artery arises from the right ventricular outflow tract and divides within the cradle of the aortic arch into the right and left main pulmonary arteries. The right pulmonary artery passes to the right hilum posterior (deep) to the ascending aorta and posterior to the superior vena cava, toward the right lung parenchyma. It gives off its first branch, the truncus anterior, before entering the lung. The right pulmonary artery is anterior and inferior to the right main stem bronchus.

The third major hilar structure proceeding in an inferior direction is the right superior pulmonary vein. The tributary pulmonary veins originate between bronchopulmonary segments draining adjacent segments. Variations are not infrequent. Three branches from the right upper lobe (apical anterior, anterior inferior, and posterior) are joined by a fourth major branch that drains the middle lobe. This inferior-most venous tributary is composed of two smaller branches draining the right middle lobe. Occasionally the right middle lobe vein drains directly into the left atrium, and rarely the right inferior pulmonary vein. The right superior pulmonary vein enters the pericardium to empty into the left atrium. Predominance (approximately two-thirds) of the vein is intrapericardial. A common pulmonary vein draining all three lobes occurs in 3% of patients. Identifying all three venous branches of the right lung is important prior to ligation and division to prevent a more extended resection on the basis of over division of the lungs venous return. The right superior pulmonary vein is anterior and slightly inferior to the first branch of the pulmonary artery, obscuring the continuation of the pulmonary artery as it becomes interlobar.

The right inferior pulmonary vein is the inferior-most structure of the right hilum, lying inferior and posterior to the superior vein. This vein is composed of two tributaries draining the right lower lobe: the superior segmental vein and the common basal vein. The bronchus intermedius is superior and anterior to the right inferior pulmonary vein.

Anterior to the hilum on the lateral pericardium is the intrathoracic phrenic nerve. Posterior to the hilum is the vagus nerve and the esophagus.

The most superior structure in the left hilum is the left pulmonary artery. The left pulmonary artery is shorter than the right pulmonary artery and passes inferior to the aortic arch to lie anterior and superior to the remaining hilar structures. The left pulmonary artery is tethered to the aortic arch by the ductus arteriosus remnant, the ligamentous arteriosum. The left recurrent nerve is located lateral to the ligament as it courses around the aorta to travel superiorly. The truncus anterior is the first branch of the left pulmonary artery, a much shorter vessel than its right counterpart. It supplies the anterior segment of the left upper lobe. Directly inferiorly and slightly anterior to the left pulmonary artery is the left main stem bronchus. At the carina the left main stem bronchus passes to the left under the aortic arch. It is longer and more acutely angled than the right main stem bronchus. It travels 4–6 cm before giving off its first branch, the left upper lobe bronchus. The left upper lobe bronchus bifurcates after 1.5 cm into a superior branch and an inferior or lingular branch. The superior bronchus subsequently divides into apical posterior and anterior segmental bronchi. The lingular branch divides into superior and inferior segmental bronchi after 1–2 cm. A short distance, less than 1 cm, beyond the left upper lobe orifice, the left lower lobe bronchus gives off the superior segmental bronchus. The basal bronchus extends an additional 1–1.5 cm to bifurcate into an anteromedial basal segmental bronchus and a common segmental bronchus to the lateral and posterior basal segments.

Directly anterior to the left main stem bronchus is the superior pulmonary vein, the most anterior structure of the left hilum. The left superior pulmonary vein is anterior and inferior to the left pulmonary artery. The left superior pulmonary vein is formed by three intersegmental veins: the apical posterior, anterior, and lingular. The lingular branch is solitary 50% of the time, but has a superior and inferior branch 50% of the time. It occasionally drains into the inferior pulmonary vein. The left inferior pulmonary vein is the most inferior structure of the left hilum, inferior and posterior to the left superior pulmonary vein. It is composed of two tributaries: the superior and inferior basal veins. As the left pulmonary veins are invested by pericardium, they join to form a common trunk before entering the left atrium in up to 25% of patients. Premature division of the pulmonary vein before accurately identifying the superior and inferior divisions can lead to a pneumectomy.

The esophagus and left vagus are posterior to the left hilum. Anomalies of the pulmonary arteries, veins, and bronchi are described in textbooks of congenital heart surgery.

The bronchial system has its own systemic arterial blood supply. This arterial supply is variable, more constant on the right than left, and generally arises from the anterolateral aspect of the descending aorta within 2–3 cm distal to the left subclavian artery takeoff. Origin of the bronchial arteries may be an intercostal artery and, infrequently, the subclavian or innominate artery. A common origin of the left and right bronchial arterial supply exists in 20% of patients.

Left Hilum

Blood Supply and Nerve Supply

The right bronchial artery arises in common with an intercostal artery from the descending thoracic aorta between T5 and T6 in the majority of cases, courses anteriorly along the anterolateral aspect of the vertebral column, and crosses the esophagus to end near the origin of the right main stem bronchus. The left bronchial artery arises from the descending aorta in the great majority of cases, but is more variable in its course to the left main stem bronchus. It usually travels posterior to the trachea toward the origin of the left main stem bronchus. As the right and left bronchial arteries enter the membranous bronchi, they form a communicating arc around the bronchus anteriorly and posteriorly with multiple intercommunicating branches that follow the arborization of the bronchus. Anastomosis occurs with the pulmonary artery distally.

A dual venous system exists to drain the bronchi. Tributary segmental veins coalesce and eventually empty into the pulmonary venous system. This accounts for the majority of venous drainage. The bronchial veins are present in the bronchial mucosa and also externally. Approximately one-third of the venous tributaries form larger veins, which flow into a perihilar venous plexus that eventually empties into the azygous system on the right and the hemiazygous system on the left.

The sympathetic plexus and the parasympathetic plexus via the vagi supply nerve rami to both lungs that control the smooth muscle of the bronchi, the bronchial arteries, and the bronchial glands. The nerves reach the hilum, where an anterior plexus is formed about the pulmonary artery and a posterior plexus around the bronchi. From these sites the nerve branches pass into the lung parenchyma, where periarterial plexuses (nonmyelinated) and peribronchial plexuses (myelinated and nonmyelinated) are formed.

Surgical Applications

Posterolateral Thoracotomy

Posterolateral thoracotomy remains the most popular access route into the thoracic cavity for pulmonary resection. It previously has been mentioned for distal tracheal and right main stem bronchus resections. The patient is positioned in the lateral decubitus position. It is essential to have proper protection and cushioning of pressure points to prevent injuries due to positioning. Pillows are placed above and below the flexed lower leg. The upper leg is rested on the underlying pillow and kept straight. The patient is then secured in position by rolled blankets secured by kerlix rolls and using adhesive tape over the hips. A soft pliable roll is placed under the axilla to prevent pressure on the brachial plexus. The lower arm may be extended straight on an arm board or flexed at the elbow and placed next to the head. The upper arm is cushioned on an arm several pillows, two to three at a right angle to the thorax, thus rotating the scapula forward. A warming blanket, arterial monitoring, Foley catheter, and single-lung ventilation utilizing a double-lumen endotracheal tube, preferred, or bronchial blocker are standard.

The incision is begun at the posterior axillary line and extended posterolaterally 2–3 cm inferior to the scapular tip and then superiorly paralleling the vertebral spines and vertebral border of the scapula. This is approximately the course of the fifth rib. The electrocautery is used to deepen the incision through the subcutaneous tissues until the aponeurosis of the latissimus muscle is identified. The latissimus muscle is divided. The inferior border of the trapezius muscle is mobilized posteriorly, and occasionally it may need to be incised. The serratus anterior muscle is reflected off the anterior chest wall and retracted medially and not divided; the posterior edge may be removed from its rib insertion for increased exposure. Ribs are palpated and counted from the superior flat first rib downward to the fifth rib. Any interspace from third to tenth may be entered, but the fifth interspace provides the best exposure of the hilar structures. It is generally unnecessary to remove a rib. The thoracolumbar fascia and paravertebral muscles are elevated with the electrocautery and retracted; they need not be divided. After the intercostal space is chosen, the three layers of intercostal muscles and the deep parietal pleura are divided along the upper border of the lower rib, utilizing the electrocautery and avoiding the intercostal neurovascular bundle. A medium rib spreader is placed anteriorly and a small rib spreader is placed medially to separate the ribs and soft tissue to expose the thoracic contents.

The limited or muscle-sparing thoracotomy may also be used for exposure of the thoracic contents. It provides excellent exposure of the intrathoracic contents for most resections, with as little disturbance of chest wall muscles and therefore chest wall mechanics as practical. It can be performed with less risk in patients with marginal pulmonary function and heals with an acceptably cosmetic result. A vertical incision is begun at the base of the axilla in the mid-axillary line and extended inferiorly to the level of the eighth or ninth rib or an anterior horizontal incision is made. Subcutaneous tissues are divided until the anterior edge of the latissimus muscle is identified. A latissimus myocutaneous flap is elevated and retracted posteriorly, then carried inferiorly or deeply to the vertebral spinous processes. The posterior edge of the serratus muscle is reflected with the electrocautery; it may be necessary to sever the muscle from its posterior rib insertions. The fifth intercostal space is identified and entered. A suction drain is placed underneath the latissimus flap after closure of the incision, because a seroma frequently develops (20% of cases).

Limited or Muscle-Sparing Thoracotomy

The median sternotomy incision is occasionally utilized for pulmonary resection and has the advantage of causing the least disturbance of pulmonary mechanics postoperatively. The incision begins in the midline at the suprasternal notch and extends inferiorly to just below the xiphi sternum. The electrocautery is used to divide the subcutaneous tissues down to and including the medial aspect of the superficial pectoral fascia. Distally (caudally) the linea alba is divided in the midline. The pectoral fascia and anterior periosteum of the sternum are divided with the electrocautery. Two venous structures are remarkably constant: one at the suprasternal notch, identified as the jugular arch connecting the left and right anterior jugular veins (sometimes called the transternal vein), and a venous branch crossing the midline

Median Sternotomy Incision

just above the xiphoid. These veins should be anticipated and clipped or ligated to prevent unnecessary and sometimes torrential blood loss. The sternum is divided in the midline with a reciprocating electric or air-powered saw, such as the Sarnes sternal saw. The footpad of the saw should be hooked beneath the suprasternal notch and the saw brought inferiorly left to right, which I prefer or the blade reversed and the saw placed inferiorly and brought superiorly right to left. Care should be exercised to keep the footpad in close contact with the posterior table of the sternum to prevent injury to the underlying structures or inadvertent pleural injury. An oscillating saw allows more precise control of the depth of penetration of the sternal saw and should be used when prior sternotomy has been performed or when the surgeon suspects that tumor abuts the posterior sternal table. Hemostasis of the anterior and posterior periosteum is obtained with discreet use of the electrocautery. Bone wax may be used sparingly to seal the bleeding marrow. Sterile towels are placed along the sternal edges, and a sternal retractor is placed in the incision. This approach provides excellent hilar exposure for right-sided pneumonectomy or lobectomies of the right upper, middle, and lower lobes. Control and division of the right inferior pulmonary vein are sometimes difficult during right lower lobectomy due to the posterior position of the right inferior pulmonary vein. Left upper lobectomy may also be performed. Left pneumonectomy and left lower lobectomy are often difficult, somewhat dangerous, and frequently impossible because the left inferior pulmonary vein underlies the left ventricle, and retraction or manipulation of the heart causes hypotension and arrhythmias. Finally, this approach is preferred for bilateral metastectomy by wedge excision for pulmonary metastasis.

Video-Assisted Thoracic Surgery (VATS)

Thousands of video-assisted thoracoscopic surgery (VATS) lobectomies have been performed since the first VATS lobectomy with anatomical dissection for lung cancer was performed in 1992. There are strong proponents for and opponents against the procedure. An increasing number of surgeons are now performing that procedure; however, some surgeons have questioned the safety and oncologic principles of VATS for lung cancer. A lobectomy performed via VATS should be the same operation performed via a thoracotomy with standard oncological principles such as individual ligation of vessels and bronchus and lymph-node dissection.

The indication and contraindications for VATS lobectomy vary within academic centers. The percent of VATS lobectomies performed at high volume centers range from 40 to 90%. Most stage I lung cancers can be potentially be resected via VATS. The limitations are primary due to size of the tumor relative to the access incisions, the ease and safety of the dissection, and the invasion of extrapulmonary structures (chest wall and pericardium). Although in some cases a VATS lobectomy is feasible after preoperative treatment with chemotherapy, radiation therapy, or both, the vascular dissection is usually more difficult, so a thoracotomy is generally required. Pathological lymph nodes, both benign and malignant, often require a thoracotomy for safe dissection. Centrally located tumors need to be evaluated to determine whether the best approach is via a thoracotomy. Elderly patients and patients with a poor performance status may tolerate a VATS procedure better than an open procedure.

Further evidence is mounting that a VATS lobectomy has advantages over an open lobectomy. Opponents believe that a VATS lobectomy is unsafe, an incomplete cancer operation, and offers no advantage over thoracotomy for lobectomy. Proponents believe that VATS lobectomy is safe and effective treatment for lung cancer. There is now enough experience with VATS lobectomy and enough data to address these issues.

VATS lobectomy mortality rates range between 0 and 7% and complications occur in 10–22% of patients. These complications include prolonged air leaks, arrhythmias, pneumonia, respiratory failure, and BPF. The frequency and occurrence of these complications after a VATS lobectomy are the same or less than those after a thoracotomy lobectomy. A randomized prospective trial from Germany showed a significant lower complication rate with VATS compared to thoracotomy.

Several series have suggested that VATS causes less pain than a thoracotomy. A randomized trial of 67 patients who underwent lobectomy showed that the pain was less for VATS than a muscle-sparing thoracotomy. Walker et al. reported that VATS patients required less narcotic use compared to thoracotomy. Patients who underwent VATS also had less sleep disturbances, fewer breakthrough pain episodes, and fewer required intercostal blocks.⁵ In another randomized trial, VATS patients had less chest wall pain and greater shoulder strength at 6 months, but there was no difference at 1 year. The evidence suggests that VATS allows earlier recovery, but at one year after the procedure, the recovery is identical for VATS and a thoracotomy.

Conversion from VATS to a thoracotomy may be necessary because of technical reasons or because of the need to control an intraoperative problem, which is usually infrequent. When the surgeon expects to perform a VATS lobectomy, the incidence of conversion to thoracotomy is approximately 10% (range, 0–20%). In 70% of these cases, conversions are for oncologic reasons that include, evaluate for sleeve resection, unsuspected T3 tumors, abnormal hilar lymph nodes, or pleural involvement.

The momentum for VATS lobectomy is growing, but several concerns continue such as intraoperative bleeding, tumor recurrence in VATS incisions, and adequacy of the cancer operation. Significant bleeding during VATS lobectomy is a rare occurrence (0.9%). Sugiura et al. found no significant difference in the average operating time for VATS and thoracotomy; however, mean blood loss was less for the VATS group. Demmy et al. also, found that VATS is associated with less blood loss. Both series had no intraoperative or major complications. In the international survey, the only intraoperative death was from a myocardial infarction and not bleeding. Most bleeding can be controlled with a sponge-stick which allows time to decide to perform a thoracotomy or not. The postoperative course and cost appear to be the same or better for VATS approach as reported by Demmy and colleagues.

Recurrence of cancer in a VATS incision is a rare event occurring at a rate of less than 0.5%. Recurrences have resulted in a fatal outcome only once, but it rarely happens and should not be an issue. All specimens, including lymph nodes are removed in protective bags. Mediastinal node dissection or sampling should be part of any lung cancer operation. Either can be part of a VATS lobectomy. Kaseda resected a mean of 23 LNs with VATS lobectomies.¹² This confirms that a significant number of

LNs can be resected via VATS and that a complete oncologic procedure can be performed. Currently, there is no proof that a node dissection provides survival superior to that of nodal sampling, but staging is improved. Survival data will not be available for several years from the ACOSOG Z30 trial that randomized patients after lobectomy for lung cancer into complete lymph-node dissection or lymph-node sampling. Hopefully, this large study will answer the question if a lymph-node dissection is warranted.

Long-term survival after VATS lobectomy for stage I lung cancer ranges from 76 to 94%. Some authors speculate that a VATS approach may even provide better survival than a thoracotomy. The difference is likely due to patient selection; a randomized prospective trial is needed to truly compare the survival rates of the two approaches. A retrospective comparison of VATS and thoracotomy showed that VATS had less of an impact on the immune system. Yim et al. compared the inflammatory reaction, as measured by cytokine response, in patients who underwent lobectomy by VATS or thoracotomy. VATS patients had reduced postoperative release of both proinflammatory and anti-inflammatory cytokines. The clinical significance of these findings remains to be fully elucidated. A VATS lobectomy does not appear to compromise cancer survival for patients with lung cancer.

There is no multicenter randomized, prospective study that compares the VATS and thoracotomy approach for lobectomy. However, the literature does suggest that VATS and thoracotomy are at least comparable. Multiple series have shown that not only VATS lobectomy is safe and feasible, but there may even be advantages to a minimally invasive approach to lung cancer surgery. Anatomic pulmonary resection by VATS have been developed in the hope of reducing morbidity, mortality, and hospital stay, while allowing a faster return to regular activities for patients after procedures that formerly required major incisions. A large, prospective randomized study is warranted to determine if VATS lobectomy is advantageous compared to an open lobectomy.

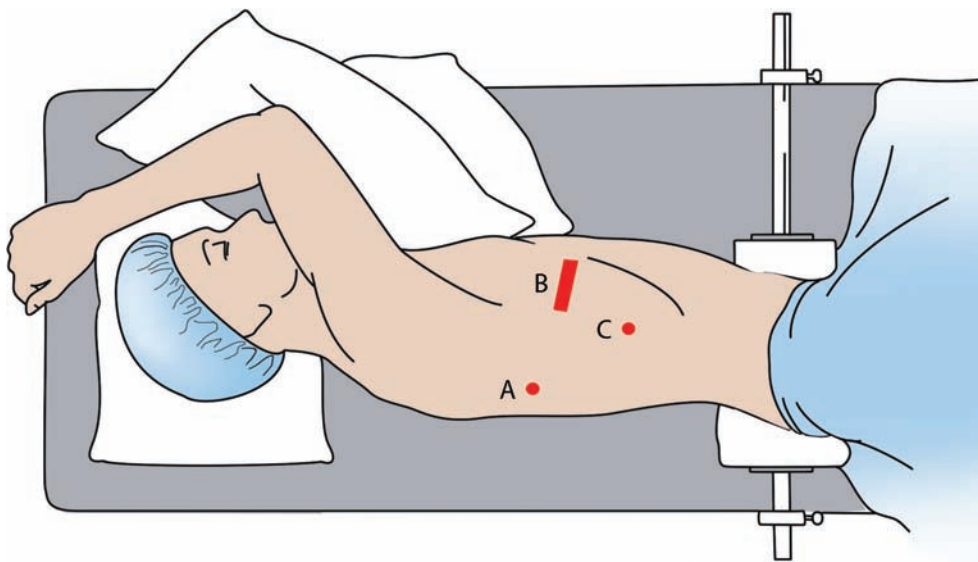


Figure 4.21

Currently, approximately 85% of stage I lung cancers at our institution are resected via VATS with a median hospital stay of about 3 days. The patient is positioned in the lateral decubitus position with the table flexed to increase the intercostal spaces (Fig. 4.1). Single-lung ventilation utilizing a double-lumen endotracheal tube is preferred and correct position of the endotracheal tube confirmed by the anesthesiologist and surgeon prior to turning the patient. Initially, the rigid zero degree thoracoscope is placed through a reusable metal port inferiorly along the anterior axillary line and 8th intercostal. A thorough investigation is carried out of the diaphragm, pericardium, and parietal pleural to determine presence of metastatic disease. Two other access incisions are placed one posterior along an imaginary thoracic incision and an anterior utility incision (4–5 cm). Access incisions are shown in Fig. 4.21. Carbon dioxide insufflation is not used.

Lobectomy and pneumonectomy are the most frequently performed resections for pulmonary malignancy. Wedge resection and segmentectomy do not have the same long-term survival as lobectomy for similarly staged lesions. In-depth description of bronchoplastic parenchymal-sparing procedures and other thoracic surgical procedures is beyond the scope and purpose of this text; the interested reader is referred to Kaiser and Aretz's *Atlas of General Thoracic Surgery* or Urschel and Cooper's *Atlas of Thoracic Surgery* for supplemental reading.

Pulmonary Resection

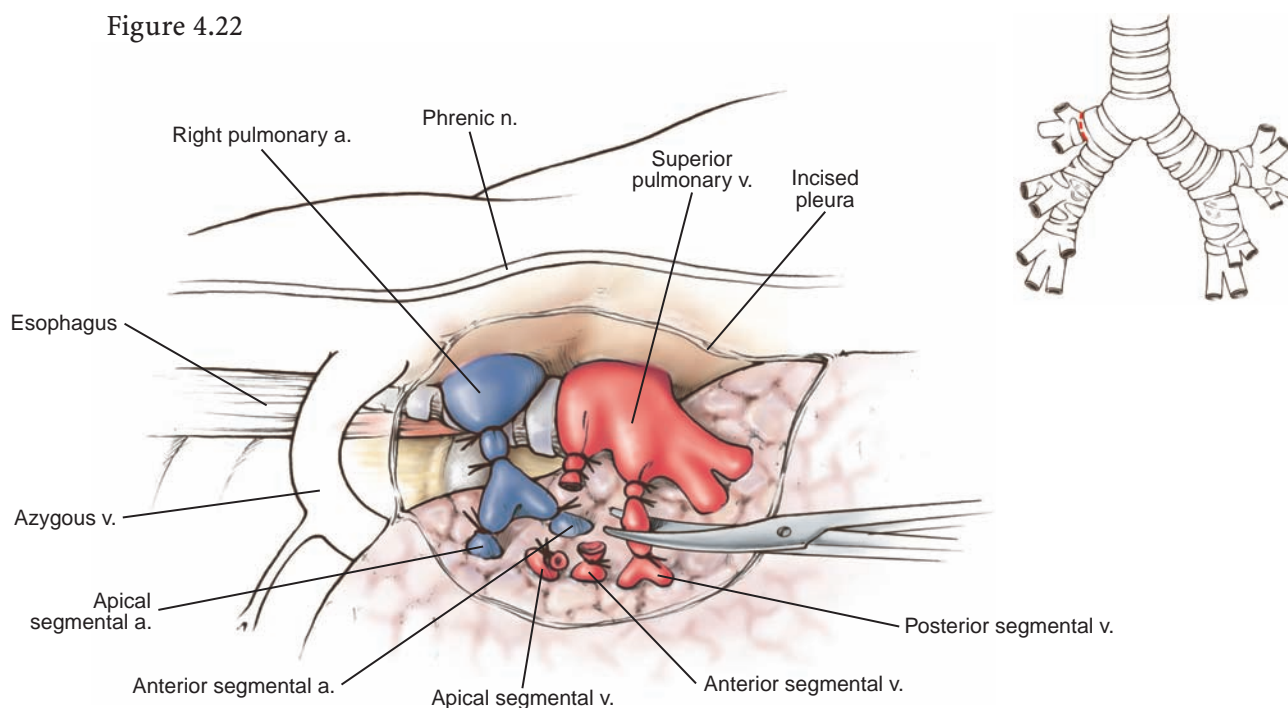
Lobectomy did not become the standard anatomic dissection for lung cancer until Churchill et al. reported the Massachusetts General Hospital series in 1950. Lobectomy is the preferred treatment for peripheral stage I, stage II, and selected stage IIIA lung cancers. After the pleural space is entered, the entire lung and pleura are inspected for synchronous tumors or metastasis not evident on preoperative imaging studies and the feasibility of lobectomy is determined. If complete resection encompassing all tumors is possible, the inferior pulmonary ligament, anterior and posterior mediastinal pleurae, and all adhesions are divided with the electrocautery. The inferior pulmonary ligament (station 9) and periesophageal (station 8) lymph nodes are excised for pathologic staging so as not to be forgotten during the later formal lymph-node dissection. Division of the pleurae facilitates hilar and lymph-node dissections. Generally the pulmonary vein or veins are ligated or stapled first to maintain the “no touch technique,” preventing tumor cell embolization. The fissure is then entered and completed with a linear stapler. The pulmonary artery branches are divided with ligatures or staples (3.5 mm vascular staples). Finally, the bronchus is mobilized and stapled with a 3.5 or 4.8-mm stapling device. The surgeon should take care not to devascularize the bronchus and avoid compromising the main stem bronchus or remaining lobar bronchi with a stapled bronchial closure. The bronchial stump may also be hand-sewn. Margins are checked for tumor with frozen-section analysis. Many surgeons prefer ligation of pulmonary artery branches first to avert congestion of the lung by blood retention, believing that manipulation of the tumor rarely releases viable tumor cells into the venous outflow. The bronchial stump is checked for a fistula under sterile water immersion to 40 cm of static pressure. If a bronchial leak is found the leak site is closed with interrupted 4–0 Vicryl sutures. If

the patient had undergone neoadjuvant radiation therapy the bronchial stump must be reinforced with vital tissue such as parietal pleural, pericardium, intercostal muscle or serratus anterior flap to prevent a bronchial pleural fistula.

Right Upper Lobectomy

The right upper lobe is most frequently resected. After division of the anterior mediastinal pleura, the right superior pulmonary vein is identified and its tributaries, the apical anterior, inferior, and posterior veins, are encircled with silk ligatures. Great care must be taken in identifying and sparing the venous tributary from the right middle lobe as it enters the superior vein. If it has been previously determined that all tumor will be encompassed by the lobectomy, these branches may be doubly ligated and divided. The truncus anterior is the first and usually the largest branch of the right pulmonary artery and may be the only pulmonary artery branch in 10% of patients. It bifurcates within 1–1.5 cm. It should be encircled at the origin and, after the bifurcation, doubly ligated and divided. The right pulmonary artery proceeds on into the lung parenchyma, giving off one (60%), two (29%), or three (1%) ascending branches that originate along the anterosuperior border of the pulmonary artery and enter the inferior surface of the right upper lobe. These branches are most easily dissected and ligated through the completed major and minor fissure. The posterior ascending artery is the most common, occurring in 88% of patients. After the vasculature is divided, the lung is retracted medially and the bronchus to the upper lobe exposed as it originates from the lateral wall of the right main stem bronchus, approximately 2 cm from the origin of the right main stem bronchus. Its anterior and posterior surfaces are dissected sharply and bluntly. The bronchial arterial supply to the remaining lung and bronchus should be disturbed as little as

Figure 4.22



possible to avert bronchial stump breakdown. The bronchus is then stapled (4.8 mm staples) and margins of the specimen examined. The surgeon should remember that rarely (1%) an anomalous apical segmental bronchus will arise from the trachea or right main stem bronchus. When the minor fissure is complete, the right middle lobe should be placed in its anatomically correct position and secured to the right lower lobe to avert possible torsion.

Right middle lobectomy is performed less often than other lobectomies. It is sometimes performed as part of a bilobectomy when the minor fissure is crossed by tumor, necessitating right upper-middle lobectomy, or when the tumor is anterior and crosses the major fissure, necessitating right middle-lower lobectomy. It may be necessary to perform a bilobectomy when N1 lymph nodes (stations 12, 13, and 14) are involved from a lower lobe tumor. Involvement of the bronchus intermedius dictates bilobectomy of the right middle and lower lobes.

The right middle lobe receives one or two branches from the pars intralobares. These branches are most easily found by dissection at the minor fissure-major fissure junction. The second artery is encountered first when proceeding in this direction, emanating from the anteromedial surface opposite the branch to the superior segment of the right lower lobe. This artery is doubly ligated and divided. The first branch to the right middle lobe is larger and the next branch of the pulmonary artery after the truncus anterior. It is found on the anteromedial surface opposite the ascending branch to the right upper lobe. This artery usually has a wide base of origin, and care in ligation and division should be exercised to avert fracture of the delicate pars intralobares. Division of this branch will expose the solitary right middle lobe

Right Middle Lobectomy

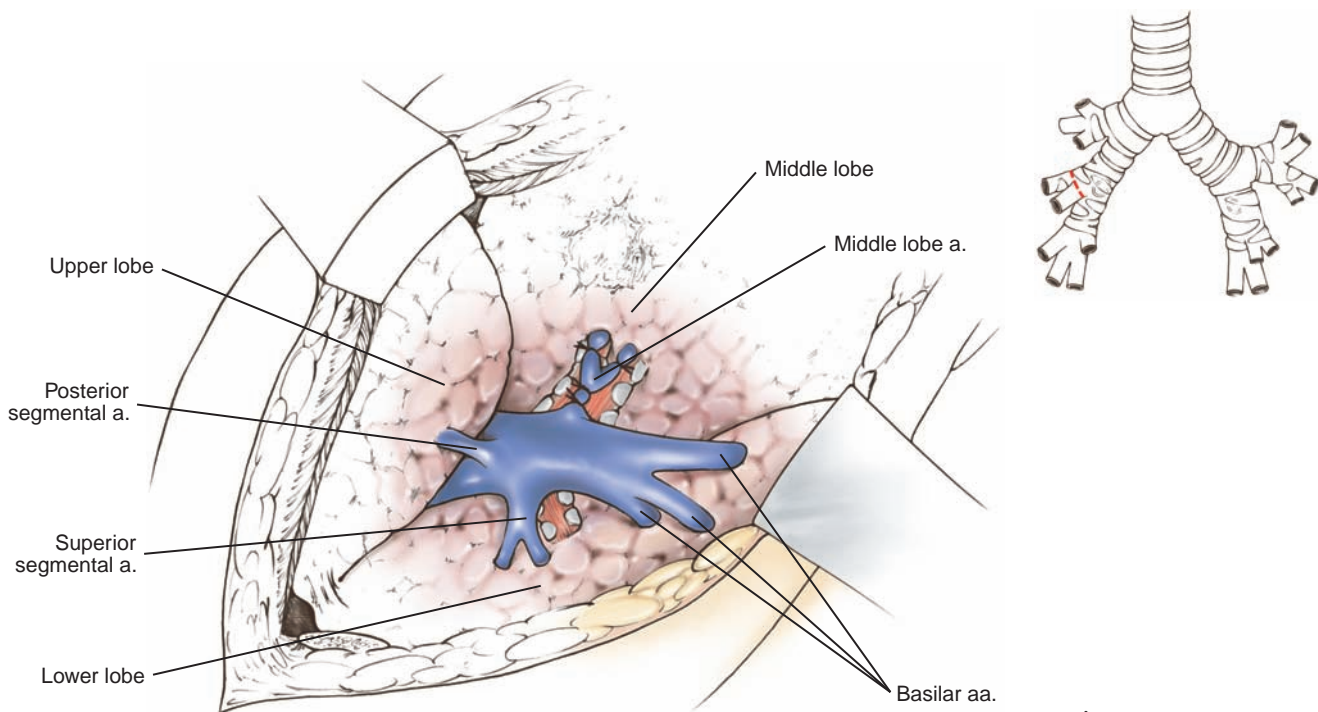


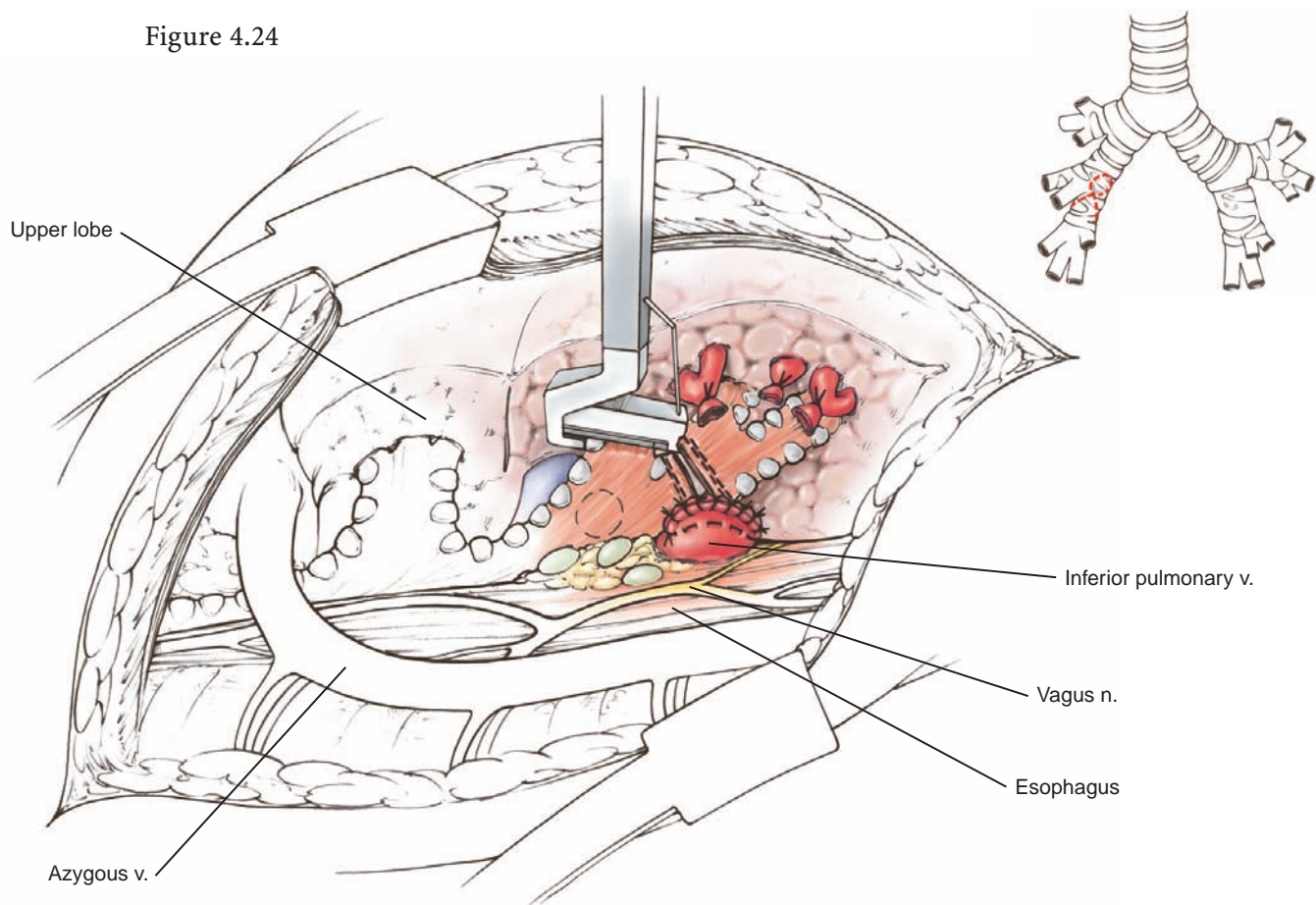
Figure 4.23

bronchus, which travels approximately 1.5–2 cm before branching into middle and lateral segmental bronchi. The bronchus is stapled and divided. The remaining structure to be dissected, ligated, and divided is the anteriorly placed right middle lobe vein formed by medial and lateral intrasegmental tributaries and draining into the right superior pulmonary vein. It is usually the most inferior branch of the superior vein and may be ligated first or last. One or both of the fissures may need to be completed with a linear stapler to finish the lobectomy.

Right Lower Lobectomy

Right lower lobectomy is begun similarly to right middle lobectomy by dissecting in the central portion of the major fissure or at the junction of the two fissures. I find it easier to begin at the junction of the two fissures, identifying the right middle lobe artery followed by the basilar arteries. The most posterior branch of the pars intralobares is the branch to the superior segment of the right lower lobe. More than 75% of the time the posterosuperior segment is supplied by one artery, the remainder of the time by two. This branch or branches are doubly ligated and divided, providing better access to the basilar branches. The basal segmental arterial supply is variable, consisting of one to three branches arising from the inferior aspect of the pulmonary artery. One branch supplies the anterior and medial segments. The pars intralobares then terminates by dividing into lateral and posterior basal segmental arteries. The

Figure 4.24



basilar branches can frequently be stapled after dividing the posterosuperior branch. Two intrasegmental vessels, the superior and common basal veins, form the inferior pulmonary vein. There tends to be a greater extrapericardial segment of this vein, allowing it to be doubly stapled and divided. The final structure to be divided is the right lower lobe bronchus, which originates at the termination of the bronchus intermedius. It divides into a superior segmental bronchus opposite and anterior to the middle lobe bronchus. The four basal segmental bronchi are the medial basal (most proximal), anterior basal, and then a common segmental bronchus to the lateral and posterior segments. Great care must be taken before dividing the bronchus to ensure that the right middle lobe bronchus is not compromised. Because the bronchus intermedius terminates abruptly, the distance between the right middle and lower lobe orifices is minimal. When the superior segment bronchus takes off high or early it may be necessary to close this bronchus and the basilar bronchus separately.

Left upper lobectomy is frequently the most challenging of all pulmonary resections for two reasons: (1) the presence of the left recurrent nerve in the aortopulmonary window is near the dissection and lymphadenectomy, and (2) the lingular, anterior

Left Upper Lobectomy

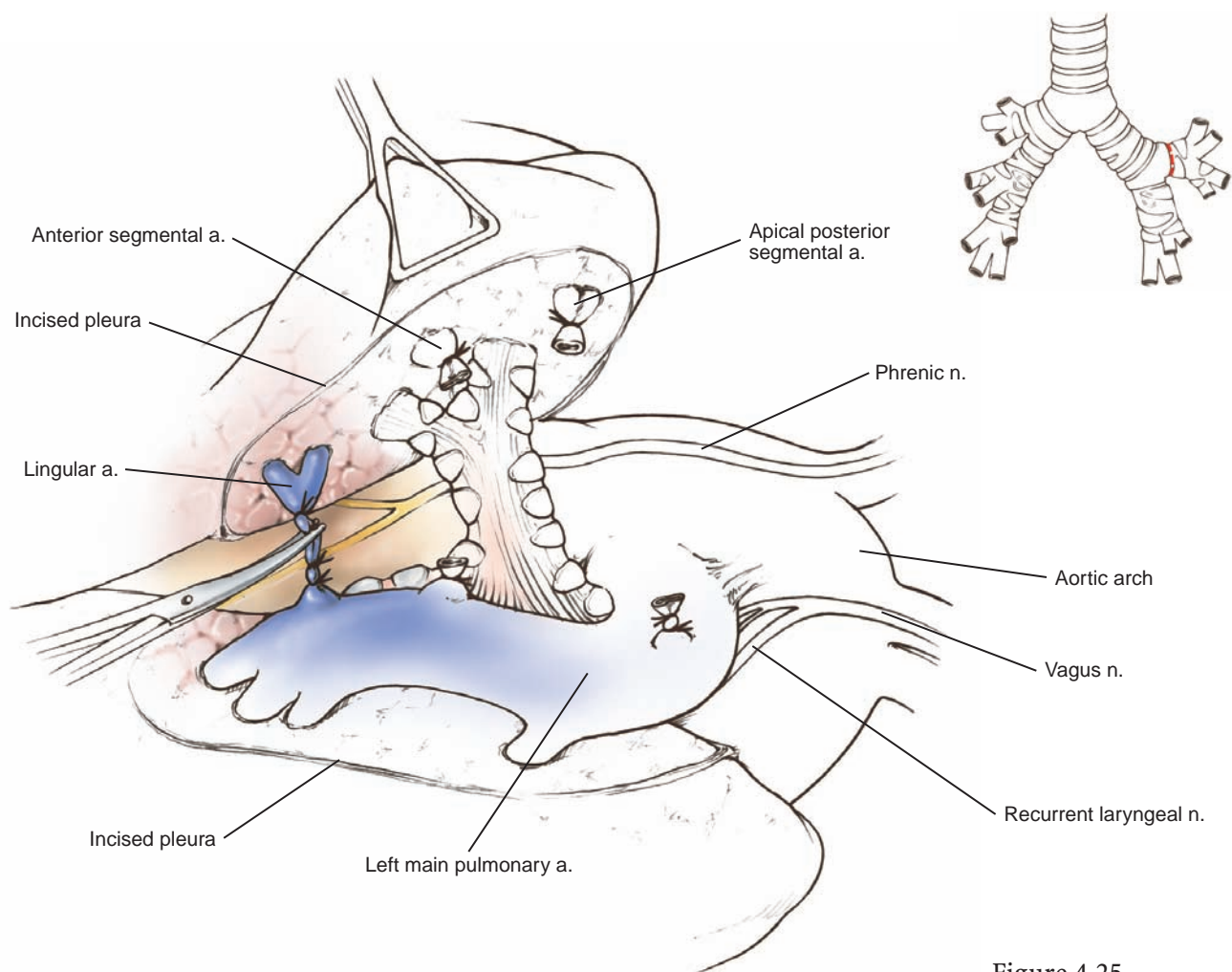


Figure 4.25

posterior, and anterior segmental vessels are short and broad based, making inadvertent traction tears not infrequent. Injury to the fragile pulmonary artery may be difficult to repair, forcing the surgeon to perform a pneumonectomy to prevent blood loss.

As on the right side, the mediastinal pleura surrounding the hilum and the inferior pulmonary ligament are divided with the electrocautery. After it has been determined that the tumor can be resected totally by lobectomy, the upper lobe is retracted superiorly and the lower lobe inferiorly, exposing the major fissure. Dissection is begun posteriorly and directed anteriorly to expose and mobilize pulmonary artery branches to the lingula. The major fissure is completed by division with a linear stapler. Dissection is then gently advanced cephalad to mobilize and isolate first the posterior branch, then the anterior branch. The anterior branch is often the shortest artery and therefore most easily injured by traction. Some authors advocate ligation of the segmental arteries at this point; however, I have found that division of the left superior pulmonary vein prior to division of the segmental arteries is safer and facilitates exposure of the anterior segmental artery. The lung is retracted posteriorly and slightly inferiorly to expose the anterior hilum and the superior pulmonary vein. The superior pulmonary vein is generally formed from three intrasegmental veins: the anterior, apical posterior, and lingular veins. These structures are doubly ligated and divided or stapled if sufficient extrapericardial vein exists. Division of the vein exposes the underlying truncus anterior. Circumnavigation of the vein must be carefully and deliberately performed to prevent injury to the underlying segmental artery.

Attention is then turned to the major fissure. The lingular branch or branches may be doubly ligated and divided. The next branches to be ligated are the posterior segmental branches (none to five in number), which are small and emanate from the medial inside curve of the pulmonary artery. The apicoposterior branch is now ligated. The short anterior segmental artery is ligated and divided. The last structure to be divided is the left upper lobe bronchus. The left upper lobe bronchus arises much more distally down the left main stem bronchus than its right counterpart. It immediately splits into the lingular orifice and common trunk to the anterior and apicoposterior segments. The bronchus is sharply and bluntly skeletonized and divided with a 4.8-mm stapling device.

Left Lower Lobectomy

Left lower lobectomy is by far the easiest to perform. The inferior pulmonary vein is formed by two intrasegmental branches: the superior segmental and common basal. Sufficient extrapericardial length usually exists for stapling the main inferior vein. The major fissure is now entered to expose the superior segmental artery (generally a single artery, double in 25% of patients). After giving off the superior segmental artery the left pulmonary artery terminates in two to four basilar arteries, usually one to the anterior medial segment and a second supplying the posterior and lateral segments. These arteries are doubly ligated and divided. The lower lobe bronchus is now easily visible. The lower lobe bronchus originates at the termination of the left main stem bronchus. It quickly bifurcates into a posterior lateral segmental bronchus to the superior segment and, 1–2 cm distally, a common basal bronchus that then

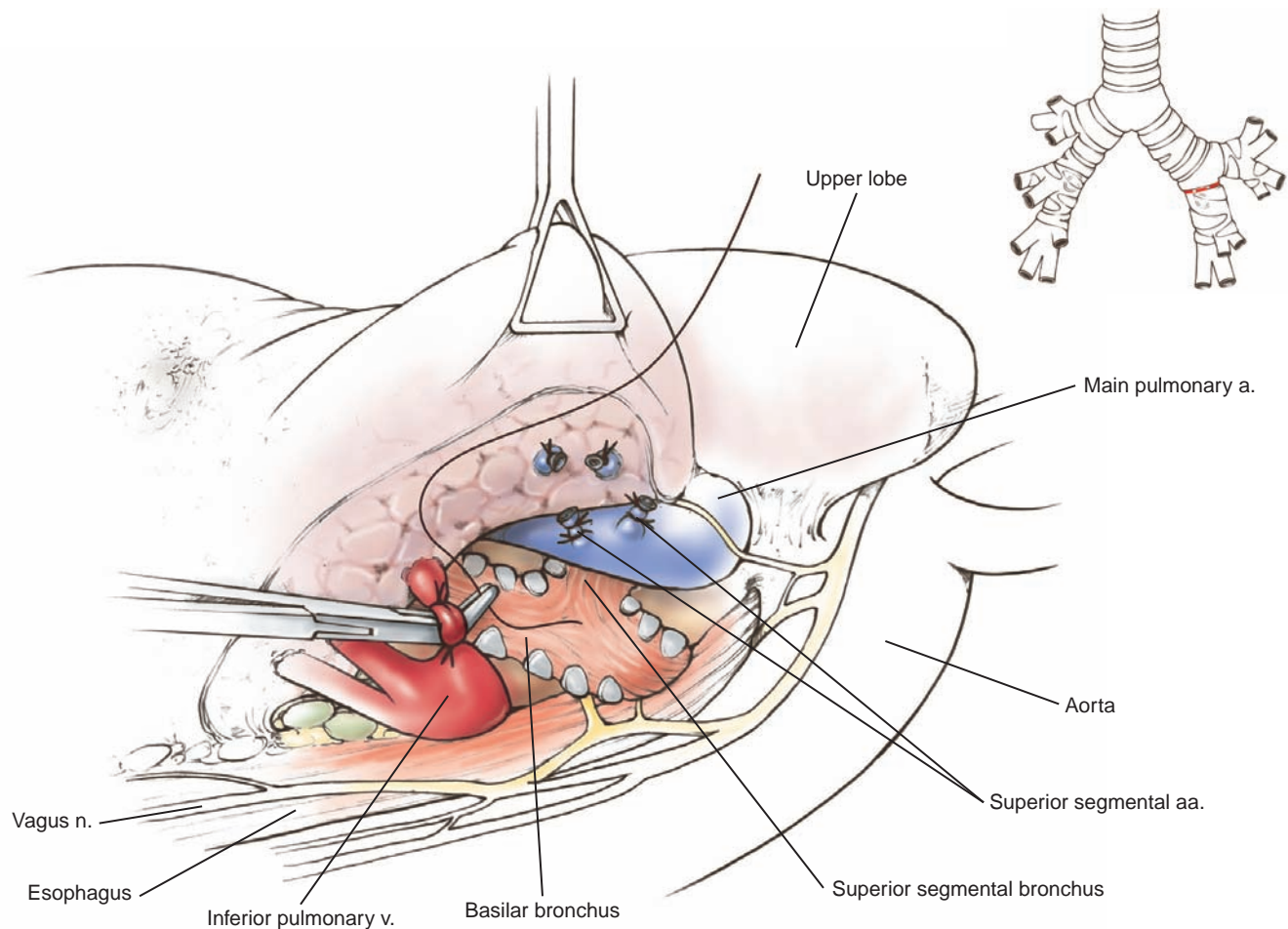


Figure 4.26

bifurcates (80%) or trifurcates. The bronchus is divided with a 4.8-mm stapler to complete the resection.

The sequence of events is different for a VATS lobectomy vs. an open lobectomy. For an upper lobectomy the dissection is initiated medially first by isolating the pulmonary vein. It is paramount to make sure each lobe has a separate drainage vein; especially on the left when approximately 10% of patients have a common vein. The vein is usually divided with an endoscopic stapler (35 or 45 mm). After the vein is divided the branches of the pulmonary artery are isolated. Care is taken in the individual isolation of the branches, especially the truncus branch to prevent injury to the base of the vessel which can lead to an expanding hematoma or avulsion. The vessels can be isolated with silks or red rubber catheters to help pass the endoscopic vascular stapler for ligation and division. I usually use the Ethicon Endosurgery, Inc (Cincinnati, Ohio) white 35 mm vascular stapler because of the small anvil size which facilitates the isolation of the vessel. After the stapler is fired attention is directed to the bronchus. All nodal tissue and lymphatics are swept distally toward the bronchus. A green endoscopic stapler (45 mm) is placed across the bronchus. Prior to firing the bronchus stapler the remaining lung is inflated to make sure there is no impingement

VATS Lobectomy

of the bronchus to the middle or lower lobes. The fissure is the last tissue to divide. I make sure that the lobe is in the correct anatomical position to make sure that the fissure landmarks are correctly identified. I usually use the Echelon 60mm Gold endoscopic stapler (EEI, Cincinnati, OH) for the fissure, which requires 2–3 firings. The lobe is brought out through the anterior access, which measures 4–5 cm in size in a sterile pouch. A complete lymph-node dissection is then performed of lymph-node stations 4R, and, 8, 9, 10R, 11%r, and 12R on the right and 5, 6, 7, 8, 9, 10L, 11L, and 12L on the left, with the help of the 5 mm Harmonic Scalpel (EEI, Cincinnati, OH) and electrocautery. The last step is to check the bronchial stump to detect an air leak under water immersion and airway pressure to 40 cm pressure. After an upper lobectomy a single straight 28 French chest tube is used, while after a lower lobectomy a single right angle tube is used. The sequence of a lower lobectomy is usually the pulmonary vein, bronchus, and lastly pulmonary artery. The left lower lobectomy is the easiest lobectomy to start with in learning the VATS approach.

Right and Left Pneumonectomy

Early attempts at pulmonary resection for malignancy began with an attempt to remove the whole lung containing the tumor. Multiple methods were tried, but not until 1933 did a patient survive the early postoperative period. By 1940 pneumonectomy had

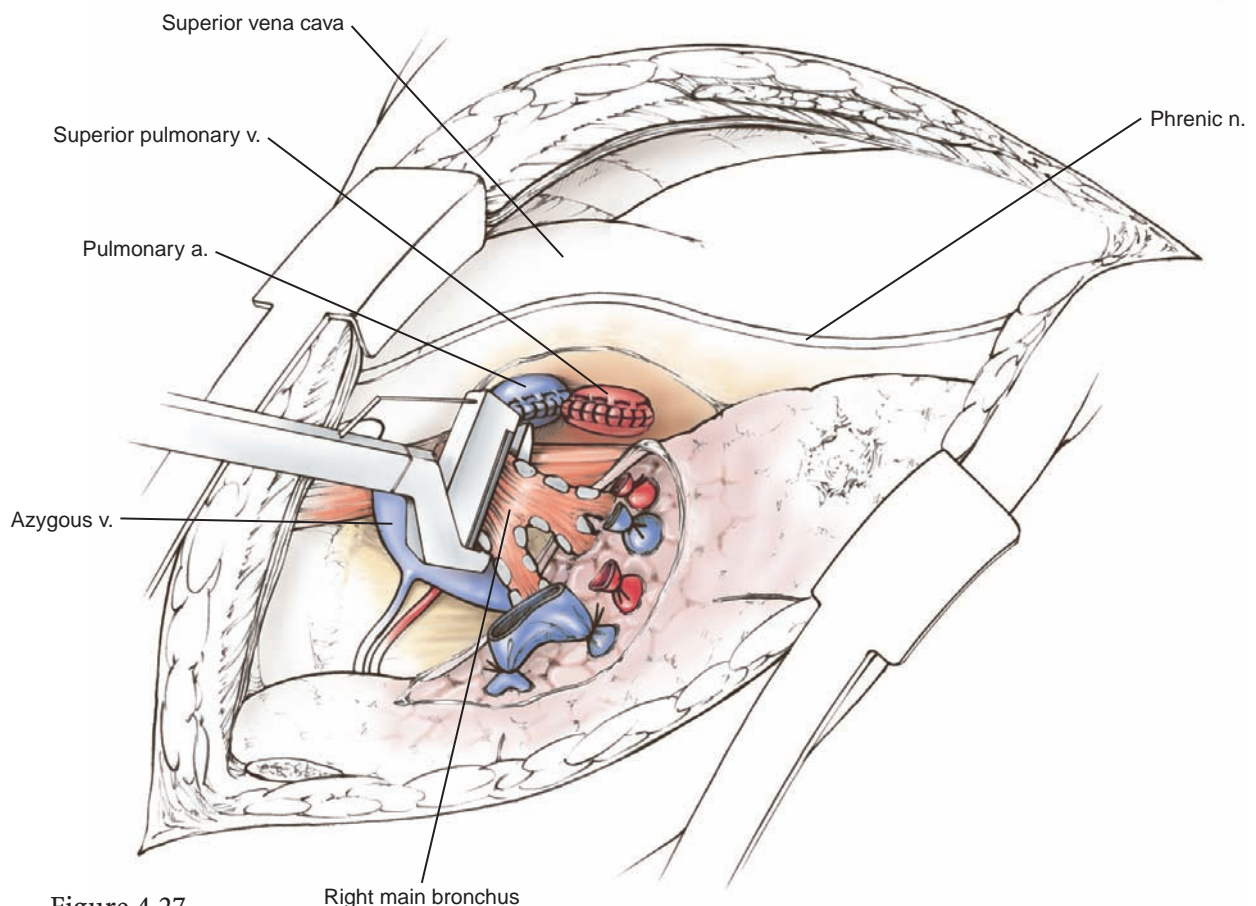


Figure 4.27

become the accepted technique for removing resectable pulmonary malignancies, despite mortality ranging from 15 to 20%. Presently the indications for pneumonectomy are (1) centrally located lung cancer, (2) lung cancer crossing major fissures, or (3) lung cancer not amenable to lobectomy. Mortality is approximately 6%.

The surgical approach is most often posterolateral thoracotomy. Once the extent of the disease is established and resectability ensured, the inferior pulmonary ligament and mediastinal pleura surrounding the hilum are divided with an electrocautery. The pulmonary artery and pulmonary veins are skeletonized. Which vessels are addressed first is dictated by the size and location of the tumor, and the surgeon should be flexible. If practical and safe, the veins are divided first. The inferior veins on both the left and right are generally the most accessible. The lung is retracted first superiorly to dissect the inferior surface, then anteriorly and superiorly to dissect the posterior surface, and finally posteriorly to dissect the anterior surface. The vein is then doubly stapled and divided. The superior veins are divided similarly. Great care must be exercised because the superior veins are closely approximated and often adherent to the underlying pulmonary artery. Inadvertent injury to the truncus anterior may be associated with audible blood loss. When a tumor is palpated within the veins, the dissection should be carried intrapericardially and the veins divided with a cuff (1–2 mm) of atrium. The pulmonary artery is divided next by first dividing the truncus anterior. This allows greater length to be obtained for stapling the main pulmonary artery. The pulmonary artery is doubly stapled and divided, taking care not to produce a traction injury. When the tumor is closely adherent to the pulmonary artery it may be necessary to divide the pericardium anteriorly to gain additional length. Further additional length on the left can be obtained by dividing the ligamentum arteriosum, carefully averting traction on or injury to the left recurrent nerve. On the right the superior vena cava can be mobilized and the artery divided medial to the superior vena cava. An initial maneuver that should be performed is to encircle the artery with a vascular tape prior to mobilization. This allows vascular control, which may be life-saving if the artery is injured.

The main stem bronchus is most often divided last. The bronchus should be divided as proximal as possible, disrupting the bronchial arterial supply as little as possible. The carina should be identified and the bronchus divided with a 4.8-mm stapler or divided and closed with absorbable sutures placed anterior to posterior. The bronchus is then tested by insufflation of the airway to 35 cm static peak airway pressure. I prefer to cover the bronchus with autogenous tissue: pericardium, pericardial fat, pleura, intercostal muscle, or on the right the divided azygous vein. A 28 French chest tube is tunneled into the chest to allow positioning of the mediastinum and as a possible monitor of blood loss. When the patient is turned to the supine position, the remaining lung is hyperexpanded and when the patient is breathing spontaneously the chest tube is removed. Some authors prefer not to use a chest tube and aspirate approximately 1,000 mL of air to bring the mediastinum back to the midline. Other surgeons prefer to use a balanced drainage system. Leaving a chest tube in the pleural space after pneumonectomy for greater than 24 h is associated with an increase risk of BPF and empyema.

Mediastinal Lymph-Node Dissection

It is essential that the surgeon know the drainage pattern to the various lymph-node groups from each lobe. The regional nodal stations and their designated numbers are illustrated. Basic dissection technique requires that the lymph nodes be left intact and therefore are usually dissected as part of an en bloc fatty tissue specimen that includes the lymph nodes. Small blood vessels and lymphatic vessels are cauterized to prevent postoperative bleeding and exudation of lymph.

Right upper lobectomy should be combined with dissection of lymph nodes in the superior mediastinum and right paratracheal and subcarinal areas. Metastasis from right upper lobe tumors involves the right upper lobe peribronchial, lobar, and intralobar hilar superior mediastinal nodes. Metastasis to nodes of the middle and lower lobes from a right upper lobe tumor is uncommon.

Resection of the middle lobe for middle lobe tumors should be accompanied by dissection of the hilar, subcarinal, and right peritracheal lymph nodes. Middle lobe tumors more frequently metastasize to the sump lymph nodes. Therefore it may be necessary to perform a bilobectomy to resect the entire nodal drainage system.

Right lower lobe tumors metastasize to the subcarinal area and the peritracheal area. They also tend to metastasize to sump nodes around the middle lobe. Therefore, as with right middle lobe tumors, bilobectomy may be necessary to encompass all lymph nodes that are affected.

Dissection of the right mediastinal lymph nodes generally involves resection of the right paratracheal lymph nodes in the 2R and 4R areas, the pretracheal lymph nodes (station 3), and the subcarinal lymph nodes (station 7).

An incision is made with an electrocautery parallel to the trachea and superior vena cava. The azygous vein may be divided if lymph nodes are enlarged or access is difficult. The underlying fat pad containing the right peritracheal lymph nodes is then excised using sharp and blunt dissection, clipping lymphatic vessels and blood vessels as necessary. The pretracheal (station 3) and tracheobronchial angle (station 4) are taken with this lymph-node pad. The dissection is carried up to the level of the right subclavian artery. Care should be taken to avoid the right recurrent laryngeal nerve and the right phrenic nerve.

The subcarinal lymph nodes are dissected by entering the subcarinal space. Dissection is begun at the edge of the right main stem bronchus and carried to the carina, and then 2 cm down the left main stem bronchus. All attempts should be made to not crush the lymph nodes. Special lymph-node forceps can be used to hold the fat pad that contains the lowest subcarinal lymph nodes (station 7) and the contralateral left main bronchial lymph nodes (station 10). The bronchial artery to the right main stem bronchus may frequently need to be ligated and divided.

On the left side, the left upper lobe tumors drain into the sump nodes between the lobes (stations 11 and 12). Pretracheal lymph nodes (station 3) may also be sites of metastasis. All peribronchial lymph nodes (station 4L) should also be taken. I also resect the paraesophageal (station 8) and pulmonary ligament (station 9) lymph nodes. Subcarinal lymph nodes are resected similarly to those on the right. Resection of the left upper lobe should also include resection of periaortic (ascending aorta

N₂ nodes:

- 1 - High mediastinal
- 2 - Upper paratracheal
- 3 - Pretracheal
- 4 - Lower paratracheal
- 5 - Aortopulmonary
- 6 - Para-aortic
- 7 - Subcarinal
- 8 - Paraesophageal
- 9 - Pulmonary ligament

N₁ nodes:

- 10 - Hilar
- 11 - Interlobar
- 12 - Lobar
- 13 - Segmental
- 14 - Subsegmental

N₃ nodes:

- Contralateral
- Paratracheal
- Supraclavicular
- Scalene

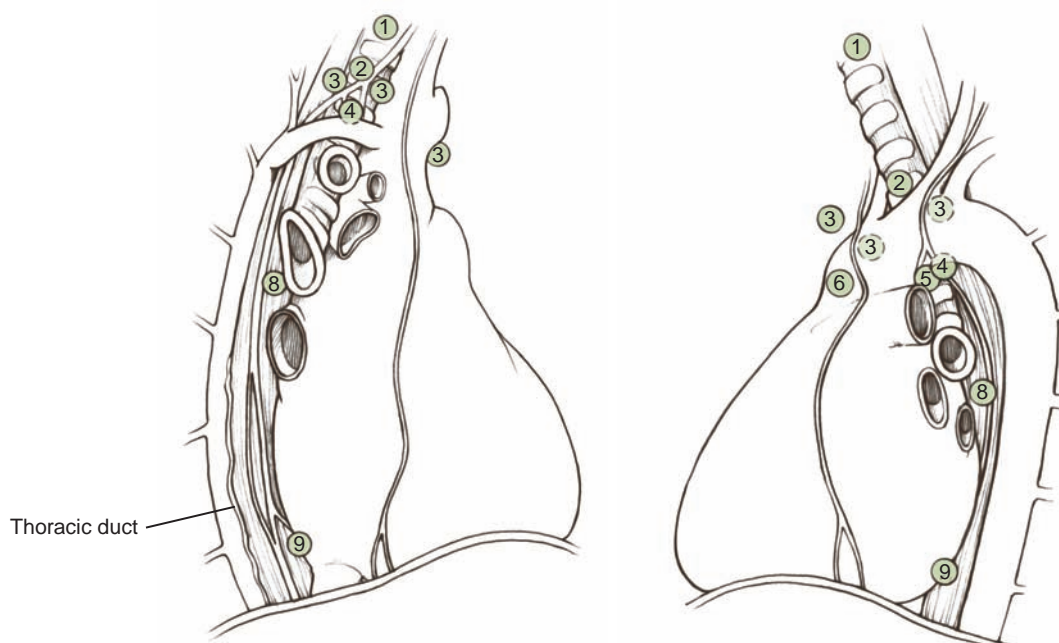
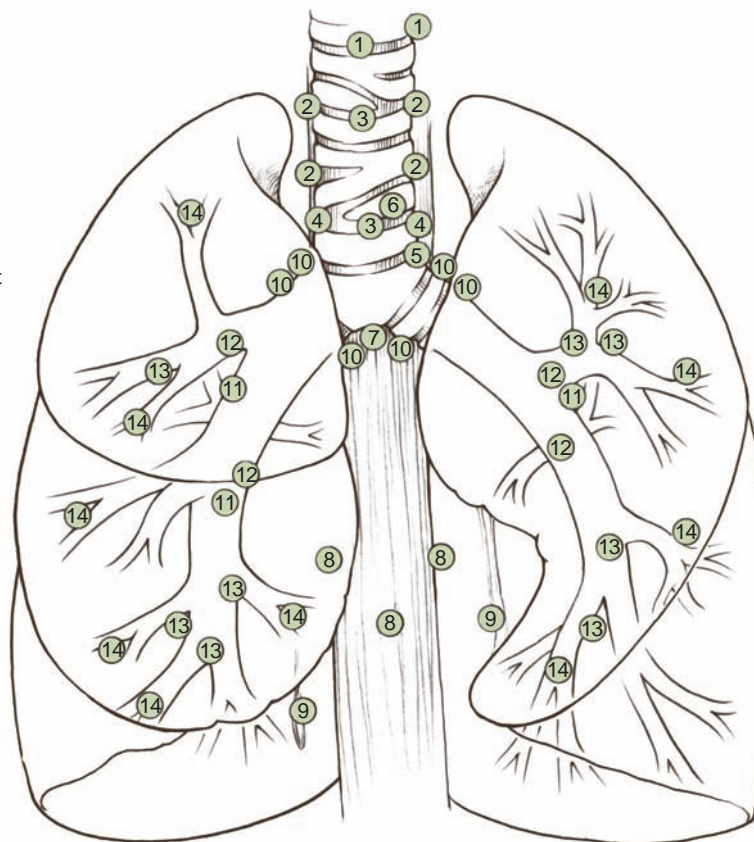


Figure 4.28

or phrenic) lymph nodes (station 6) and subaortic (aortopulmonary window) lymph nodes (station 5). Great care should be taken in dissecting the aortopulmonary window lymph nodes, as the left recurrent nerve is just lateral to the ligamentum arteriosum. In this area I prefer to identify the nerve first and then resect the fat and all the lymph nodes within the aortopulmonary window without using electrocautery. Tumors of the lower lobe generally metastasize to the subcarinal lymph nodes (station 7), paraesophageal nodes (station 8), and inferior pulmonary ligament nodes (station 9)

Anatomic Basis of Complications

- Most frequently occurring error is injury to the truncus anterior branch of the pulmonary artery on the left side. This short, friable artery is easily injured by traction. Every effort should be made to produce as little tension on the artery as possible during its dissection and mobilization to avert injury.
- The left recurrent nerve is easily injured during dissection of the aortopulmonary window lymph nodes. This can be prevented by knowing the course and location of the recurrent nerve. The electrocautery should not be used in this area, and extreme care should be maintained during the dissection to prevent inadvertent injury from traction.
- The surgeon should have adequate knowledge of the intrapericardial anatomy of the pulmonary arteries and pulmonary veins if control of these vascular structures is needed in the event of their injury during dissection of large tumors.
- Resection of the right upper or lower lobe may leave the right middle lobe bronchus in a precarious or compromised position. The right middle lobe bronchus must not be injured or narrowed during bronchial resection of the right upper or lower lobe. Compromise of the right middle lobe bronchus leads to atelectasis and eventual infection of the lobe that is difficult to manage.
- Division of the superior vein on the right upper lobectomy may narrow the drainage of the right middle lobe if care is not taken to prevent narrowing of the middle lobe vein.
- After a right upper lobectomy the middle lobe should be secured with sutures or a staple firing to the right lower lobe in correct anatomical position to prevent torsion of the middle lobe.
- Dissection during a VATS upper lobectomy is initiated first medially with dissection of the vein, artery, and then the bronchus. The fissure is divided last which has been associated with less air leaks postoperatively. Meticulous dissection around the pulmonary artery branches to prevent possible injury prior to division of the vessels.

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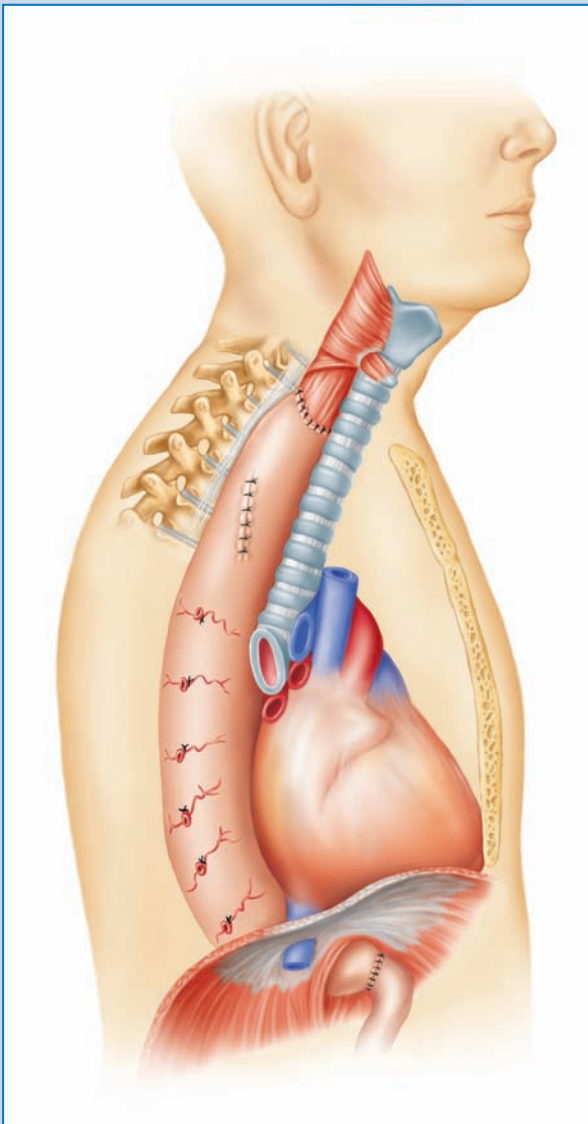
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Esophagus and Diaphragm

Seth D. Force,
Panagiotis N. Symbas,
Nikolas P. Symbas



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Esophagus

A variety of benign or malignant tumors may arise in the esophagus. Benign tumors may be epithelial, such as polyps, adenomas, papillomas, and cysts, or nonepithelial, such as leiomyomas, fibromas, fibromyomas, and lipomas. However, these neoplasms are exceedingly rare, accounting for less than 1% of all esophageal tumors. The majority of malignant esophageal tumors are either squamous cell carcinomas or adenocarcinomas, but other tumors, such as sarcomas and melanomas, can be found in the esophagus.

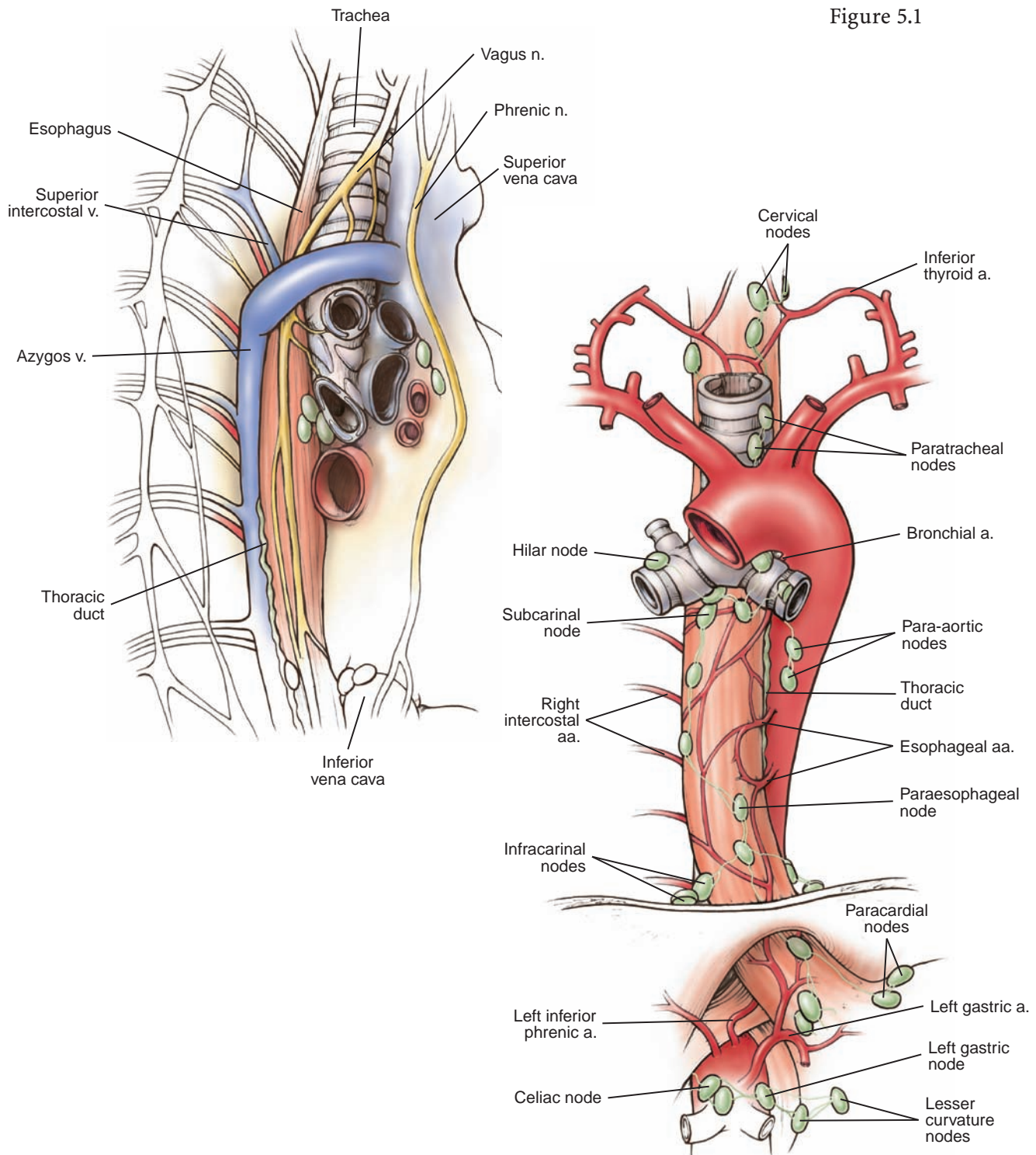
Benign esophageal tumors can be separated into epithelial and nonepithelial types. The most common benign tumor, the leiomyoma comprising 60–80% of all benign neoplasms, is classified as a nonepithelial tumor. Other benign tumors, in descending order of frequency, include cysts, lipomas, fibromas, and vascular or neurogenic tumors. Esophageal adenomas, papillomas, granular cell tumors, myxofibromas, and lymphangiomas are rare.

Carcinoma of the esophagus constitutes approximately 2% of all reported cancers. Esophageal cancer will be diagnosed in over 15,000 people, in the United States, in 2007 and will be responsible for over 13,000 deaths. Although squamous cell carcinoma accounts for the majority of esophageal cancers in North America, the incidence of adenocarcinoma has been rising over the past two decades. Affected persons are usually diagnosed between 50 and 70 years of age, and the disease is three to five times more common in men than in women. Esophageal carcinoma should be suspected in any patient with persistent dysphagia, particularly in those older than 40. The diagnosis may be established by barium swallows, esophagoscopy or computerized tomography. During esophagoscopy, esophageal washings should be obtained for cytologic examination, in addition to a biopsy of the esophageal lesion. After the diagnosis of esophageal carcinoma is established, a complete workup, including thoracoabdominal computed tomography (CT), should be performed. In patients with upper and middle third esophageal carcinoma, bronchoscopy should be performed to exclude tumor invasion of the trachea or left main bronchus. More recently, endoscopic ultrasound and positron emission tomography (PET) have been introduced as staging modalities. Endoscopic ultrasound, much like for rectal carcinoma, has been shown to be the best study for determining tumor depth and for locating and biopsying periesophageal lymph nodes. PET scanning is somewhat controversial with regard to its overall benefit in staging esophageal cancer, but it has shown its superiority over CT scanning for identifying metastatic disease. Treatment of both benign and malignant lesions of the esophagus is surgical excision whenever feasible. The type and extent of resection are tailored to the type of lesion.

Surgical Anatomy

The esophagus is a muscular tube connecting the pharynx and stomach. It lies posterior to the trachea and anterior to the aorta in the chest and abdomen. The esophagus can be separated into three anatomic parts; the cervical esophagus traveling 3–5 cm

from the lower border of the cricoid cartilage, at the level of the sixth cervical vertebra, to the aortic arch; the thoracic esophagus, traveling 18–22 cm, from the aortic arch to the diaphragm; and the abdominal portion, traveling 3–6 cm from the diaphragm to the stomach. In general, the axis of the esophagus is straight except for three minor deviations from the midline. The first is toward the left at the base of the neck, the second toward the right at the level of the seventh thoracic vertebra, and the third, the most prominent angulation to the left, is located just above the esophagogastric



junction. This course of the esophagus is important in determining the type of exposure depending on the location of the lesion. The length of the esophagus varies with age, sex, and body habitus. In adults, when it is measured using the nostrils or the incisor teeth as a landmark, the length is 13–16 cm to the cricoid cartilage, 23–26 cm to the tracheal bifurcation, and 36–48 cm to the gastric opening.

The esophagus is surrounded by many vital structures. Anterior to the esophagus are the trachea, the aortic arch, the right pulmonary artery, the left main bronchus, the pericardium, the anterior vagal trunk, and the esophageal hiatus. The important posteriorly located structures are the posterior vagal trunk, the anterior wall of the descending aorta, the thoracic duct obliquely from T7 to T4, and the right posterior intercostal arteries. Structures situated laterally to the right include the azygos vein and the right main bronchus, and left laterally are the aortic arch, the left recurrent laryngeal nerve, the thoracic duct from T4 to C7, and the descending thoracic aorta. Planned or accidental injury to any of these structures accounts for the major complications during and after esophagectomy.

In the mediastinum, the esophagus is enveloped by loose connective tissue that connects it to the neighboring structures and allows great mobility. Within this connective tissue are vessels, nerve fibers, and lymphatic channels and nodes. This anatomic characteristic permits, in selected cases, the so-called blunt esophageal resection. Such resection is not feasible and is hazardous when extraesophageal tumor extension or postinflammatory dense adhesions are present.

The structure of the esophagus parallels that of the rest of the digestive tube, except for the lack of a serosal layer. The outer layer of the esophagus, the muscularis externa, consists of a longitudinal and a circular layer. The longitudinal layer represents one sheet of multiple flat and delicate muscle bundles that completely wrap the esophageal wall. The muscle fibers of the circular layer do not form closed rings, instead they are circles with superimposed ends. Between these two layers of the muscularis externa are the myenteric ganglia of Auerbach, which, together with those of Meissner's plexus in the submucosa, coordinate esophageal movement.

The mucosal layer consists of nonkeratinizing squamous epithelium. Underneath it is the lamina propria, which contains loose connective tissue, a network of capillaries and lymphatic vessels, and mucus-producing tubular glands. The next layer of the mucosa is the muscularis mucosa, which is composed mainly of bundles of longitudinal smooth muscle. The submucosal layer contains collagenous elastic fibers and blood vessels, nerves, and mucus-producing glands. The collagenous fibers of this layer, together with the muscularis mucosa, are the main structures that provide strength to the esophageal suture line.

The squamous epithelium of the distal esophagus may be destroyed when gastroesophageal reflux is present. Cephalad migration of the columnar gastric lining then reepithelizes the injured area. The resulting columnar epithelial lining of the distal esophagus, extending at least 3 cm above the gastroesophageal junction, is known as Barrett's esophagus. Barrett's esophagus may be found in up to 15% of patients undergoing routine esophagoscopy. Barrett's esophagus is felt to be the starting point for the potential development of dysplasia and eventual invasive carcinoma. The true

incidence of carcinoma arising from benign Barrett's esophagus is not known, but the estimated risk ranges from 30 to 169 times the risk in the normal population. Because of the greater risk for malignancy, close surveillance of patients with Barrett's esophagus is recommended. Newer ablative techniques utilizing radiofrequency ablation, photodynamic therapy, or endomucosal resection have been recommended, with or without fundoplication, as a way of removing the abnormal mucosa.

Blood Supply

Six pathways provide most of the blood supply to the esophagus. The three most important are the inferior thyroid arteries, the bronchial arteries, and the left gastric artery, followed by the esophageal arteries, which arise from the descending aorta, the right intercostal arteries, and the left inferior phrenic artery. All of these vessels supply the muscularis externa before reaching the submucosa, where they join plexuses of vessels that extend throughout the length of the esophagus. This submucosal vascular network provides blood to the extramural branches. As a result, ligation of

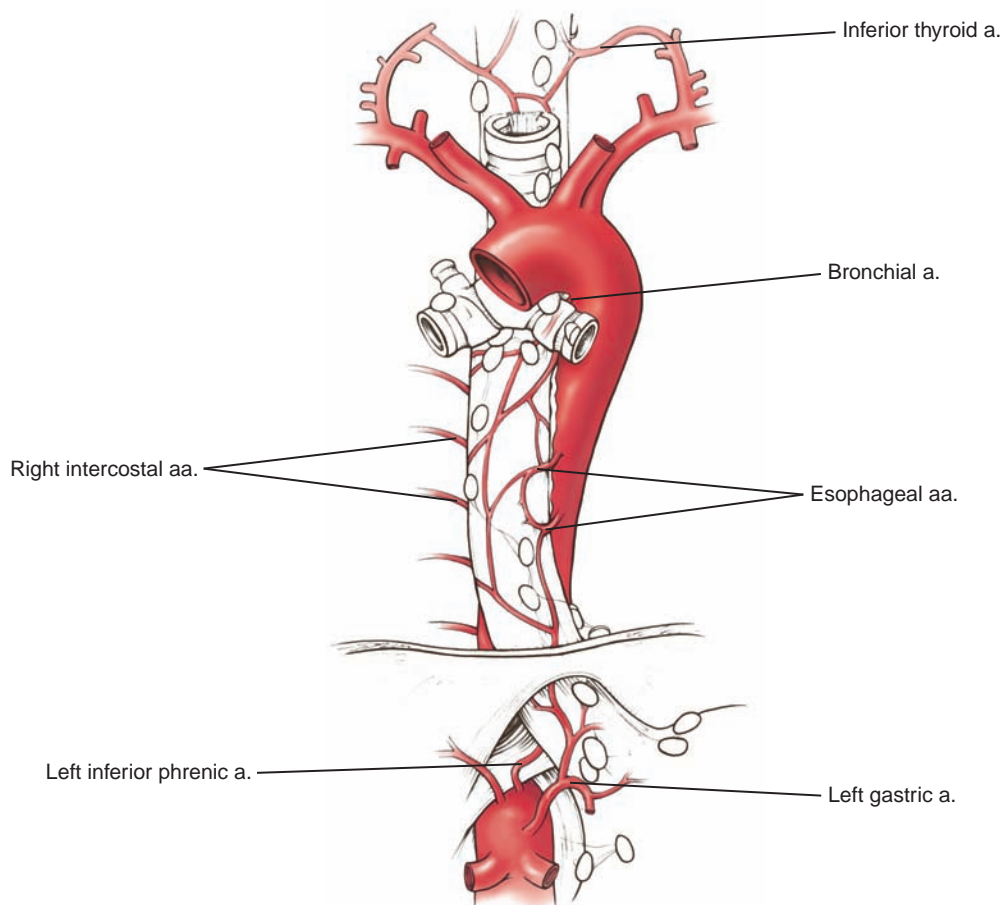


Figure 5.2

an extramural vessel and mobilization of a short esophageal segment do not compromise the viability of the related esophageal wall. Also, failure of an anastomosis between the esophagus and another conduit is not usually due to the blood supply of the esophagus but to that of the visceral substitute.

Lymphatic Drainage

The esophageal lymph drains from the lymphatic capillaries and the collecting channels to the subadventitial and the mediastinal trunks and then to the regional nodes. The lymphatic capillaries are in the submucosal layer and form longitudinally arranged collecting channels. This lymphatic arrangement perhaps permits the intramural spread of carcinoma along the longitudinal axis of the esophagus. Intramural microscopic spread of carcinoma has been shown to occur cephalad 3–6 cm from the tumor in about 65% of cases and 10 cm in the rest, and caudally about 4 cm from the tumor.

The lymphatic trunks drain into the periesophageal, subcarinal, peritracheal, cervical, paracardial, left gastric, and celiac axis nodes. Lymph flow from the upper

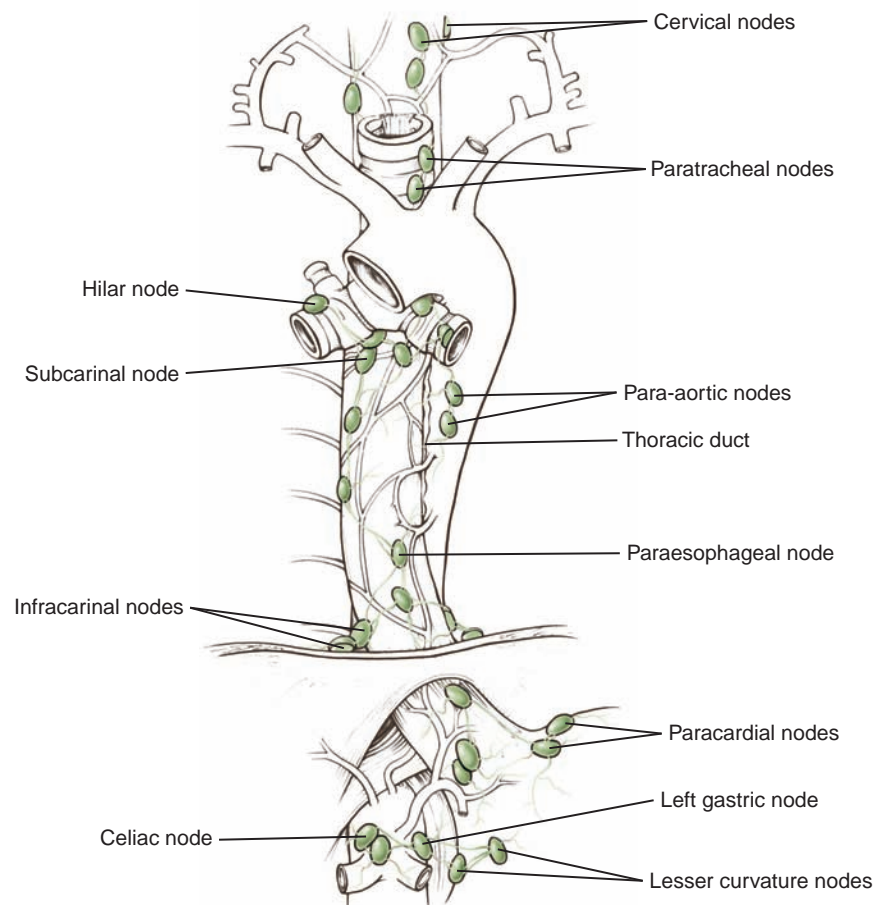


Figure 5.3

third of the esophagus is primarily to the upper mediastinal and cervical nodes. Lymph drainage from the middle third of the esophagus is to the upper mediastinal and cervical nodes and to the abdominal nodes, and lymph flow from the lower third is to the abdominal nodes. As a result, carcinoma of the upper third of the esophagus usually metastasizes to the cervical nodes, carcinoma of the middle third to the cervical and the celiac axis nodes, and carcinoma of the lower third to the celiac axis nodes.

Nerve Supply

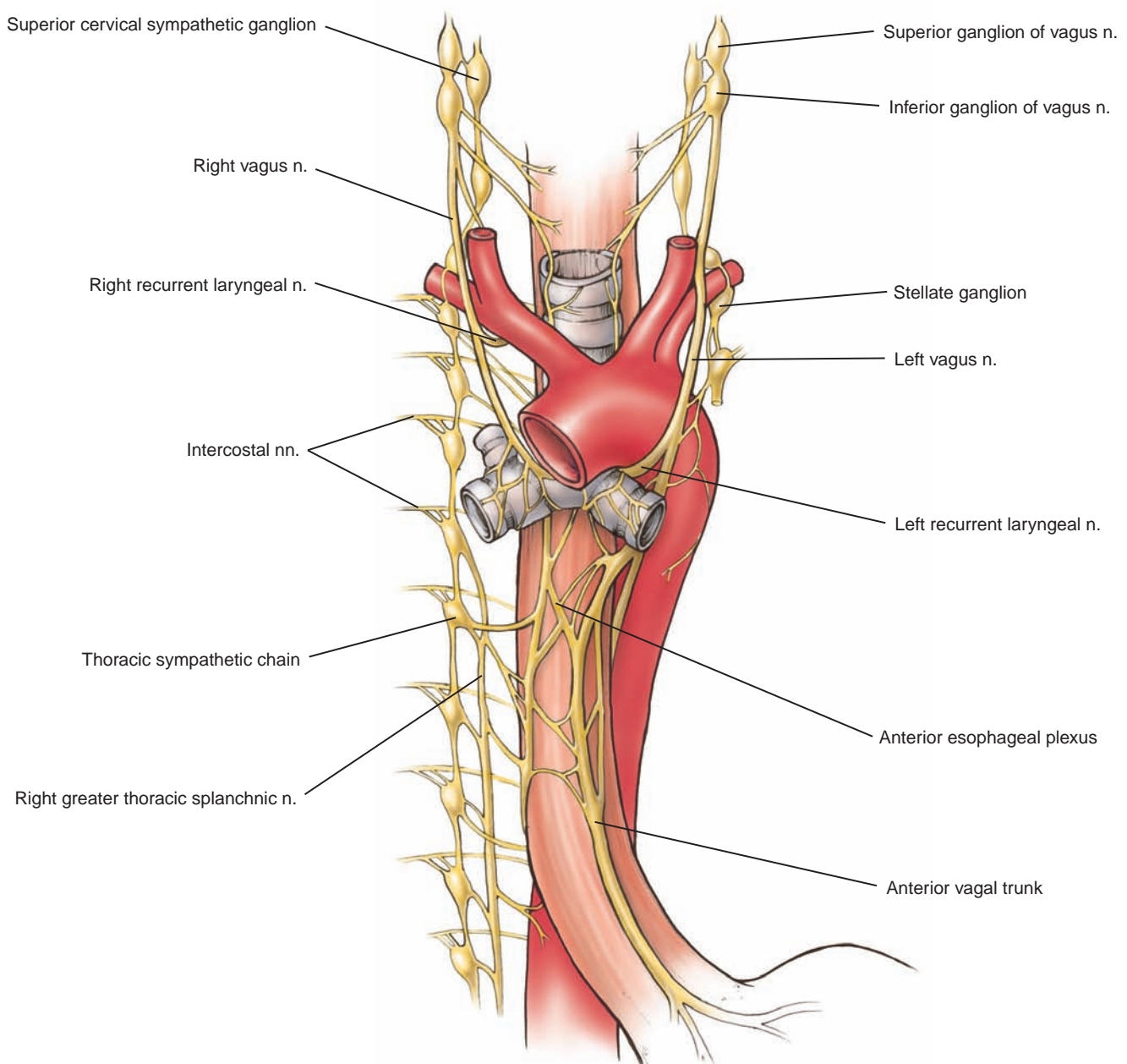


Figure 5.4

The esophagus is innervated by sympathetic nerves from the cervical and thoracic chains and by parasympathetic nerves from the vagus nerves. Because of their anatomic location, both vagus nerves are severed during esophagectomy. This compelled vagectomy is considered to cause gastric atony and lack of pyloric relaxation, resulting in poor emptying of the gastric pouch. For this reason, pyloromyotomy or pyloroplasty is recommended after esophagectomy, to assist gastric emptying. Some surgeons feel that the incidence of poor gastric emptying is not any greater without these procedures and choose not to perform gastric emptying procedures.

Carcinoma of the Esophagus

The type of treatment of esophageal cancer depends on the location of the tumor, the stage of the disease and the overall medical status of the patient. If patients are unable to tolerate a major surgical procedure because of coexisting medical conditions and there is no evidence of metastasis to the liver, radiation therapy with or

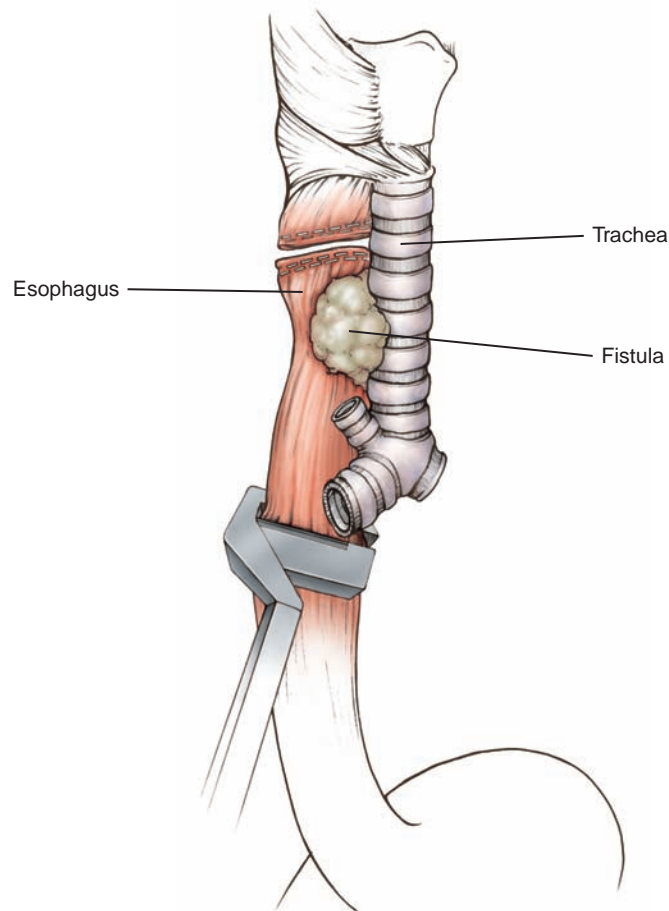


Figure 5.5

without chemotherapy is administered. In patients with preoperative evidence of liver metastasis and major dysphagia, treatment includes insertion of an endoesophageal prosthesis or careful mechanical dilation. A passage may be cored through the tumor under endoscopic vision, but with significant risk for perforation. Insertion of an endoesophageal prosthesis may also be used to protect from aspiration of saliva or food in the patient with a tracheoesophageal or broncho-esophageal fistula.

Occasionally, exclusion of the fistula, esophagectomy, or esophagogastrostomy, followed by radiation therapy may be used in highly selected patients with tracheoesophageal fistula. In patients without evidence of liver metastasis or other distal metastasis, resection of the carcinoma is the treatment of choice, with or without preoperative radiation therapy and chemotherapy. The most commonly used surgical approach for the resection of carcinoma of the thoracic esophagus incorporates two incisions, a right thoracotomy and upper midline laparotomy with or without a cervical incision. Less commonly used approaches are the left thoracotomy and the trans-hiatal dissection through an upper midline abdominal and a cervical incision or a minimally invasive approach.

Preoperative or postoperative radiation therapy had been added to surgical treatment of esophageal carcinoma, but no improvement has been noted in either median or 5-year survival. During the last several years, preoperative treatment with combined

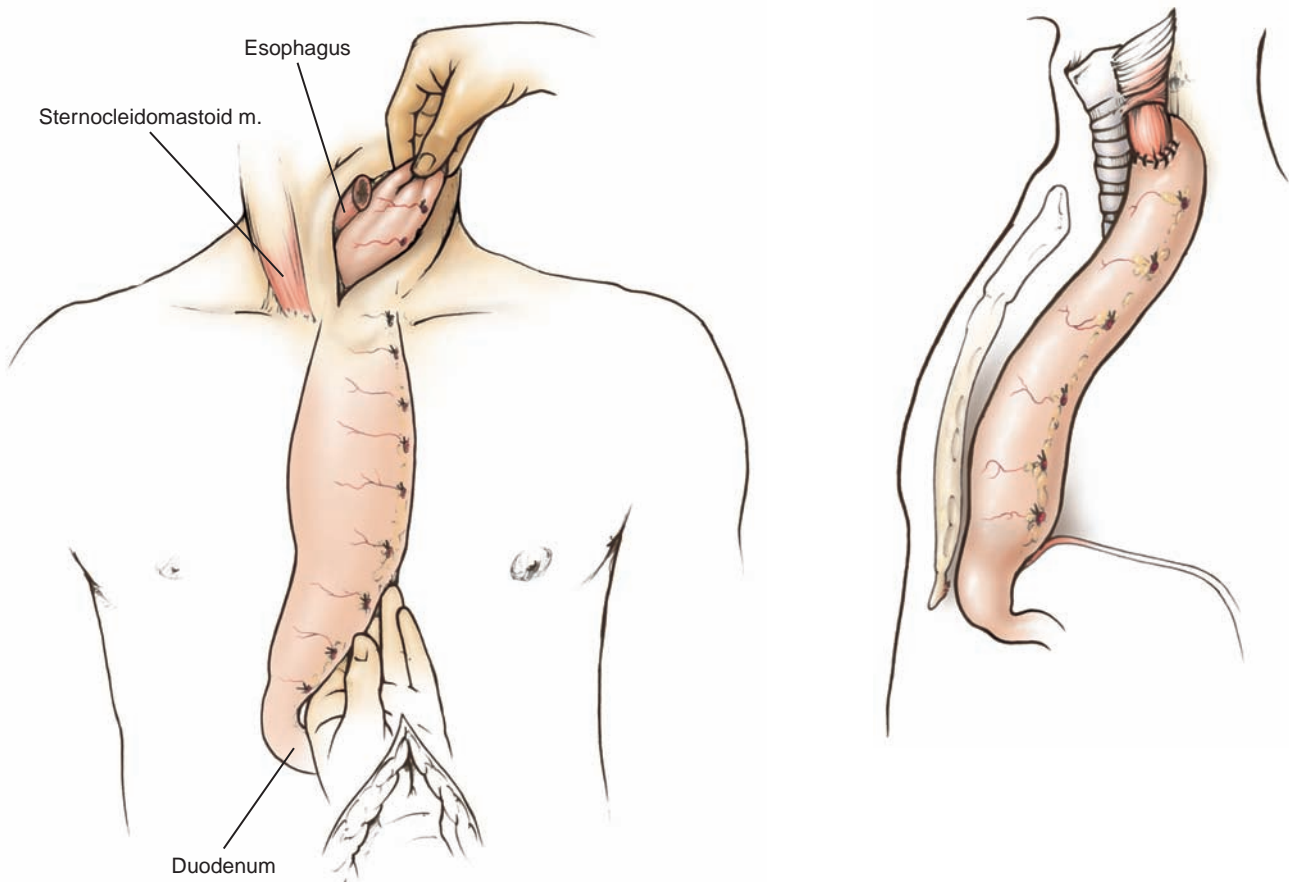


Figure 5.6

radiation therapy and chemotherapy has been used widely, most frequently radiation plus 5-fluorouracil (5-FU) and mitomycin or cisplatin. At present the precise benefit of preoperative treatment of esophageal carcinoma with the combination of radiation and any of the chemotherapeutic agents has not been clearly established and more prospective studies are needed.

Surgical Applications

Esophagectomy Through Right Thoracotomy and Laparotomy (Ivor-Lewis Approach)

In 1946, Dr. Ivor-Lewis described a technique for removing the esophagus utilizing a right thoracotomy and upper midline laparotomy. This technique allows easy resection of the esophagus, the ability to perform an intrathoracic esophagogastrostomy and, in particular, provides excellent exposure to the airway. All patients undergoing esophagectomy should have an esophagogastronomy performed by the surgeon and a bronchoscopy should be added for proximal and mid-esophageal tumors to rule out airway invasion.

The patient is initially placed in the supine position for the laparotomy to be performed first. If there is some concern with regard to intra-abdominal metastases, laparoscopy can be performed prior to laparotomy. The arms are tucked, and the patient is prepped from the lower thoracic area to the pubis. An upper midline vertical incision is made from the xiphoid process to the umbilicus. The falciform ligament is clamped, divided, and ligated, and then the liver and peritoneum are inspected for evidence of metastasis. If liver metastasis is present, and the patient has significant esophageal obstruction, an endoesophageal prosthesis and a feeding gastrostomy tube are inserted. If no hepatic metastases are found, then dissection is begun by incising the left triangular ligament of the liver, with electrocautery, and mobilizing the left lobe of the liver medially. An abdominal retractor is then positioned so as to retract the right and left costal margins cephalad and laterally. The left lobe of the liver should also be retracted medially so as to expose the diaphragmatic hiatus. Next, the hepatogastric ligament is opened with electrocautery. A replaced left hepatic artery may be present in the ligament and, if found, it should be preserved. The dissection is then carried onto the phrenoesophageal ligament, and the right and left crura of the diaphragm are exposed. The distal esophagus is then bluntly dissected and encircled with a large 1 in. penrose drain. The esophageal hiatus is widened to about four fingerbreadths by incising the right crus of the diaphragm, and the distal esophagus is mobilized as far as possible into the mediastinum. Some of this can be performed bluntly but retraction of the hiatus allows for visualization and division of esophageal vessels with electrocautery or some other thermal device.

Gastric mobilization is begun with the division of the short gastric vessels. The lesser sac is entered with electrocautery and the short gastric vessels are then divided, from caudal to cranial, with a Harmonic Scalpel or Ligasure Device approximately 2–3 cm from the gastroepiploic artery. The right gastroepiploic artery should be

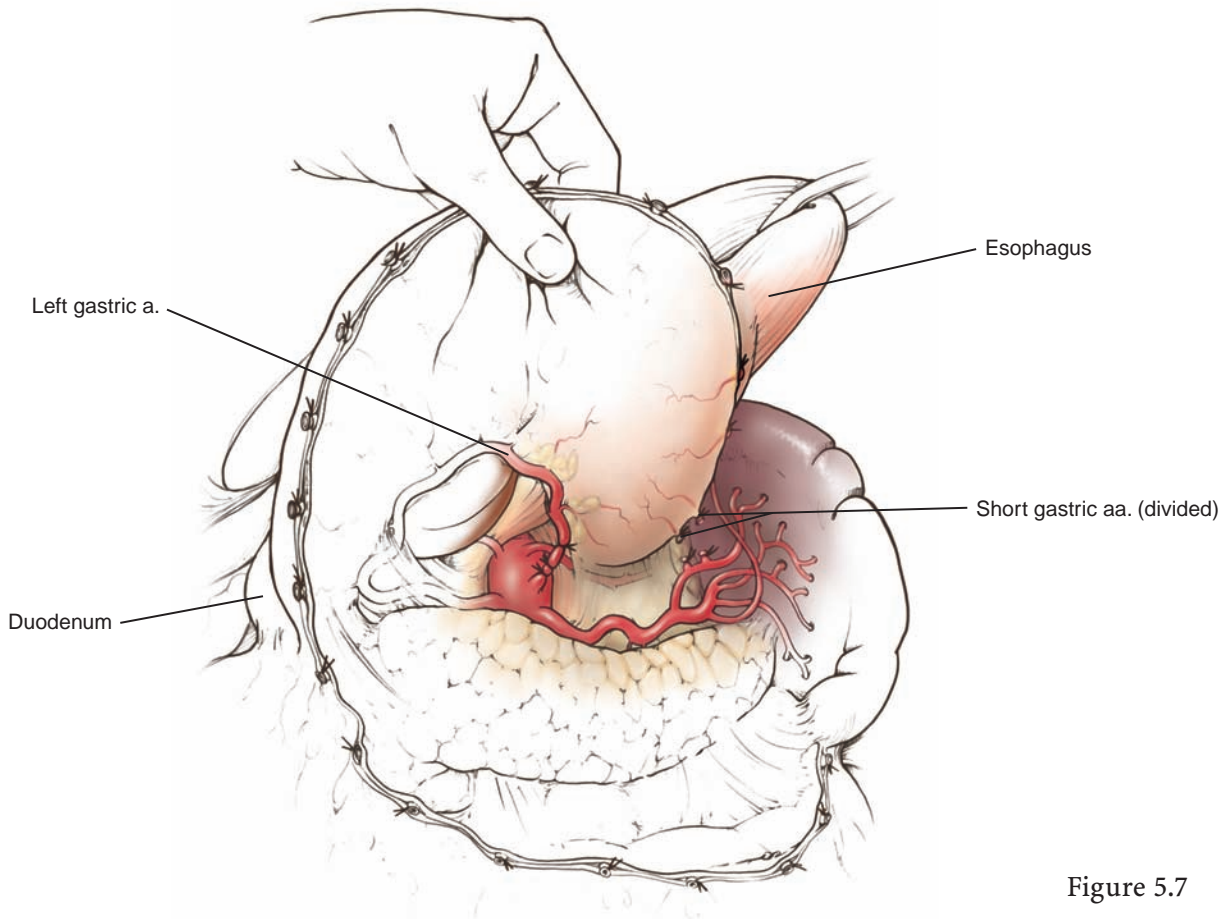


Figure 5.7

evaluated, at this time, to ensure that it is suitable to support the gastric conduit, and care is taken not to traumatize the artery while retracting the stomach. After the entire greater curvature of the stomach is mobilized, the stomach is retracted to the patient's right, and the left gastric vessels are exposed, double ligated, and divided. All of the left gastric lymph nodes should be swept toward the lesser curvature of the stomach and removed, en bloc, with the specimen.

The remaining gastrohepatic ligament is then incised toward the hiatus and the pylorus, carefully protecting the right gastroepiploic artery and the hepatic artery, portal vein, and common bile duct. A Kocher maneuver is performed, incising the parietal peritoneum, and the duodenum is mobilized medially as far as possible. This allows for an additional 1–2 cm of length for the gastric conduit.

A pyloromyotomy or pyloroplasty is performed next. If a pyloroplasty is chosen, the pylorus is opened longitudinally and the incision is extended into the distal pylorus and the proximal duodenum and then closed transversely, with a single layer of 3–0 silk sutures. Finally, a feeding jejunostomy can be placed, if desired, using a 14 French red rubber catheter. The abdomen is closed and the patient is then turned to a left lateral decubitus position and the right chest is prepped and draped.

A small right posterolateral thoracotomy is made, and the pleural space is entered through the fourth or fifth intercostal space. The right lung is deflated, and ventilation

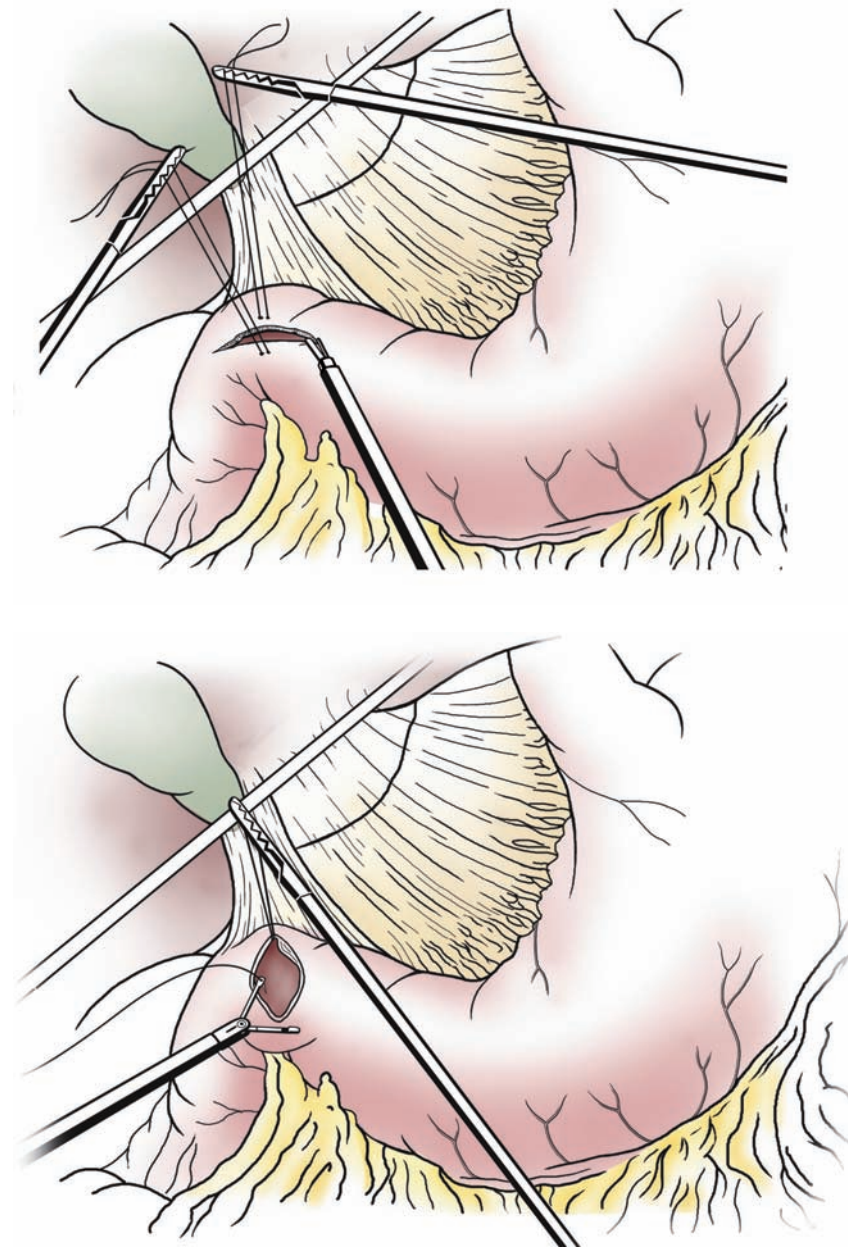


Figure 5.8

is maintained only through the left lung during the entire endothoracic portion of the procedure. The inferior pulmonary ligament is divided up to the inferior pulmonary vein, the right lower lobe is retracted upward and medially, and the distal esophagus, which usually has been mobilized previously during the trans-hiatal dissection, is encircled with a 1 in. penrosedrain. The mediastinal pleura is then opened medial and lateral to the esophagus, with cautery, up to the level of the azygous vein. The azygous vein is ligated and divided and the mediastinal pleural is incised up toward the apex of the chest. Care should be taken to avoid injuring the thoracic duct during the posterior esophageal mobilization. If a thoracic duct injury is suspected then the duct should be ligated at the level of the hiatus.

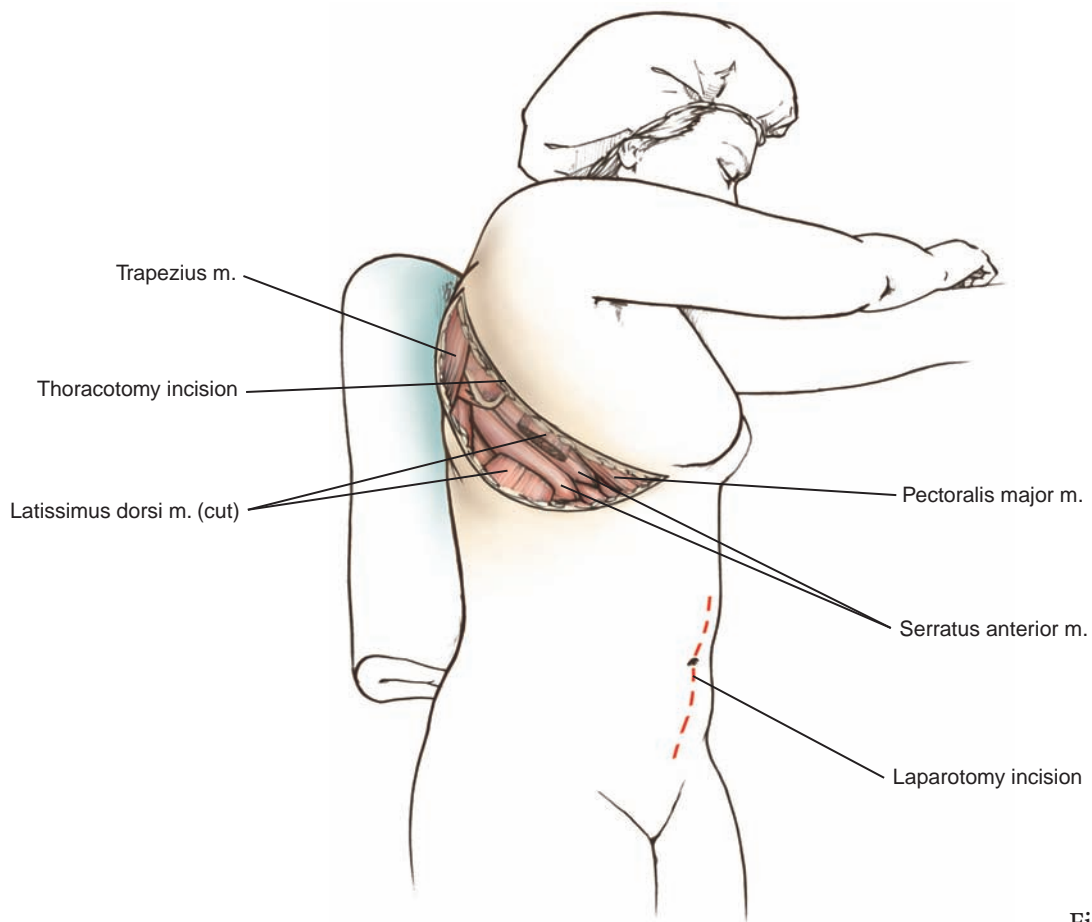


Figure 5.9

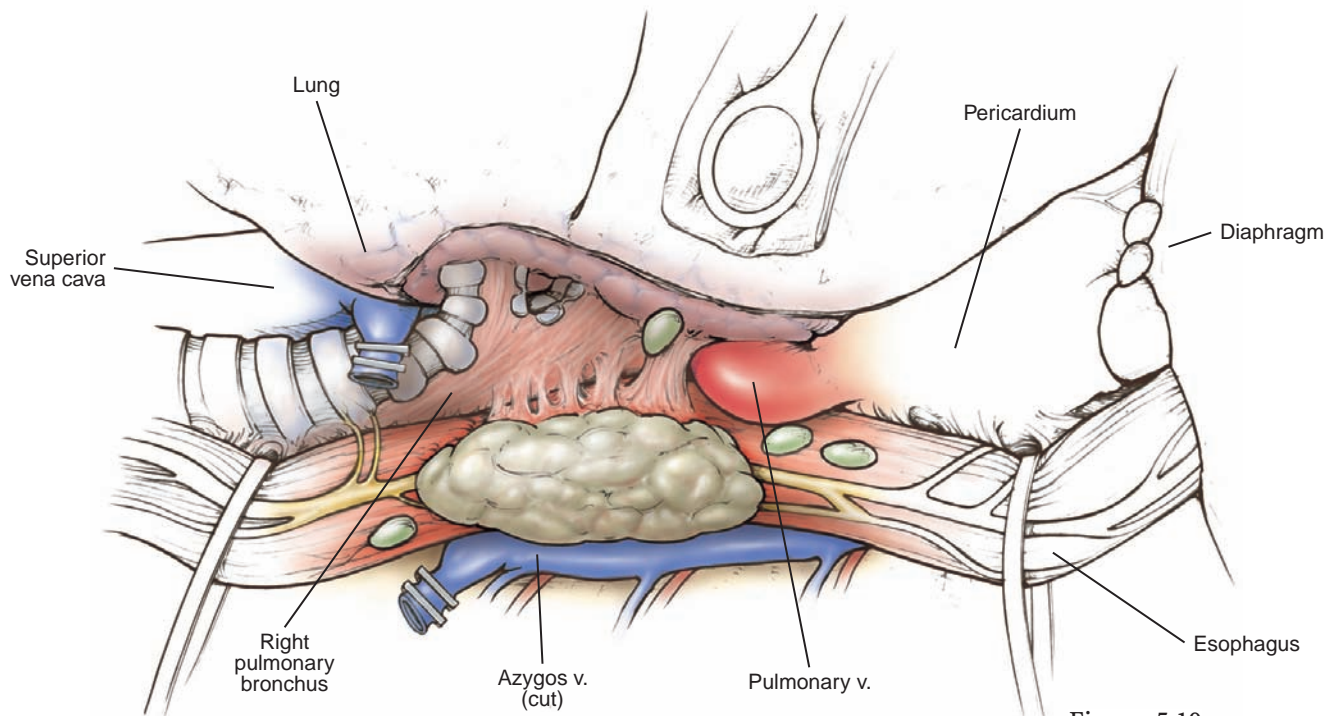


Figure 5.10

Attention is then turned toward the esophagus as it crosses the carina and left main bronchus. Low energy cautery or sharp dissection is used to carefully dissect the esophagus away from the airway in this area. All subcarinal lymph nodes should be removed either separately or en bloc with the esophagus. If the airway is injured then this should be repaired with 4-0 absorbable sutures and covered with a pedicled muscle flap. Dissection is then carried down toward the hiatus and the pleura is incised exposing the intra-abdominal esophagus. Aortic perforators are either ligated and divided or divided with the Harmonic Scalpel. The esophagus should be exposed 5 cm above the azygous vein. The stomach is delivered through the hiatus into the right pleural space, paying special attention not to twist it by keeping the lesser curvature toward the lateral chest wall. Correct positioning can be confirmed by palpating the pyloroplasty anteriorly.

The lesser curvature is then cleared of loose fatty tissue and the right gastric artery is divided at the level of the second crow's foot. The specimen is then transected, distally, with a GIA stapler beginning lateral to the Angle of His and then proceeding toward the second crow's foot on the lesser curvature of the stomach so that the resected specimen encompasses the esophagus, the periesophageal tissue and nodes,

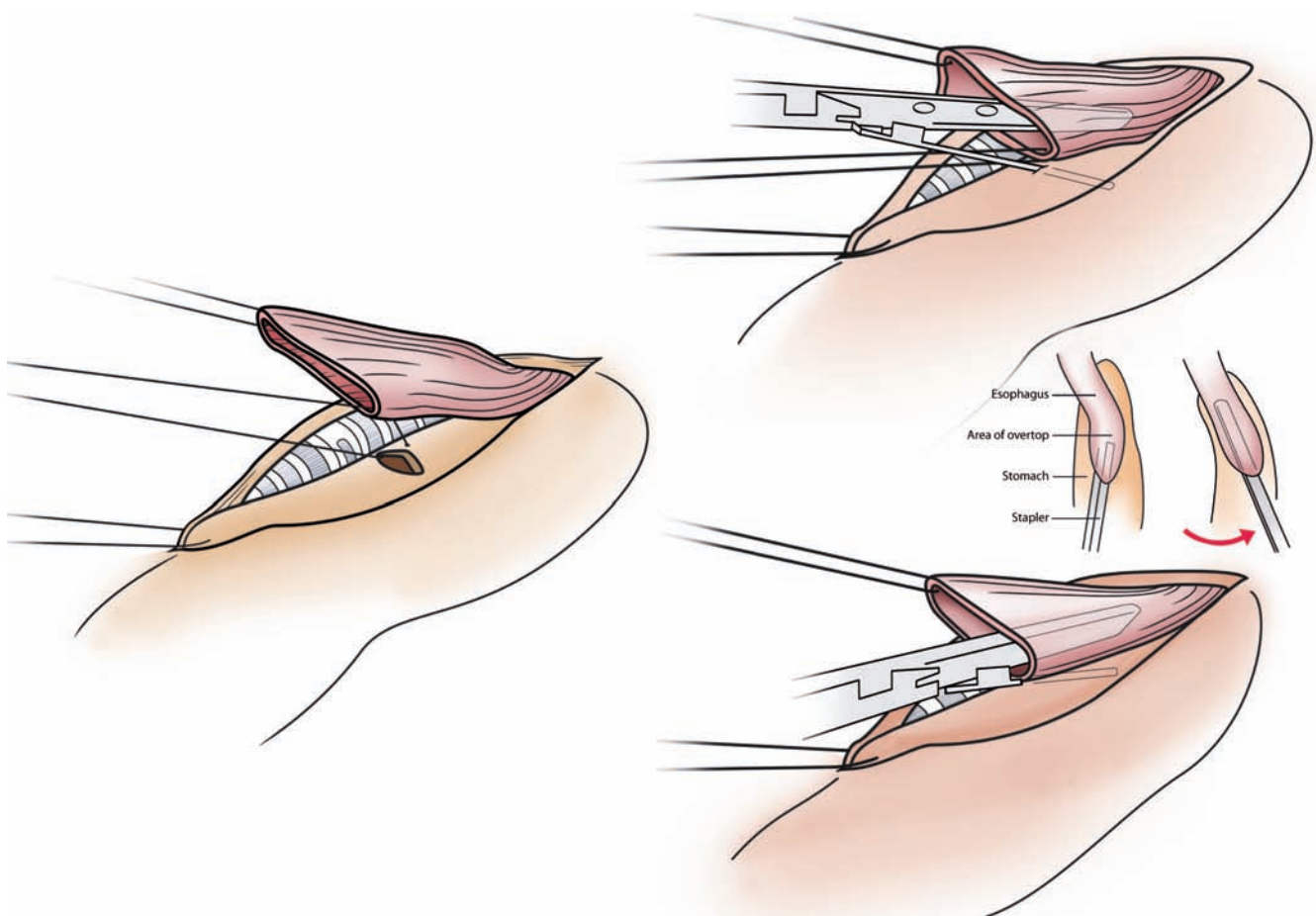


Figure 5.11

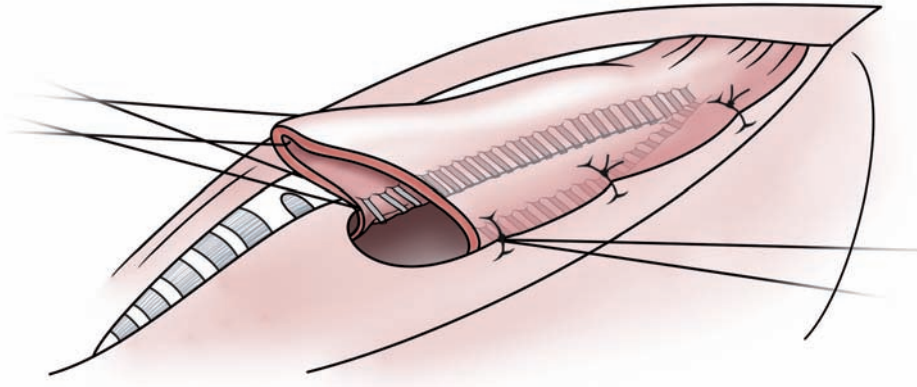


Figure 5.12

the cardia, and part of the lesser curvature and its regional nodes. The esophagus is then divided with an endoGIA stapler at the level of the azygous vein.

The esophagogastric anastomosis should always be performed at, or above, the level of the azygous vein. The type of esophagogastric anastomosis is not as important as maintaining a good arterial supply to the gastric tube and avoiding venous congestion and anastomotic tension. Multiple techniques are available for performing the anastomosis including sutured, stapled, and combined sutured and stapled. The totally stapled anastomosis, utilizing an EEA stapler, is relatively fast to employ but it is associated with a significant stricture rate for any anvil smaller than 28 mm. Sutured anastomoses can be performed as single or multiple layers with permanent or absorbable suture. The combined, stapled-sutured, technique allows for a very large anastomosis and a low leak and stricture rate. This is performed by cutting off the staple line on the esophagus at an angle so that there is more esophagus laterally than medially (from an anatomic viewpoint). A small gastrostomy is then made, with cautery, at least 6 cm from the tip of the gastric conduit.

Stay sutures of 3-0 silk are placed at the corners of the gastrostomy and esophagostomy. An additional suture is placed at the apex of the esophagostomy and the stomach and esophagus are aligned. The posterior anastomosis is performed in a stapled fashion. An endoGIA stapler, with a blue staple load, is positioned so that the anvil side is in the esophagus and the cartridge side is in the stomach. Care is taken to make sure that the gastric and esophageal mucosa are aligned and that the stapler is not too close to the tip of the stomach or the lesser curvature staple line since these are areas with relatively poor blood supply. The stapler is then closed and the area is inspected to make sure that the stomach and esophagus are still aligned properly and that no extra tissue is caught in between the two organs. Then the stapler is fired.

The anterior layer is performed with interrupted 3-0 silk sutures. Prior to tying these, a nasogastric tube is placed into the stomach. If any extra stomach tube is left, this can be sutured over the anastomosis using interrupted 3-0 silk sutures. Two 28 French chest tubes are placed in the chest; one by the diaphragm and one near, but not directly at, the anastomosis, and the chest is closed in a standard fashion.

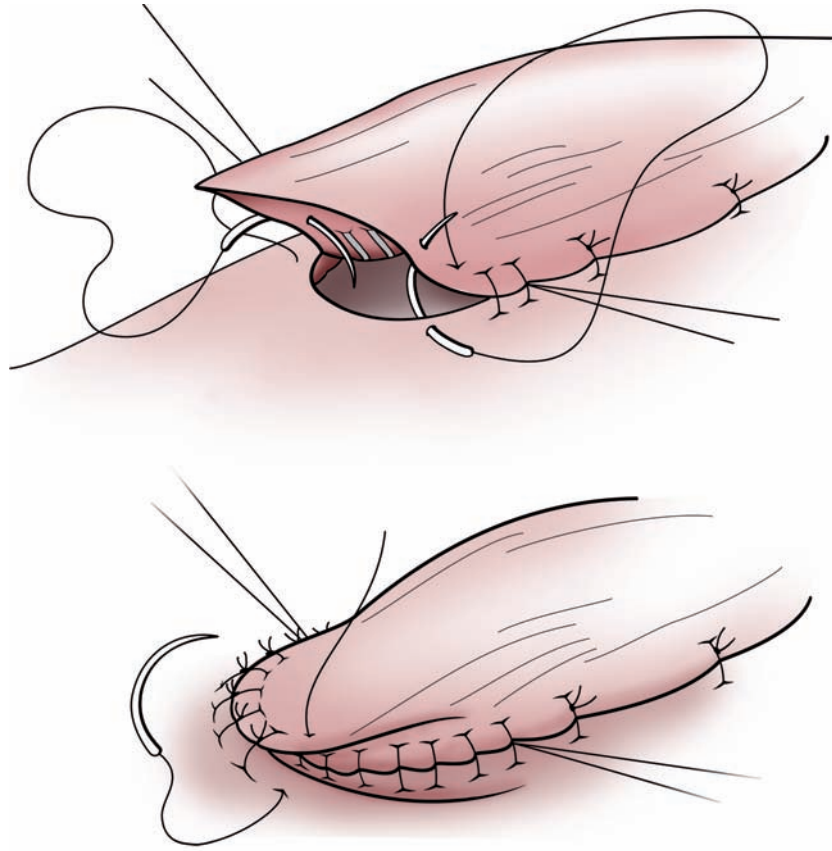


Figure 5.13

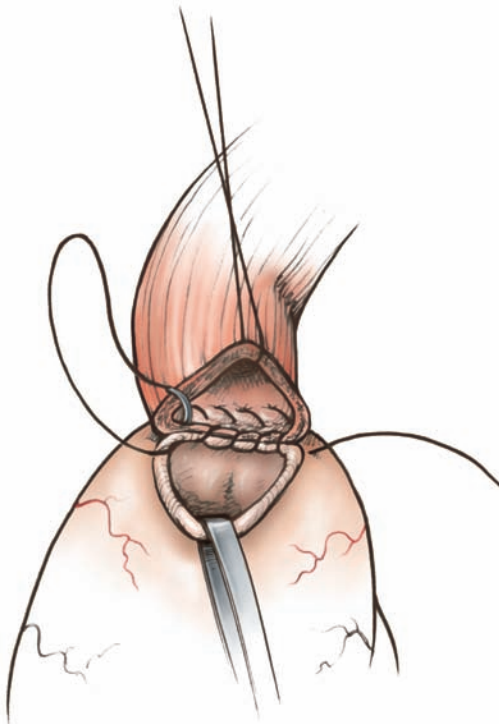


Figure 5.14

A cervical anastomosis may be necessary in order to achieve a negative margin for proximal esophageal tumors. The McKeown esophagectomy is similar to the Ivor-Lewis esophagectomy except that the right posterolateral thoracotomy is performed first. The esophagus is mobilized from the hiatus to the apex of the right chest. Further, blunt dissection should be performed up into the neck to make the cervical portion of the procedure easier. Once the thoracic portion is completed the patient is turned to a supine position with the head extended and turned toward the patient's right. The patient is then prepped from neck to abdomen. If multiple surgeons are available the procedure can be expedited by beginning the abdominal and cervical dissections simultaneously. The abdominal portion is performed as stated above in the description of the Ivor-Lewis esophagectomy.

The cervical portion is begun making a 5-cm incision along the anterior border of the left sternocleidomastoid muscle (SCM). The subcutaneous tissue and platysma muscle are divided with cautery and the SCM and carotid sheath are retracted laterally. The larynx and trachea are retracted medially with the assistant's fingers to avoid injuring the left recurrent laryngeal nerve with metal retractors. Next, the omohyoid muscle, inferior thyroid artery, and middle thyroid vein are divided. The esophagus is then dissected bluntly, posteriorly to expose the prevertebral fascia. Extensive dissection performed from the chest portion helps to facilitate this part of the neck dissection. The esophagus is then dissected away from the trachea with

Three-Hole (McKeown) Esophagectomy and Transhiatal Esophagectomy

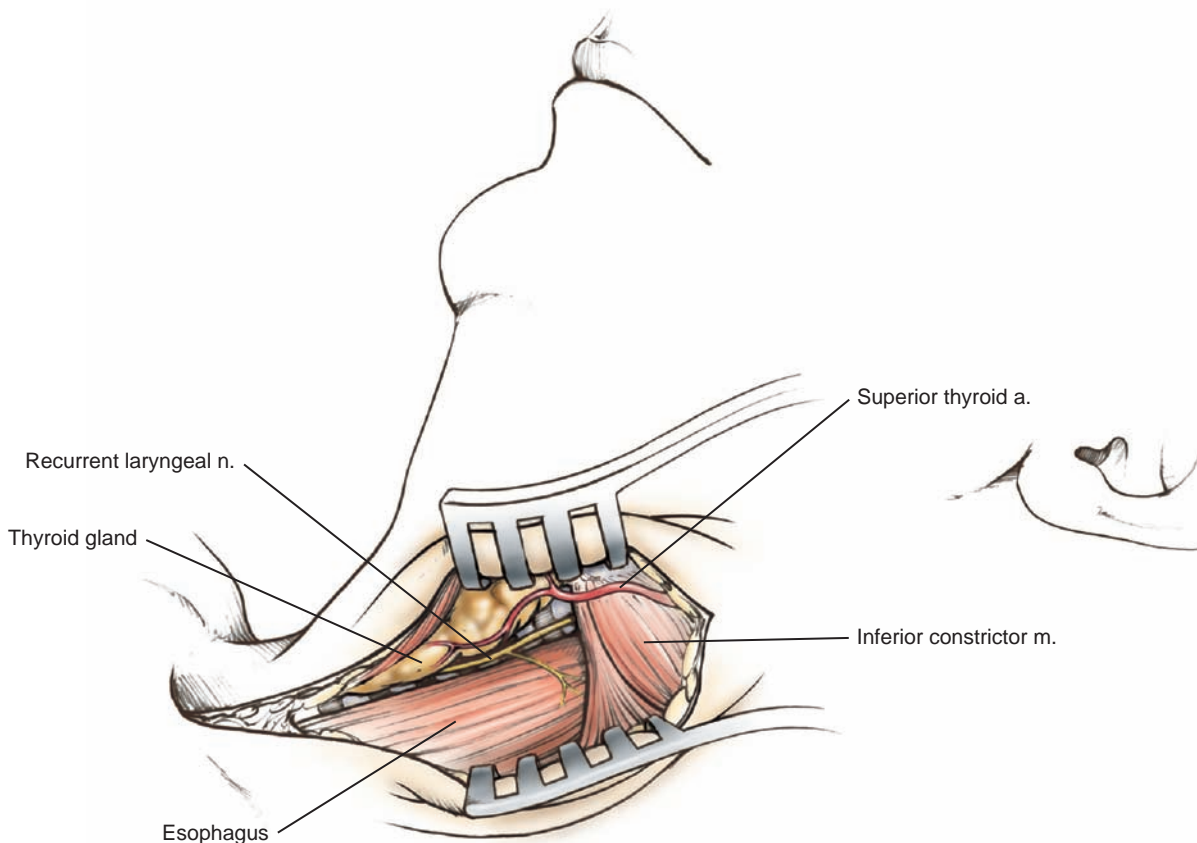


Figure 5.15

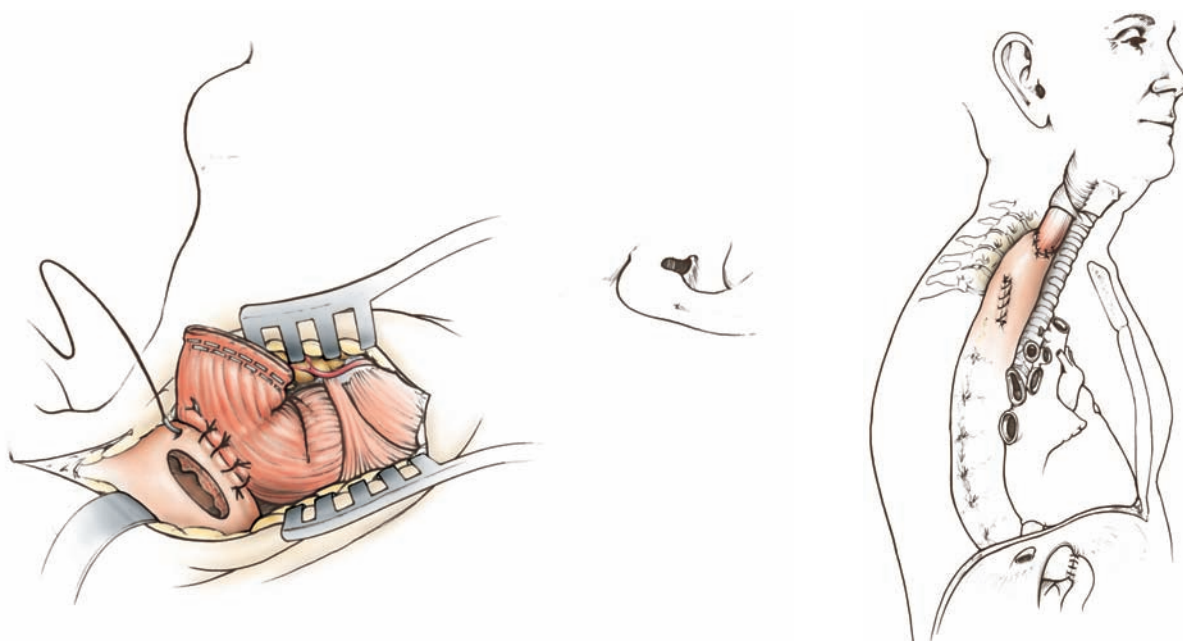


Figure 5.16

a combination of blunt and sharp dissection and with special care to avoid injury to the recurrent laryngeal nerve. The esophagus is then dissected circumferentially and encircled with a penrose drain. Gently, traction is applied from the neck and the abdomen to ensure that the esophagus is completely free from all mediastinal attachments. The esophagus is then clamped and transected in the neck with a scalpel. The distal end is oversewn to avoid spillage of gastric contents and then sutured to an extra-large penrose drain.

The esophagus is then pulled into the abdomen making sure to maintain a portion of the penrose drain in the neck. The stomach is then transected in the abdomen, and the specimen is passed off the field.

The gastric conduit is then placed into a sterile camera bag which is sutured to the penrose drain. The gastric tube is then delivered into the neck by a combination of gently pushing from the abdomen and pulling from the neck. The esophagogastric anastomosis is then performed as discussed above, a closed suction drain is placed and the neck is closed in standard fashion. Some authors have recommended suturing the stomach to the prevertebral fascia in the neck but there have been several reports of spinal abscess formation due to this technique and it is no longer recommended.

Trans-Hiatal (Blunt) Esophagectomy

The blunt or trans-hiatal esophagectomy follows the same steps in the neck and abdomen as outlined above but the mediastinal dissection is performed without thoracotomy.

Retractors placed in the hiatus are used to expose the esophagus which is bluntly dissected away from the spine and mediastinal attachments.

With traction of both the proximal and distal esophagus, its midportion, the area at the tracheal bifurcation, is dissected bimanually by inserting one hand through

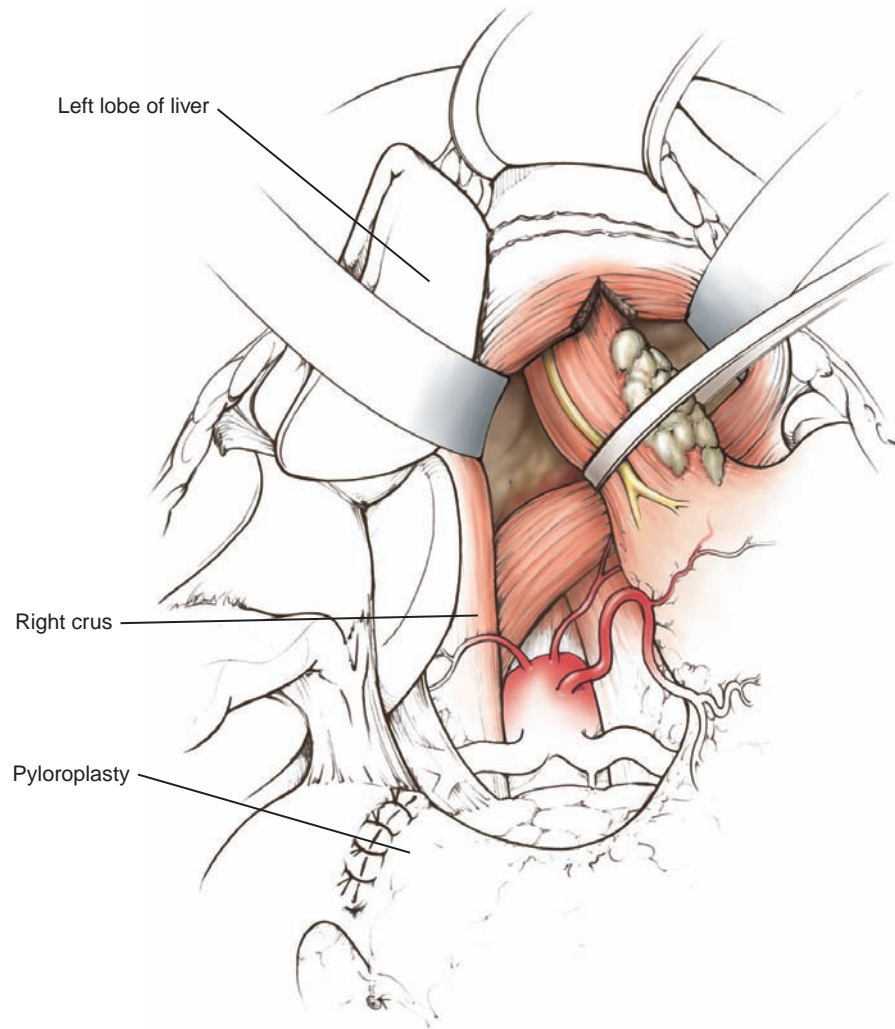


Figure 5.17

the hiatus and the other through the cervical incision. The dissection is first done posteriorly and then anteriorly, with intermittent brief periods of dissection to avoid prolonged displacement and compression of the heart. Arrhythmias and hypotension may occur while the surgeon's hand displaces the heart. These complications can be minimized or prevented by sufficiently replenishing the patient's blood volume before this phase of the esophageal dissection and by making each dissection period short. The bimanual dissection is continued until the fingers of the two hands meet.

Two structures that can be injured during the blunt esophagectomy are the azygous vein and the left main bronchus. If either is thought to be injured they must be repaired, expeditiously, through a right thoractomy. Once the esophagus is entirely free from its mediastinal attachments the rest of the procedure follows the steps outlined in the McKeown esophagectomy.

This approach is mainly applicable with carcinoma of the distal esophagus, particularly of the gastroesophageal junction. One of the major drawbacks of this technique is that the anastomosis cannot be performed any more proximal than the aortic

**Esophagectomy
Through Left
Thoracotomy**

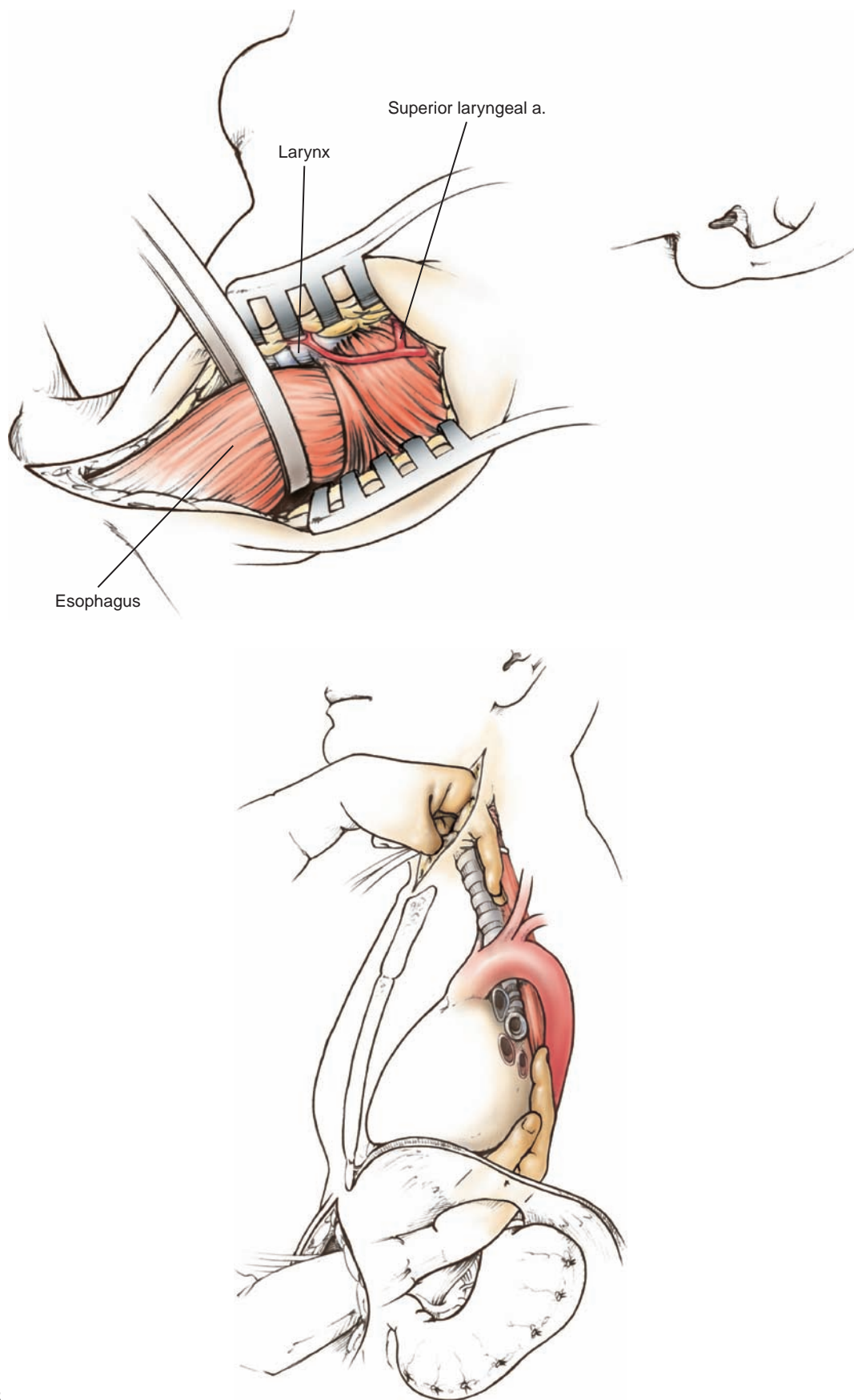


Figure 5.18

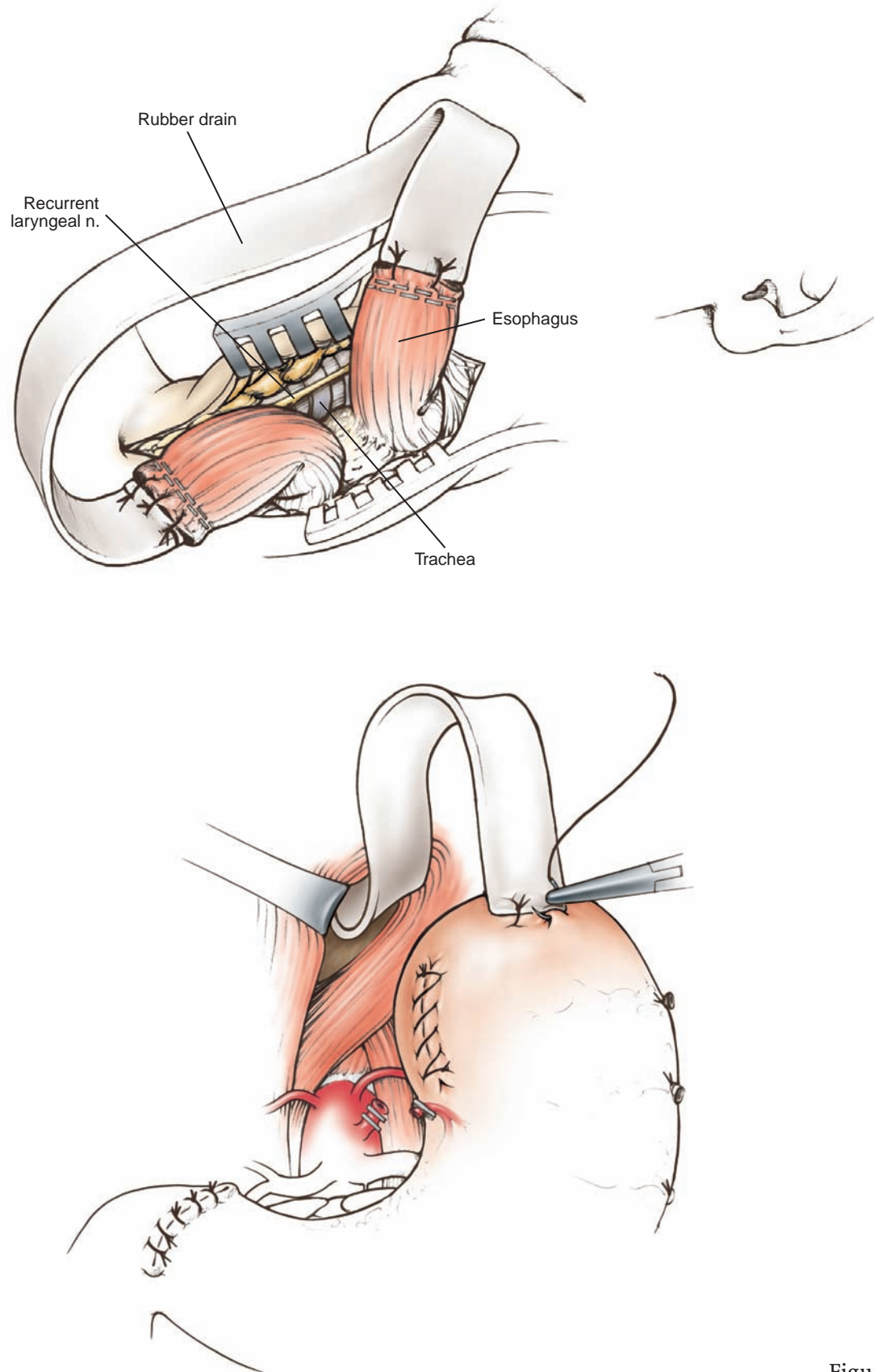


Figure 5.19

arch. With the patient in the right lateral decubitus position, a left posterolateral thoracotomy through the seventh intercostal space is performed.

The left lung is collapsed and retracted medially and the mediastinal pleura between it and the aorta is incised. This incision is extended into the posterolateral segment of the diaphragm while protecting the intra-abdominal organs from injury. When additional exposure is needed for mobilization of the stomach, the diaphragmatic incision can be extended curvilinearly anteriorly, leaving a 1–2-cm diaphragmatic rim attached to the chest wall in order to facilitate closure. A segment of the lower esophagus is mobilized and encircled with tape. With gentle traction on the tape, the esophagus is freed up 10–12 cm from the tumor margin. Then through the diaphragmatic incision the stomach is dissected free, and pyloromyotomy or pyloroplasty is performed. The tumor with adequate cephalad and caudal margins is resected along with all the visible nodes, and esophagogastrostomy is performed as described previously. If more of a proximal margin is needed then a cervical dissection and anastomosis can be added.

Esophagectomy Without Thoracotomy

Minimally Invasive Esophagectomy

Minimally invasive esophagectomy deserves some mention. Although not yet applied widely, this technique has been shown to achieve results that rival the more standard techniques when performed by accomplished laproscopic/thoracoscopic surgeons.

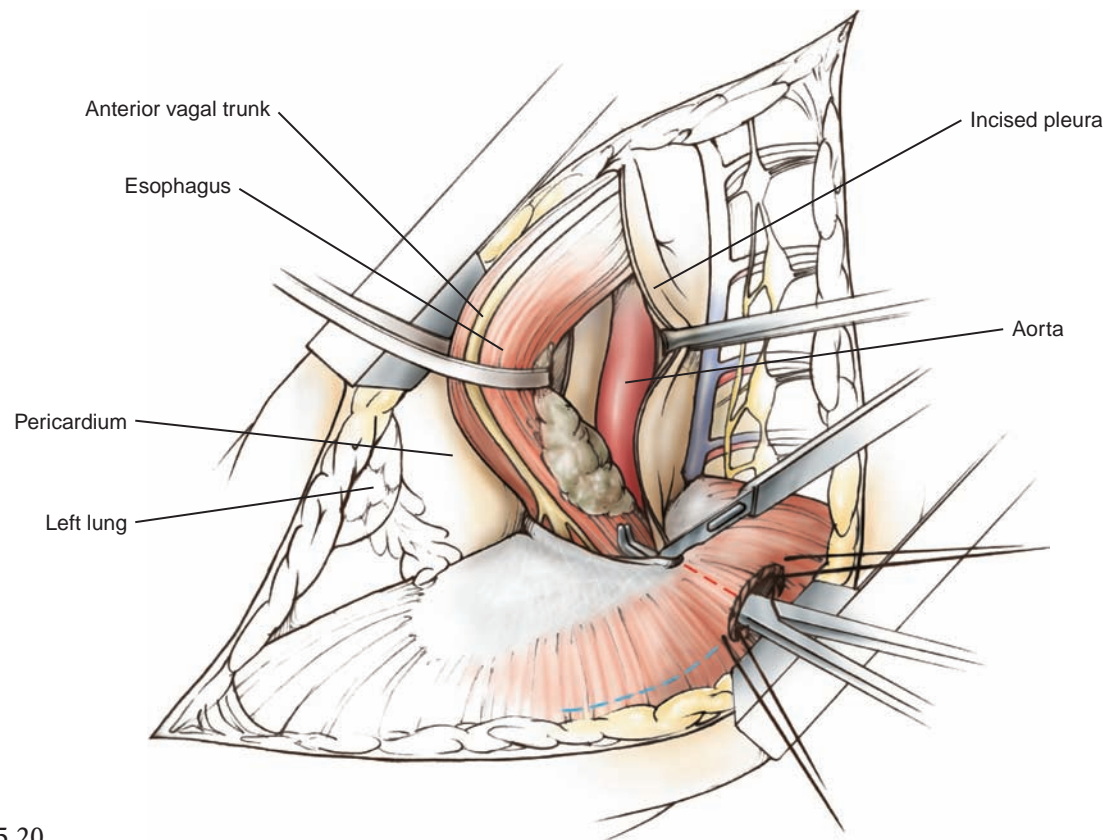


Figure 5.20

The procedure can be performed utilizing a cervical or intrathoracic anastamosis and the steps follow those used for an Ivor-Lewis or McKeown esophagectomy.

The abdominal portion is performed with five laproscopic ports placed similar to the locations used for a laparoscopic Nissen fundoplication. Four thoracoscopic ports are placed in the right chest. A 10-mm camera port is placed in the seventh interspace in the midaxillary line, a 5-mm port is placed in the eighth or ninth interspace 2 cm posterior to the posterior axillary line, for thermal shears, a second 5 mm port is placed posterior to the tip of the scapula and a final 5 mm port is placed in the fourth interspace at the anterior axillary line. These last two ports are used for esophageal retraction. A retraction suture is placed in the lateral portion of the central tendon of

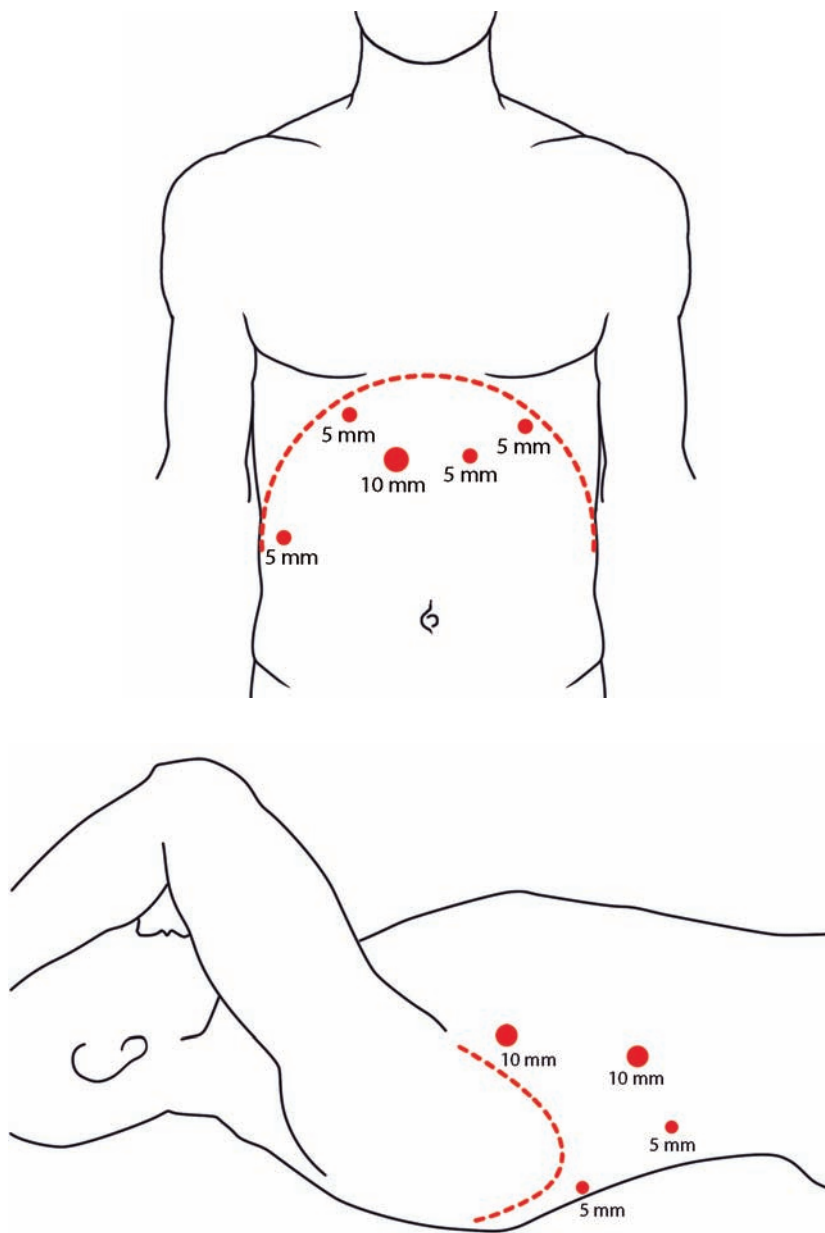


Figure 5.21

the diaphragm and pulled out through a small incision in the inferior portion of the chest to facilitate exposure of the distal esophagus.

Mobilization of the esophagus is performed using the same techniques employed during an open Ivor–Lewis exposure. If an intrathoracic anastomosis is performed then a minithoracotomy is made to facilitate removal of the specimen and creation

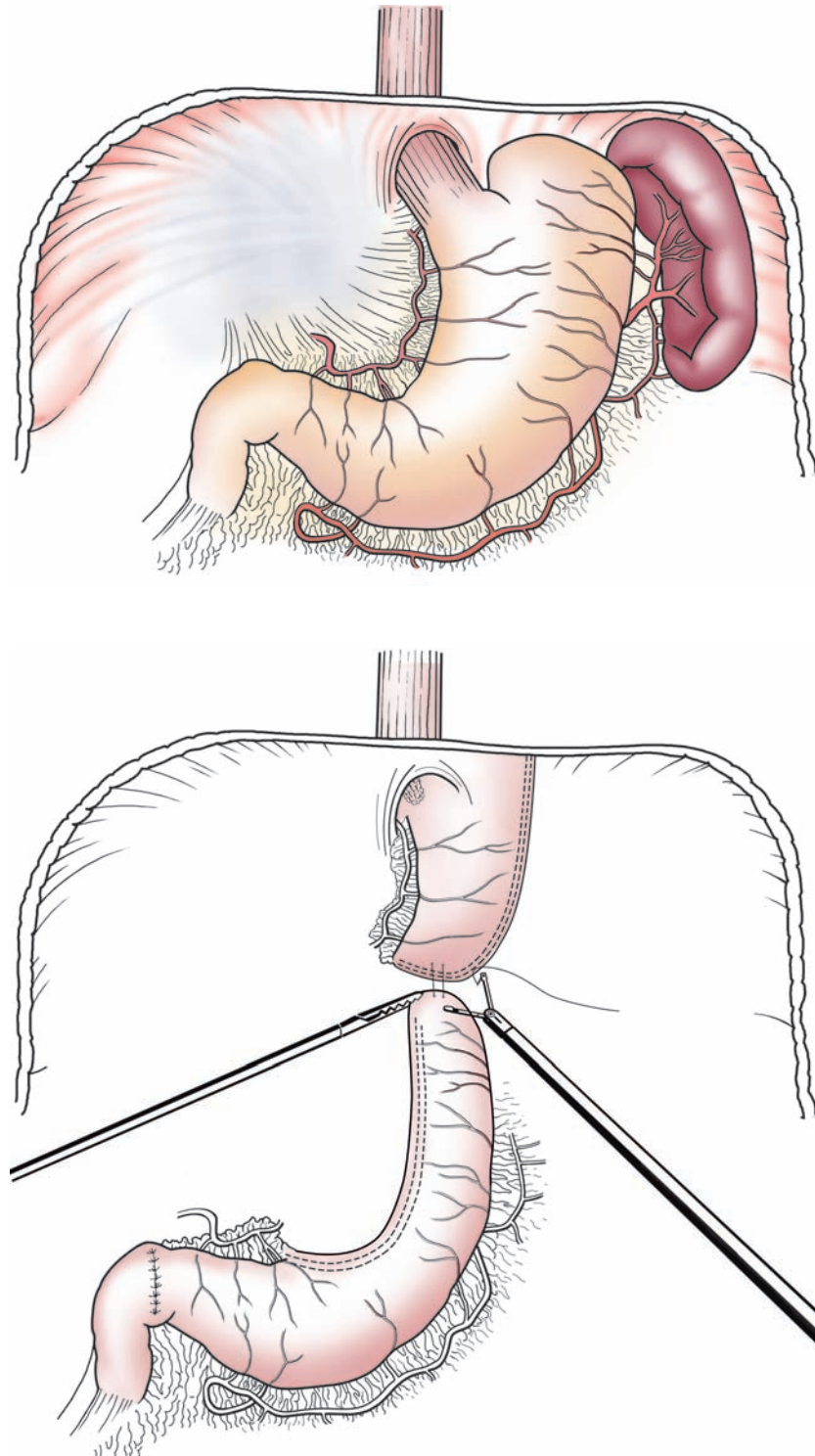


Figure 5.22

of the anastomosis. The latter can be performed with a combined stapled-sewn technique or a completely stapled technique using an EEA stapler. Alternatively the procedure can be performed as a minimally invasive three-hole procedure with a cervical anastomosis.

Postoperative Management

Postoperative management centers around fluid replacement and pulmonary toilet. The nasogastric tube can be removed by postoperative day 2 or 3. Early removal will help aid coughing and improve patient comfort whereas longer nasogastric tube use has not shown to provide any additional benefits. Analgesia should be well-controlled with a combination of an epidural pain catheter, placed preoperatively, and parenteral analgesia. Isotonic fluid should be used for the first 24–48 h to replace fluid lost at the time of surgery and from significant third spacing after surgery. This extravascular fluid is usually mobilized on the third or fourth postoperative day, sometimes causing pulmonary congestion and decreased partial pressure of arterial oxygen (P_{aO_2}). Enhancement of diuresis, good pulmonary toilet, and assisted ventilation, if needed, will correct these changes. Chest radiographs should be obtained daily for the first 4–5 postoperative days to monitor any pulmonary changes and assess drainage of the stomach and the status of the mediastinum.

Milky chest tube drainage usually indicates a chylothorax from a thoracic duct injury. This can be confirmed by demonstrating a high pleural fluid triglyceride level and it should be dealt with by thoracoscopy or thoracotomy and thoracic duct ligation. Pulmonary insufficiency and atrial fibrillation can occur in up to 30% of patients postoperatively. These are often easily treated with diuresis, pulmonary toilet and beta blockers; however, one must also consider these to be harbingers of more serious problems such as anastomotic leak or gastric necrosis. Anastomotic leaks occur in up to 5% of patients who have an intrathoracic anastomosis and up to 10% of patients who undergo a cervical anastomosis. These can often be treated conservatively as long as the leak is controlled by internal or external drainage. If the leak is not controlled, then options include temporary endoluminal stenting, primary repair or takedown of the anastomosis with cervical esophagostomy.

Recurrent laryngeal nerve injury occurs in up to 20% of patients following esophagectomy with cervical anastomosis. Recurrent nerve injury has been reported following intrathoracic anastomosis but the incidence is low. Any patient who is hoarse following an esophagectomy should undergo a laryngeal examination. If a paralyzed vocal cord is found, it should be treated by an otorhinolaryngologist with an injection of a temporary agent. This can help to protect the airway and prevent aspiration. All patients undergo a cervical dissection and anastomosis could benefit from a formal speech pathology evaluation to rule out silent aspiration. This incidence of aspiration following esophagectomy is higher than expected and may account for some of the respiratory failure seen postoperatively.

A gastrograffin, followed by thin barium, esophagogram is obtained on the fifth to seventh postoperative day to determine the integrity of the esophagogastronomy

suture line and emptying of the stomach. Patients are started on a liquid diet if the study is normal and advance to a soft diet upon discharge. The chest tube should be left in until the swallow has been performed and until the patient is tolerating a fatty diet to be sure that there is no thoracic duct injury.

Results

The overall results of treatment of esophageal carcinoma are discouraging, mainly due to the fact that most patients present with advanced disease. In large studies the reported 5-year survival for stage I disease was 60–70%, compared with 5–6% for stage IV disease. Reported surgical mortality for esophagectomy is currently 4–5%. Current studies have not definitively proven a benefit to neoadjuvant chemotherapy or chemoradiation therapy; however, patients with clinical stage II and III disease should be encouraged to enter ongoing neoadjuvant therapy trials prior to resection.

Benign Tumors of the Esophagus

Benign Tumor Resection

The method of excision of benign esophageal lesions depends on their site and type. Pedunculated intraluminal lesions with a narrow base are removed endoscopically with a diathermy loop, whereas sessile intraluminal tumors are resected through vertical esophagotomy. Intramural tumors usually can be removed without entering the esophageal lumen, through posterolateral thoracotomy or with the use of video-assisted thoracoscopy.

For resection of sessile intraluminal and intramural tumors the esophagus is exposed through the appropriate incision according to the site of the lesion. Tumors of the cervical esophagus are removed through a longitudinal skin incision along the anterior border of the left sternocleidomastoid muscle or through a collar incision starting two fingerbreadths above the sternal notch, to the right of the midline, and extending into the left supraclavicular fossa, parallel to the clavicle. The platysma and the omohyoid muscles are divided, the carotid sheath is retracted laterally, and the esophagus is exposed and carefully dissected from the membranous portion of the trachea and encircled with tape. Tumors of the upper or middle third of the thoracic esophagus are excised through a right posterolateral thoracotomy at the fourth or fifth intercostal space. Tumors of the lower third of the esophagus are resected through a left posterior lateral incision through the sixth or seventh intercostal space.

After the site of the tumor is exposed, the overlying mediastinal pleura is incised vertically and the esophagus above the site of the mass is encircled with tape. Intermural tumors are usually covered with a thin muscular layer and can be seen or palpated easily. The muscle fibers are split apart, and the tumor is exposed. With blunt dissection, the tumor is carefully separated from the surrounding tissue, paying particular attention

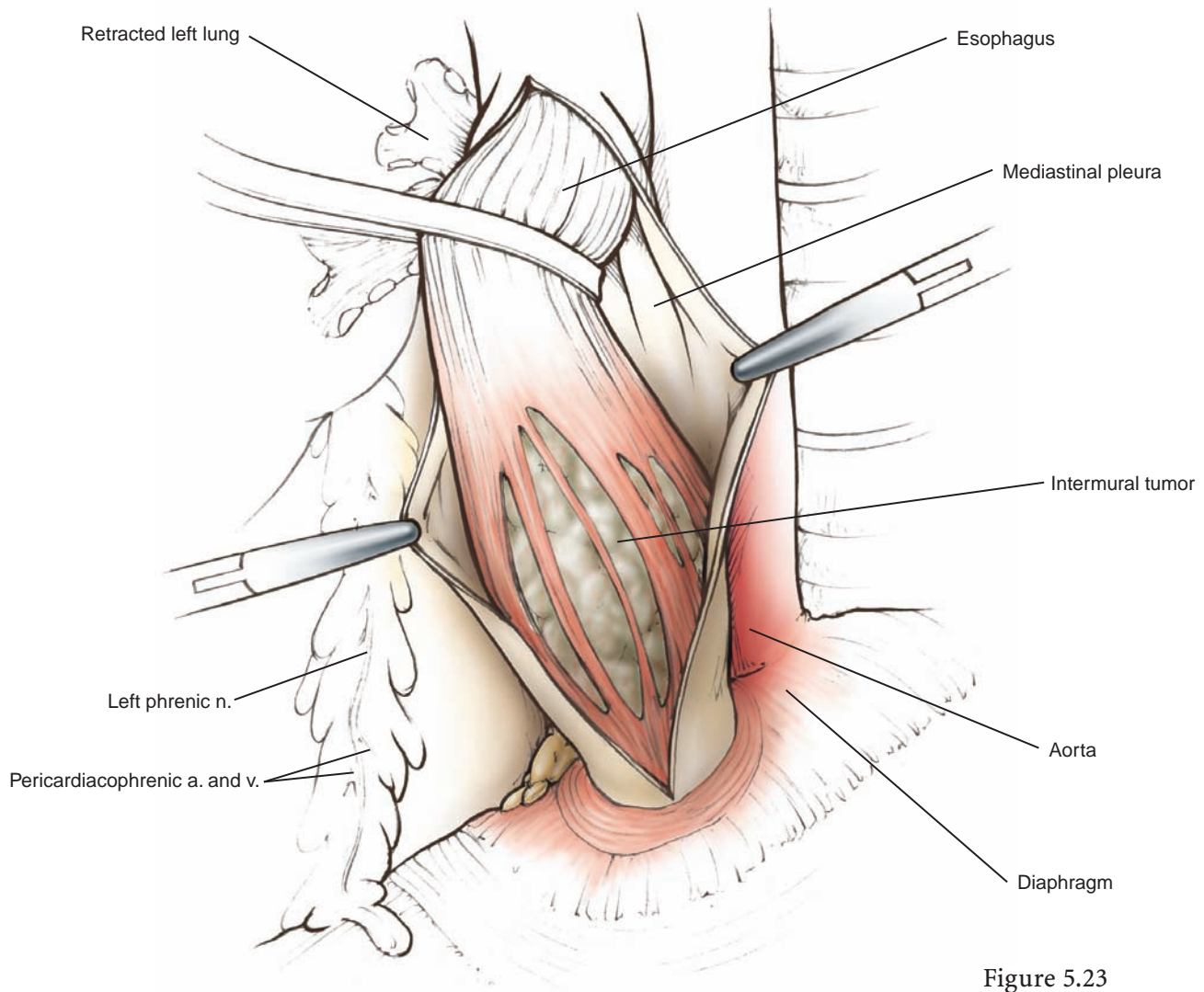


Figure 5.23

not to injure the mucosa. This is usually easily accomplished, because most tumors are encapsulated and are not firmly adherent to the mucosa, unless endoscopic biopsy of the tumor has been previously done, in which case mucosal injury is more common.

After the tumor is removed, the muscularis is reapproximated with interrupted silk sutures. When mucosal injury occurs, the defect is first repaired with interrupted absorbable sutures and the muscularis is approximated. Sessile tumors of the mucosa are removed through a longitudinal esophagotomy opposite the site of the tumor. The mass is then removed with a healthy tissue margin of several millimeters. The created mucosal defect is closed with interrupted sutures taking care not to significantly narrow the esophageal lumen. The muscle fibers are approximated with interrupted sutures.

Excision of intramural tumors of the thoracic esophagus also can be done under video-assisted thoracoscopy. The patient is placed in the left lateral decubitus position with a roll under the right upper torso to widen the left intercostal spaces. Four same-size ports are placed in a rhomboidal configuration. The position of the ports depends on the site of the tumor. For lesions of the upper and middle thirds of the

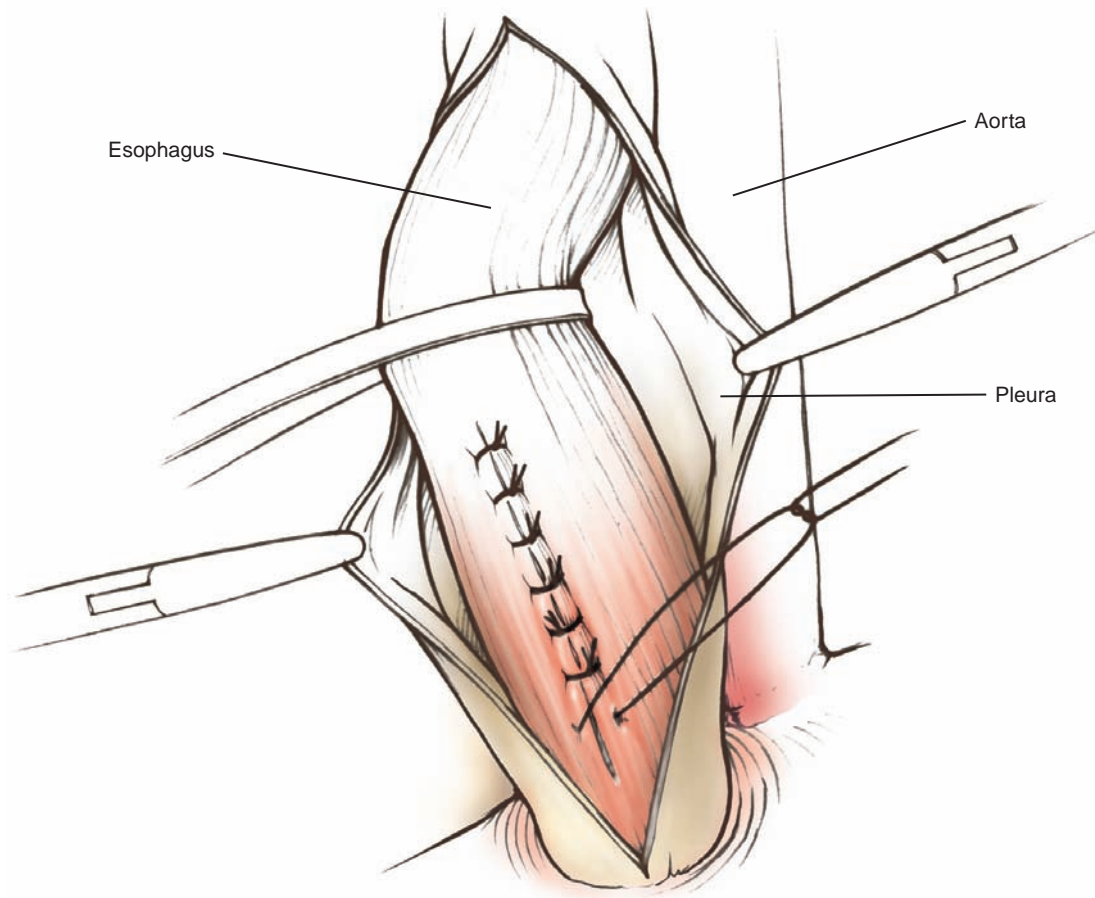


Figure 5.24

esophagus, the trocars are placed distal to the lesion. The first port is inserted in the seventh or eighth intercostal space at the midaxillary line; a second trocar is inserted in the sixth or seventh intercostal space anteriorly to the anterior axillary line; and the other two ports are placed in the fifth and fourth intercostal spaces at the posterior and anterior axillary lines, respectively. For tumors of the distal third of the esophagus, the first trocar is positioned in the fourth intercostal space at the anterior axillary line, the second in the fifth intercostal space behind the posterior axillary line, and the other two as seems desirable along the sixth intercostal space. With sharp and blunt dissection the tumor is removed through a conventional thoracotomy as described.

Anatomic Basis of Complications

- Major**
- Injury of the recurrent laryngeal nerve causes paralysis of a vocal cord.
 - Injury of the thoracic duct results in chylothorax.
 - Severance of the vagus nerve causes gastric atony and lack of pyloric relaxation.
- Minor**
- Injury of the intercostal nerve may result in chronic chest pain.

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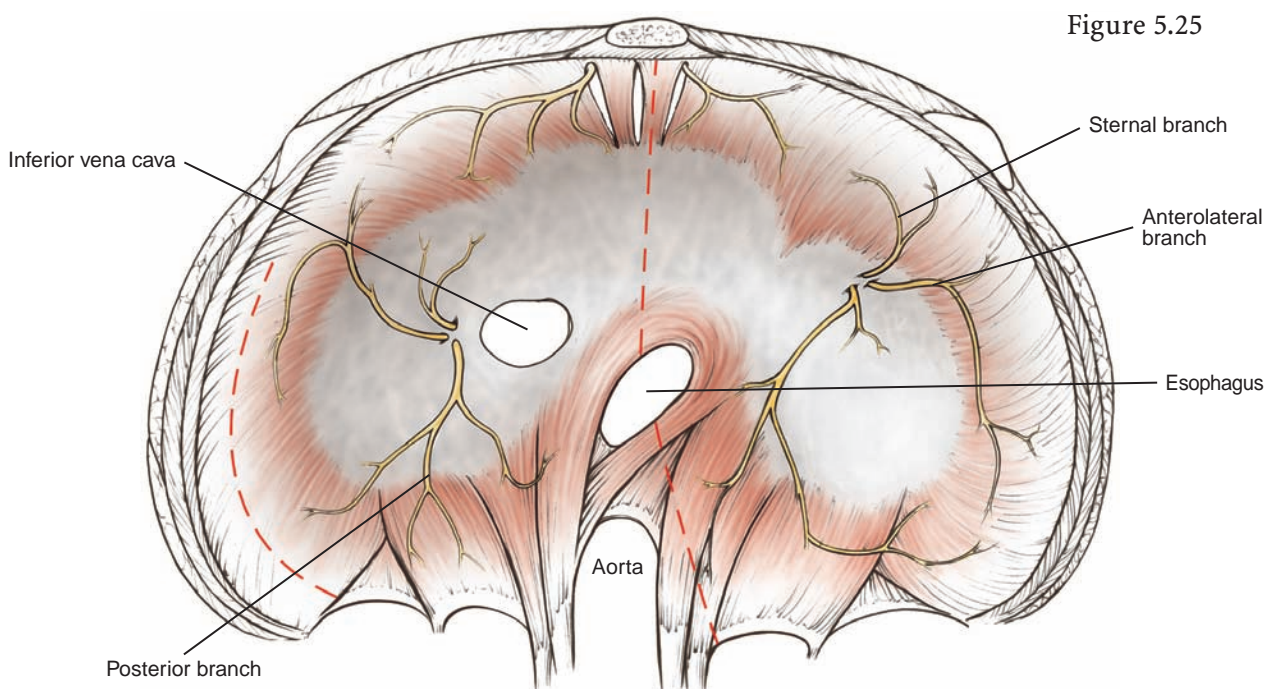
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Diaphragm

Surgical Anatomy

The diaphragm is a dome-shaped musculofibrous septum that separates the thoracic and peritoneal cavities. It originates from the dorsum of the xiphoid process, from the inner surface of the cartilage and adjacent portions of the last six ribs and from the first and second lumbar vertebrae. The motor nerve to the diaphragm is supplied by the right and left phrenic nerves. The right phrenic nerve enters the diaphragm through the central tendon just lateral to the inferior vena cava, and the left pierces the superior surface of the muscular portion of the diaphragm just lateral to the left border of the heart. Both nerves trifurcate and the branches are distributed into the muscular portion of the diaphragm.

Because of this topography of the nerves, when incision of the diaphragm is required to expose organs in the pleura or peritoneal cavity, a radial incision from the hiatus to the posterior chest wall or to the paraxiphoid region, or a curvilinear incision about 2 cm from the diaphragmatic attachment to the ribs, will result in the least impairment of diaphragmatic function.



Carcinoma of the Diaphragm

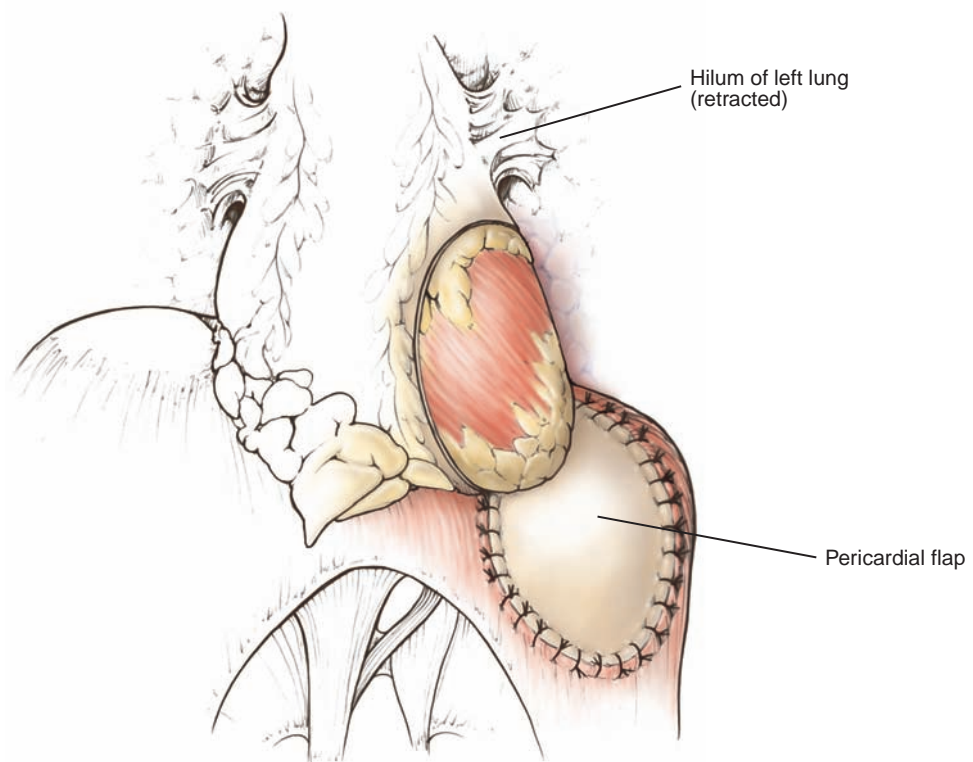
Although diaphragmatic tumors can be primary or secondary, the majority of malignant tumors are either due to direct extension from a neighboring organ or distant metastases. Primary tumors may be benign or malignant, but all secondary tumors are malignant. Neurofibromas, lipomas, angiofibromas, and mesothelial cysts are the most common benign tumors, and sarcomas are the main malignant tumors.

Surgical Applications

Resection and Reconstruction

Treatment of these lesions is local excision of benign tumors and wide resection of malignant tumors. With the patient in the lateral decubitus position, the diaphragm is exposed either through a posterolateral thoracotomy at the seventh intercostal space or utilizing a thoracoscopic approach. Benign lesions are excised and the diaphragmatic defect is closed with interrupted 0 sutures. The malignant tumors are removed along with 3 cm margins of normal diaphragm around the tumor. The resultant diaphragmatic defect is repaired with interrupted sutures, if feasible, or for large diaphragmatic defects, a mesh prostheses such as Gortex is used. Pedicled autologous tissue such as muscle or preferably pericardium may also be used in selected cases for the repair of large diaphragmatic defects.

Figure 5.26



The pericardium is incised posterolaterally along the phrenic nerve and anterior to it, as well as anteriorly, up to the root of the great vessels. The created pedicle is left attached to the membranous portion of the diaphragm and sutured to the diaphragmatic defect with interrupted sutures.

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Stomach and Abdominal Wall

Charles A. Staley,
William S. Richardson



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Stomach

Charles A. Staley

Gastric cancer is the fourth most common cancer and accounts for approximately 600,000 new cases each year worldwide. Seventy-five percent of gastric cancer occurs in developing countries in the regions of Eastern Europe and East Asia. The incidence of gastric cancer in the United States has been decreasing over the last 60 years, and in 2007, there were 21,260 new cases diagnosed. Almost two-thirds of these patients will die of their disease. Ninety-five percent of gastric carcinomas are adenocarcinomas. The remaining 5% are lymphoma, carcinoids, and gastrointestinal stromal tumors (GIST). Factors associated with an increased risk of gastric adenocarcinoma include diets high in salt and smoked foods, male gender, black race, and low socioeconomic class. *Helicobacter pylori*, a gram negative bacteria, is now known to play a central role in the pathogenesis of gastric cancer and is considered to be a carcinogen by the International Agency for Research on Cancer at the World Health Organization. Chronic long-term infection of the gastric mucosa with *h pylori* seems to be a major promoter of gastric carcinoma. In developing countries, 80–90% of children are infected with *h pylori*. Currently in the United States, the problems of *h pylori* infections have been steadily declining, probably because of smaller family size, better hygiene, and increased use of antibiotics during childhood. The decline in *h pylori* has probably contributed to the downward trend of gastric adenocarcinoma. Along with a decrease in gastric cancer, there has also been a steady decrease in mortality from gastric carcinoma in the United States.

Unfortunately, gastric adenocarcinoma usually presents with very nonspecific symptoms of weight loss, nausea, fatigue, and as the disease progresses, anorexia and vomiting. At the time of diagnosis in the United States, most patients either have locally advanced or metastatic disease. The distribution of disease or presentation is 24% with localized disease, 32% with node positive disease, and 32% with metastatic disease. Endoscopy with biopsy, CT, and endoscopic ultrasound, all aid in the diagnosis and staging of gastric carcinoma. Combined CT/PET is also extremely helpful in ruling out patients with metastatic disease. The overall accuracy of PET/CT is superior to either modality alone. Because of the limitations of CT and PET in the evaluation of peritoneal disease, diagnostic laparoscopy should be done before an open procedure in asymptomatic patients to avoid an unnecessary laparotomy. Several prospective studies have shown that laparoscopy will detect metastatic disease in 24–32% of patients thought to be resectable by standard imaging criteria. Multivariate analysis revealed that patients with diffuse gastric disease and lymphadenopathy, defined as nodes greater than 1 cm, were significant, are independent predictors for M1 disease. If a palliative resection and/or bypass are/is already planned, then laparoscopic staging is not necessary. In addition, laparoscopy can be a useful staging tool before neoadjuvant therapy is initiated.

Accurate clinical staging is critical in determining the most appropriate therapy and overall long-term outcome. In 2002, the AJCC and UICC agreed on a common

Primary tumor (T)			
TX	Primary tumor cannot be assessed		
T0	No evidence of primary tumor		
Tis	Carcinoma in situ: intraepithelial tumor without invasion of the lamina propria		
T1	Tumor invades lamina propria or submucosa		
T2a	Tumor invades muscularis propria		
T2b	Tumor invades subserosa		
T3	Tumor penetrates serosa(visceral peritoneum) without invasion of adjacent structures		
T4	Tumor invades adjacent organ structures		
Regional lymph nodes (N)			
NX	Regional lymph node(s) cannot be assessed		
N0	No regional lymph-node metastasis		
N1	Metastasis in 1–6 regional lymph nodes		
N2	Metastasis in 7–15 regional lymph nodes		
N3	Metastasis in more than 15 regional lymph nodes		
Distant metastasis (M)			
MX	Distant metastasis cannot be assessed		
M0	No distant metastasis		
M1	Distant metastasis		
Stage grouping			
Stage 0	Tis	N0	M0
Stage 1A	T1	N0	M0
Stage 1B	T1	N1	M0
	T2a/b	N0	M0
Stage II	T1	N2	M0
	T2a/b	N1	M0
	T3	N0	M0
Stage IIIA	T2a/b	N2	M0
	T3	N1	M0
	T4	N0	M0
Stage IIIB	T3	N2	M0
Stage IV	T4	N1–3	M0
	T1–3	N3	M0
	Any T	Any N	M1

Table 6.1 TNM staging system for gastric carcinoma

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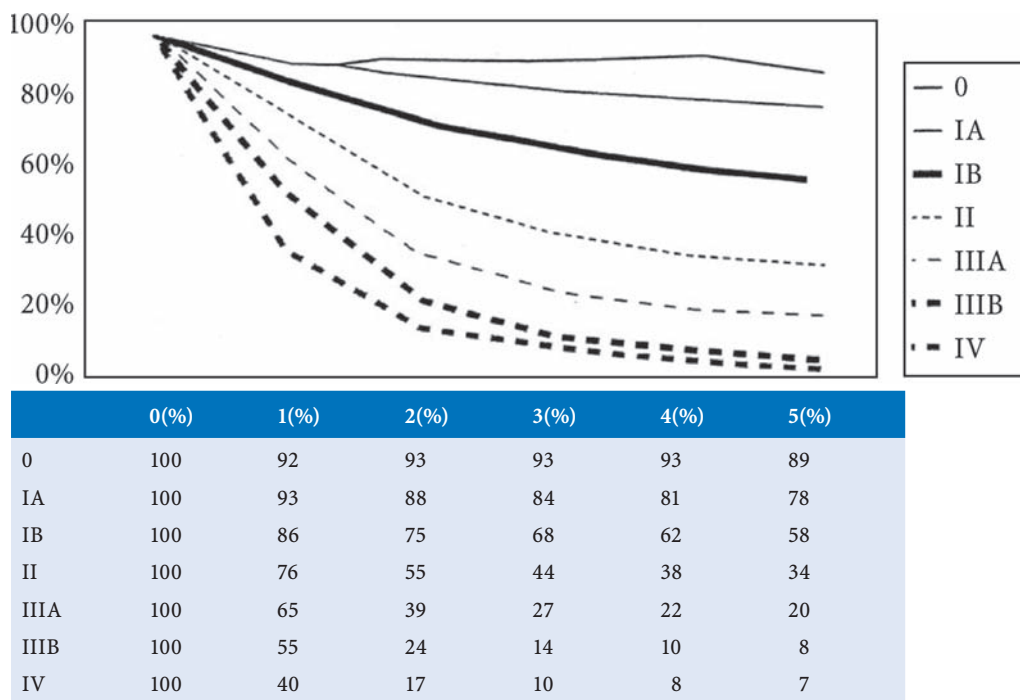
staging system with the release of the AJCC sixth addition (Table 6.1). The previous nodal staging system, which was based on distance from the primary tumor was changed to a classification based on the number of positive lymph nodes. Many factors affect prognosis in gastric cancer; however, the number of positive lymph nodes is the most consistent prognostic indicator. Five-year survival rates in patients with 1–6, 7–15, and greater than 15 nodes were 43, 21 and 13%, respectively. Karpeh and colleagues from Memorial Sloan-Kettering Center reported that patients with

pathologically positive lymph nodes had an improved median survival when 15 or more lymph nodes were resected for each end stage compared with patients who had fewer than 15 nodes. This has established a pathological minimum of 15 lymph nodes that should be resected during a curative gastrectomy.

Proximal tumors of the cardia and mid-body, which are increasing in incidence, usually require a total gastrectomy. Distal pancreatic and splenic resection should be avoided and performed only for direct organ involvement. Distal tumors, which account for 35–40% of all gastric adenocarcinomas, usually necessitate a subtotal distal gastrectomy. A 5-cm gross tumor margin is required with adenocarcinoma because of the propensity of tumor cells to migrate along the stomach wall. If splenectomy is contemplated, a pneumococcal vaccine should be given before surgery. The role of extended lymph-node dissections will be discussed later in this chapter.

Except for rare, early gastric carcinomas (T1N0M0), overall survival of gastric adenocarcinoma remains poor with 5-year survival rates of only 15% (Table 6.2). The role of adjuvant therapy in gastric cancer has been studied extensively during the last 30 years in an attempt to improve the prognosis of patients with gastric cancer who have undergone curative surgery. Many of the trials have been underpowered and poorly designed to answer the question of the benefit of adjuvant therapy. The U.S.A Intergroup Phase III study evaluated the combination of radiotherapy plus 5-FU/Leucovorin in resected gastric cancer vs. surgery alone. This study showed a significant overall survival benefit in the chemoradiation arm with a median survival of 36 months vs. the control of 27 months. There was also a significant increase

Table 6.2 Gastric cancer survival by AJCC stage.



Reproduced with permission from Balch CM, et al. Cancer staging for stomach. In: Greene FL, Page DL, Fleming ID, et al. editors. AJCC cancer staging manual. 6th ed. New York: Springer; 2002. p. 101

in local control of 30 months vs. 19 months. The results of this trial have led to a standardization of adjuvant chemoradiation in the United States. A neoadjuvant approach seems advantageous for gastric cancer because of the potential benefits, including downstaging of tumors, treatment of micrometastasis, and improved tolerance of chemotherapy. The most important large Phase III neoadjuvant study was done by the Medical Research Council Adjuvant Gastric Infusional Chemotherapy (MAGIC) trial. This was the first well-powered Phase III neoadjuvant chemotherapy study to assess the efficacy of perioperative chemotherapy. Five hundred and three patients with potentially resectable gastric cancer were randomly assigned to both preoperative and postoperative ECF (epirubicin, cisplatin, 5-Fluorouracil) chemotherapy vs. surgery alone. The results of this trial demonstrated a statistically significant improvement of the study arm in progression-free survival and overall survival compared with surgery alone. Further Phase III studies will help define the role of adjuvant and neoadjuvant therapy for gastric cancer.

In contrast to the decreasing incidence of gastric adenocarcinoma, the incidence of gastric lymphoma is steadily increasing. Gastric lymphomas account for two-thirds of all gastrointestinal lymphomas. The average patient age is 60 years, and they usually present with abdominal pain, weight loss, bleeding, and fatigue. Obstruction and massive bleeding are rare. Endoscopy establishes the diagnosis in 80% of cases. Treatment of gastric lymphomas varies among institutions, with some centers using surgery and others promoting chemotherapy and radiation. Overall, there seems to be a general trend toward treatment with aggressive chemotherapy alone, especially since the reported response rates are greater than 90%. Surgical resection is now reserved for patients with residual disease or recurrent disease or for patients in whom perforation, bleeding, or obstruction develop during treatment.

Many benign and malignant gastric cancers, along with a host of unresectable and metastatic intra-abdominal cancers, may require either a curative or palliative surgical procedure involving the stomach. Whether it is a palliative procedure such as a gastrostomy tube or gastrojejunostomy or a potentially curative gastric resection and lymphadenectomy, knowledge of the clinical anatomy and technical operative expertise in gastric surgery are imperative. Understanding the natural history and defining the patients for surgical intervention by appropriate clinical staging will minimize unnecessary surgery in patients with an overall poor survival.

Surgical Anatomy

The stomach is the first abdominal organ of the digestive tract and acts as a reservoir for ingested food to begin both mechanical and chemical digestion. It lies principally in the left upper quadrant of the abdomen but terminates across the midline and frequently descends below the plane of umbilicus. The position of the stomach is variable, depending on body position, contents, and respiratory movements.

Topography

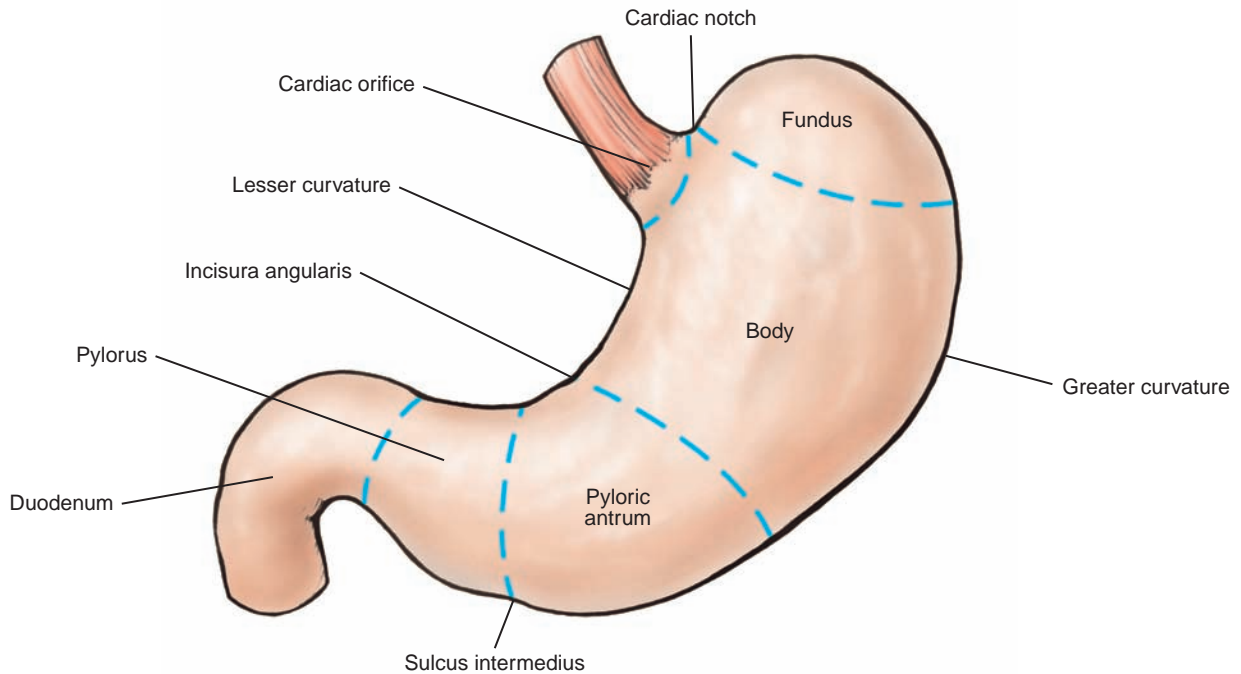


Figure 6.1

The anatomic regions of the stomach are divided into the cardia, fundus, body, and pylorus. The cardiac orifice marks the transition from the esophagus to the stomach. The cardia of the stomach is the portion immediately surrounding the esophageal opening and has a relatively stable location due to the esophageal attachments of the diaphragm and the peritoneal reflections (gastrophrenic ligament). At the esophago-gastric junction a deep notch, defined as the cardiac notch, separates the esophagus and the fundus. The cardiac notch, together with decussating fibers of the diaphragm and circular fibers of the lower esophagus, forms a lower esophageal sphincter that prevents esophageal reflux under normal conditions. The fundus of the stomach expands upward, filling the dome of the diaphragm on the left side, and is limited below by the horizontal plane of the cardiac orifice. The incisura angularis, a sharp indentation about two-thirds of the distance along the lesser curvature, marks a vertical separation between the body of the stomach to its left and the pyloric portion of the stomach to its right and is used surgically as the proximal line of transection for antrectomy. The pyloric portion of the stomach consists of the pyloric antrum, the pyloric canal, and a markedly constricted terminal pylorus, composed of a greatly thickened muscular wall constituting the pyloric sphincter. The thickened sphincter marks the termination of the stomach and its transition to the retroperitoneal duodenum, which is fixed to the posterior body wall.

Curvatures and Surfaces

The axis of the stomach is oblique and extends from the fundus downward to the right and ventral. The lesser curvature marks the right border of the stomach and extends from the esophagogastric junction along a concave curve to the right, terminating at the pylorus. The greater curvature is the left and inferior border of the stomach. It

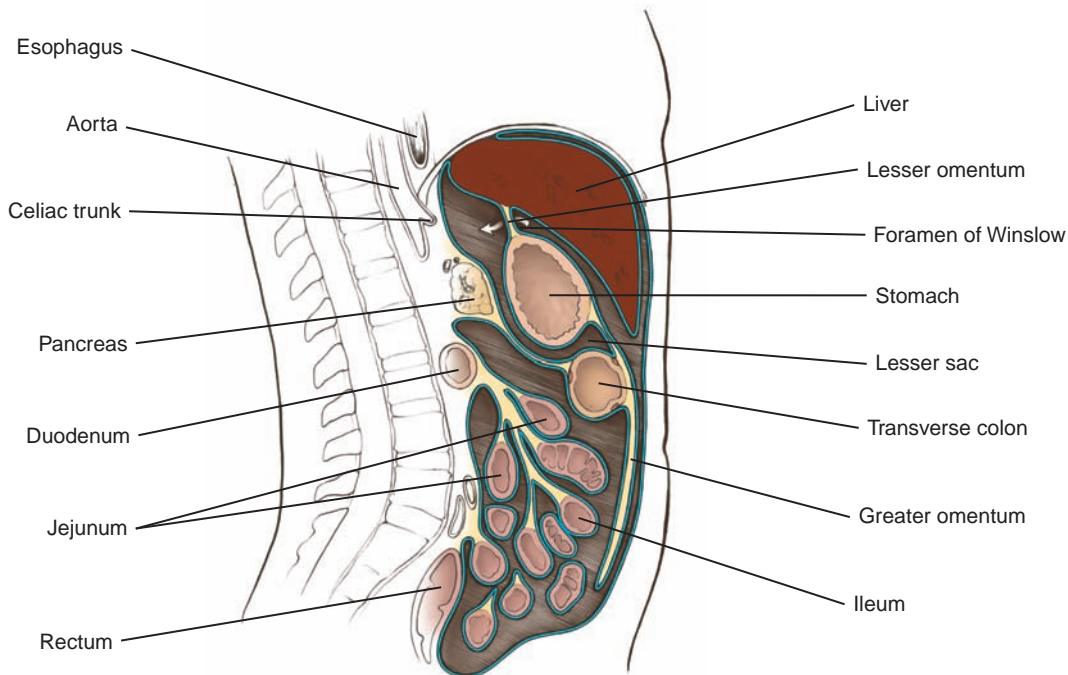


Figure 6.2

begins at the cardiac notch, follows the superior curvature of the fundus, and then the convex curvature of the body down to the pylorus. The greater curvature is four or five times longer than the lesser curvature.

The rotation of the stomach during embryologic development creates a space, known as the lesser sac or omental bursa, between the stomach and the posterior abdominal wall. This space is bounded anteriorly by the stomach and lesser omentum, superiorly by the liver, inferiorly by the greater omentum (and its fusion to the transverse colon), and to the left by the spleen and its ligaments. On the right, the lesser sac opens into the greater sac through the epiploic foramen (of Winslow). The greater sac of the abdomen fills the remaining space within the peritoneal cavity.

The stomach is entirely covered by the peritoneum except for the areas where the blood vessels course along the curvatures, and a small triangular space behind the cardiac orifice. Here the stomach is left bare by the gastrophrenic peritoneal reflection. At the lesser curvature the two layers of peritoneum extend to the liver as the gastrohepatic portion of the lesser omentum. From the greater curvature the greater omentum spreads widely to the diaphragm as the gastrophrenic ligament, to the spleen as the gastrosplenic ligament, and to the transverse colon as the gastrocolic ligament.

Peritoneal Relations

The stomach wall is composed of four distinct histologic layers: the mucosa, submucosa, muscularis, and serosa. The mucosa is thrown into a series of coarse gastric folds known as rugae. These are oriented chiefly longitudinally along the lesser curvature. The submucosal layer is a loose, areolar, vascular layer. The muscular layer of

Structure

the stomach is composed of an outer longitudinal and inner circular muscular layer, typical of the gastrointestinal tract, but also contains an internal oblique layer. The circular muscle is the dominant muscle layer of the stomach. The outer longitudinal layer is not as uniform as the circular layer, being concentrated particularly along the curvatures. The serosal layer is the peritoneum.

The gastric epithelium consists of a single layer of columnar cells. The stomach has specialized glands in the different regions of the stomach that vary in structure and function.

The cardiac glands are found in the region of the esophageal opening. Each gland is composed of a few branching tubules containing cells that secrete a form of mucus.

Fundic or gastric glands in the fundus and body of the stomach have long secreting tubules with short ducts opening into shallow gastric pits. Three types of cells line these tubules. The mucous neck cells in the upper part of the gland secrete mucus. The chief or zymogenic cells secrete pepsin, a proteolytic enzyme of the gastric juice. At intervals throughout the length of the tubule are large eosinophilic cells between the chief cells known as parietal cells, which are responsible for secretion of the hydrochloric acid in the gastric juice.

The pyloric glands are short, branched tubules opening into long duct-like gastric pits. The exact contribution of the pyloric glands to the gastric secretion is not known, although they resemble mucous neck cells. Gastrin, a hormone that increases acid production from the parietal cells and gastric motility, is secreted by the G cells in the pylorus of the stomach.

Blood Supply

The blood supply to the stomach is extensive and is based on vessels from the celiac trunk. The four major vessels that supply the stomach are the right and left gastric and the right and left gastroepiploic arteries.

Celiac Trunk

The aorta passes through the aortic hiatus of the diaphragm into the abdominal cavity in front of the lower border of the twelfth thoracic vertebra. The celiac trunk and the superior mesenteric and inferior mesenteric arteries are the three principal ventral unpaired branches of the aorta and supply the majority of the gastrointestinal system.

The celiac trunk arises from the front of the abdominal aorta, just below the aortic hiatus and at the level of the upper portion of the first lumbar vertebra. Only 1–2 cm long, the celiac trunk passes forward above the upper margin of the pancreas and then divides behind the posterior body wall peritoneum into the left gastric, common hepatic, and splenic arteries. In the region of the celiac trunk lie the celiac lymph nodes and the celiac plexus of nerves and their ganglia.

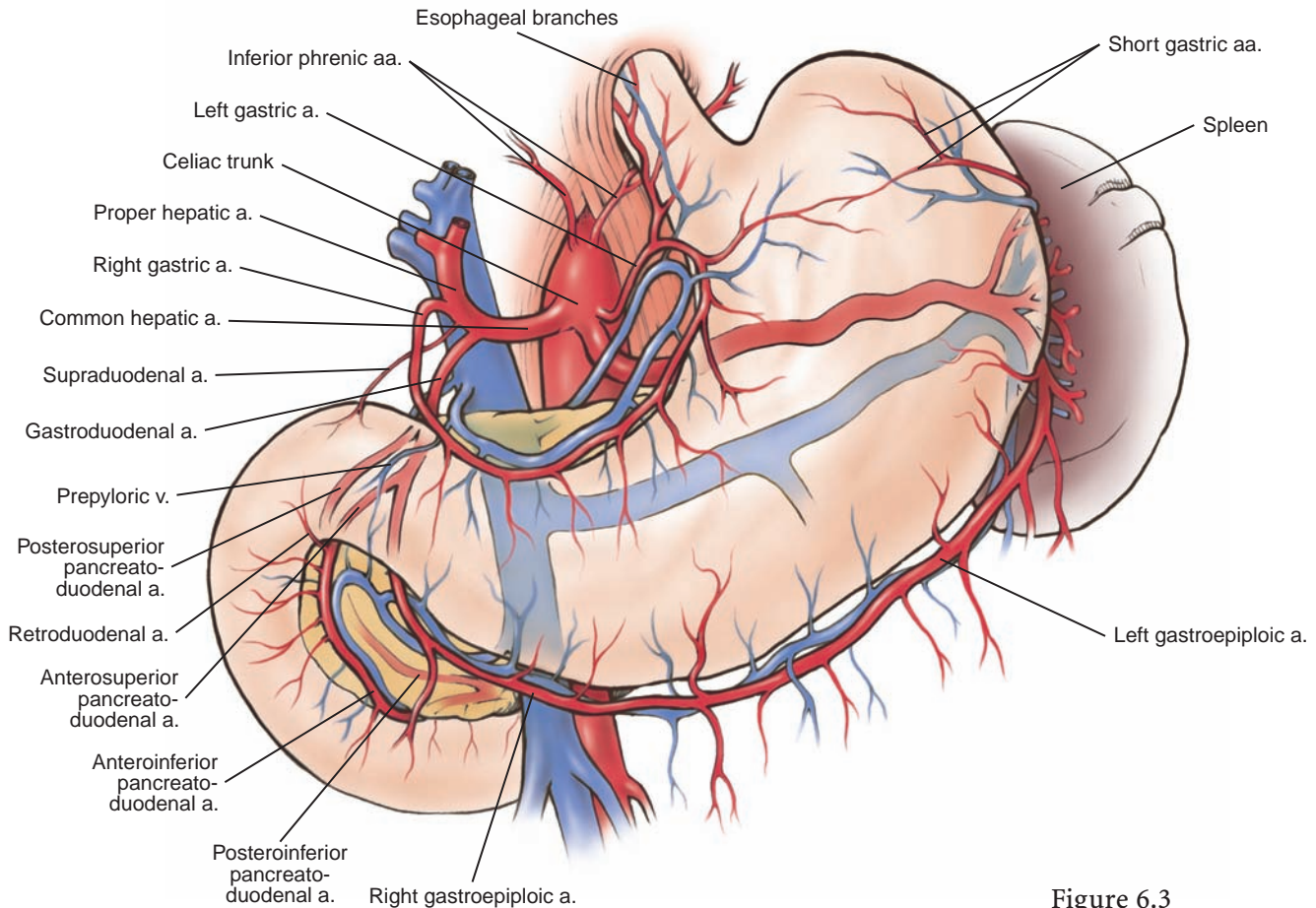


Figure 6.3

The left gastric artery, the smallest branch of the celiac trunk, courses upward and to the left toward the cardiac end of the stomach. The vessel lies behind the body wall peritoneum in the floor of the lesser sac, where it frequently raises a fold of peritoneum, the left gastropancreatic fold. It reaches the stomach in the bare area behind the cardia, giving off esophageal branches that ascend along the esophagus to provide a portion of its arterial supply. The left gastric artery then turns onto the lesser curvature of the stomach between the layers of the hepatogastric ligament and follows this curvature as far as the pylorus, providing branches to both surfaces of the stomach, and anastomoses terminally with the right gastric artery.

Left Gastric Artery

The common hepatic artery arises from the celiac trunk, runs forward and to the right along the upper border of the pancreas, passes into the lesser omentum giving off the gastroduodenal artery, and continues to the liver as the proper hepatic artery. The gastroduodenal artery is a short, thick branch that takes its origin from the common hepatic artery at the upper border of the first part of the duodenum. It descends behind this portion of the duodenum and divides at its inferior border into the right gastroepiploic and anterosuperior pancreaticoduodenal arteries.

The right gastroepiploic artery passes from right to left along the greater curvature of the stomach between the layers of the gastrocolic ligament. It anastomoses

Right Gastric and Right Gastroepiploic Arteries

with the left gastroepiploic artery to form a vascular arch along the greater curvature, from which pass gastric branches to both surfaces of the stomach and omental branches to the greater omentum.

The proper hepatic artery, which is the continuation of the common hepatic artery distal to the gastroduodenal artery, usually gives off the right gastric artery, and terminates by dividing into the right and left hepatic arteries. The small right gastric artery descends through the lesser omentum to the pyloric end of the lesser curvature of the stomach. It supplies branches to both surfaces of the pyloric portion of the stomach and anastomoses with the left gastric artery. The right gastric artery is most commonly a branch of the proper hepatic artery, but may arise from the left hepatic, gastroduodenal, or common hepatic arteries.

Left Gastroepiploic Artery

The splenic artery runs a highly tortuous course along the superior border of the pancreas, behind the peritoneum of the floor of the lesser sac. The left gastroepiploic artery arises from the splenic artery or an inferior terminal branch, passes toward the greater curvature of the stomach through the gastrosplenic ligament, and forms a vascular arcade with the right gastroepiploic artery. Its gastric and epiploic branches are distributed to both surfaces of the stomach and to the greater omentum.

The short gastric arteries are four or five small vessels that arise directly from the splenic artery and pass through the gastrosplenic ligament to reach the fundus of the stomach.

Veins

The veins of the stomach run parallel with the arteries and drain into the portal venous system.

The left gastric vein arises from tributaries on both surfaces of the stomach. It passes from right to left along the lesser curvature to the cardia, where it receives esophageal veins. The left gastric vein then turns to the right and descends in company with the left gastric artery, behind the posterior body wall peritoneum. Passing beyond the celiac arterial trunk, the left gastric vein ends in the portal vein. This circular course, first along the lesser curvature and then inferiorly on the body wall, is expressed in the old name “coronary vein.”

The small right gastric vein is formed from the tributaries of both surfaces of the pyloric region of the stomach. It accompanies the right gastric artery between the layers of the lesser omentum and, passing from left to right, ends directly in the portal vein. A prepyloric vein ascends over the pylorus to the right gastric vein and is an anatomic landmark that enables the surgeon to identify the pylorus.

The right gastroepiploic vein accompanies the right gastroepiploic artery within the layers of the gastroduodenal ligament. It receives tributaries from the inferior portions of both the anterior and posterior surfaces of the stomach and from the greater omentum. The vein crosses the uncinate process of the pancreas and ends in the superior mesenteric vein.

The left gastroepiploic vein completes the arch of veins along the greater curvature of the stomach and has the same pattern of drainage as the right gastroepiploic vein. It

is directed to the left in the folds of the gastrocolic ligament. Entering the gastrosplenic ligament, the left gastroepiploic vein ends in the beginning of the splenic vein.

The short gastric veins, four or five in number, drain the fundus and the superior part of the greater curvature of the stomach. They pass between the layers of the gastrosplenic ligament toward the hilum of the spleen, where they terminate in the splenic vein.

The lymphatic vessels of the stomach have a pattern similar to that of its arteries and veins. There are four major routes of lymphatic drainage from the stomach.

A large group of lymphatic vessels drain the surfaces toward the lesser curvature of the stomach to the left gastric nodes. These form a chain of 10–20 nodes extending from the angular notch of the stomach upward to the cardia. At the cardia a small group of five or six paracardiac nodes surround the esophagogastric junction. The left gastric nodes follow the left gastric blood vessels to the celiac nodes.

Another group of nodes drain the pyloric portion of the lesser curvature to the two or three right gastric nodes. These in turn run along the right gastric artery and drain into the hepatic nodes.

The left half of the stomach drains by lymphatic channels directed toward the greater curvature. Lymphatic vessels from the fundus and the upper portion of the

Lymphatic Drainage

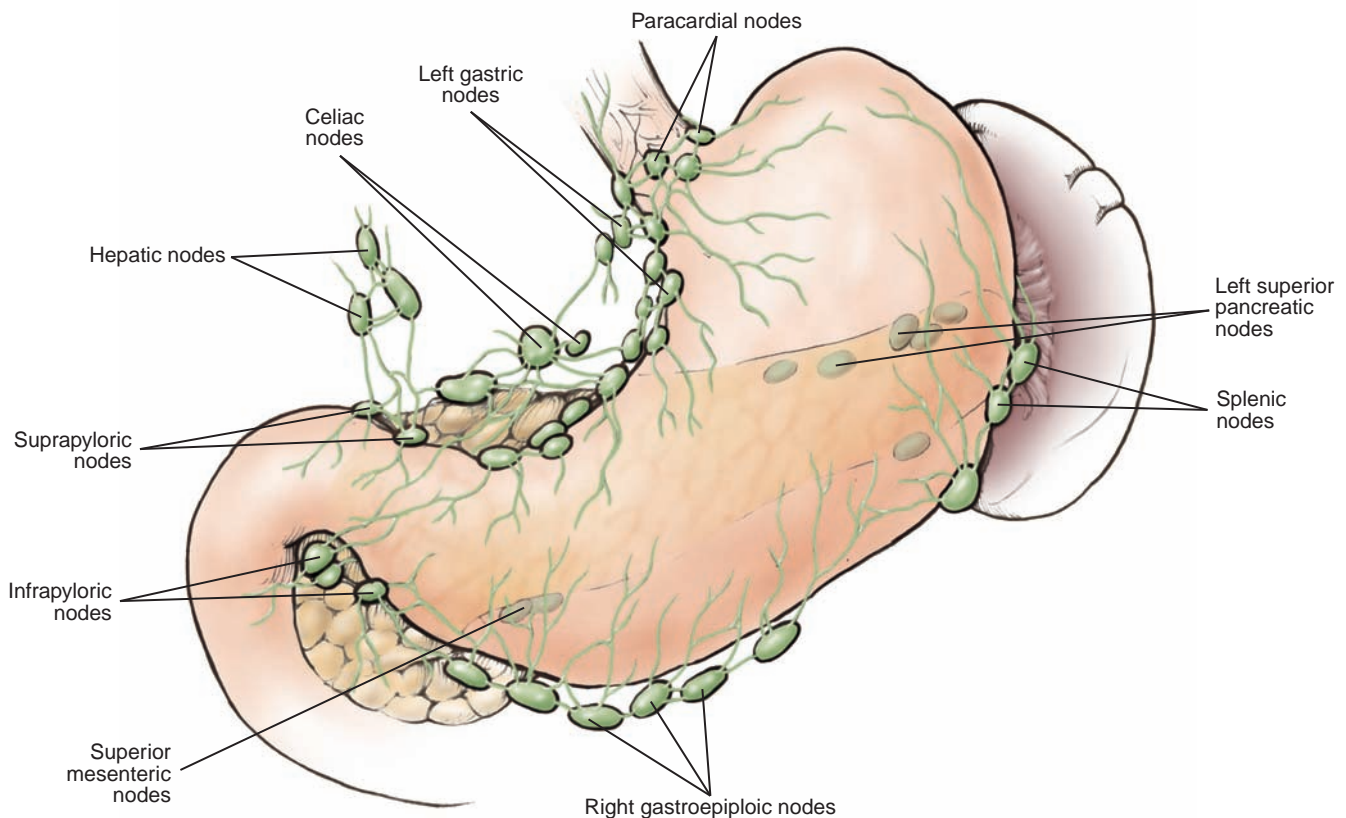


Figure 6.4

body of the stomach follow the short gastric and left gastroepiploic blood vessels to the pancreatosplenic nodes. Three or four lymph nodes are situated along the poster-osuperior border of the pancreas on the splenic blood vessels. The pancreatosplenic nodes drain the stomach, spleen, and pancreas and then drain into the celiac nodes.

Finally, from the lower portion of the left half of the stomach, lymphatic vessels drain to the 6–12 right gastroepiploic nodes, the efferents of which pass to the right to the pyloric nodes. The pyloric lymph nodes are six to eight nodes located in the angle between the first and second parts of the duodenum in close relation to the terminal division of the gastroduodenal artery. Their efferents pass along this artery to the hepatic nodes and then to the celiac nodes.

Lymph draining from the stomach by means of these various routes passes through the lymph-node groups described and ultimately reaches the celiac nodes. The efferent channels of the celiac nodes help form, with efferents from the superior mesenteric nodes, the intestinal trunk.

Nerve Supply

The nerves of the stomach are both parasympathetic by way of the vagus nerve and sympathetic by means of perivascular plexuses from the celiac plexus.

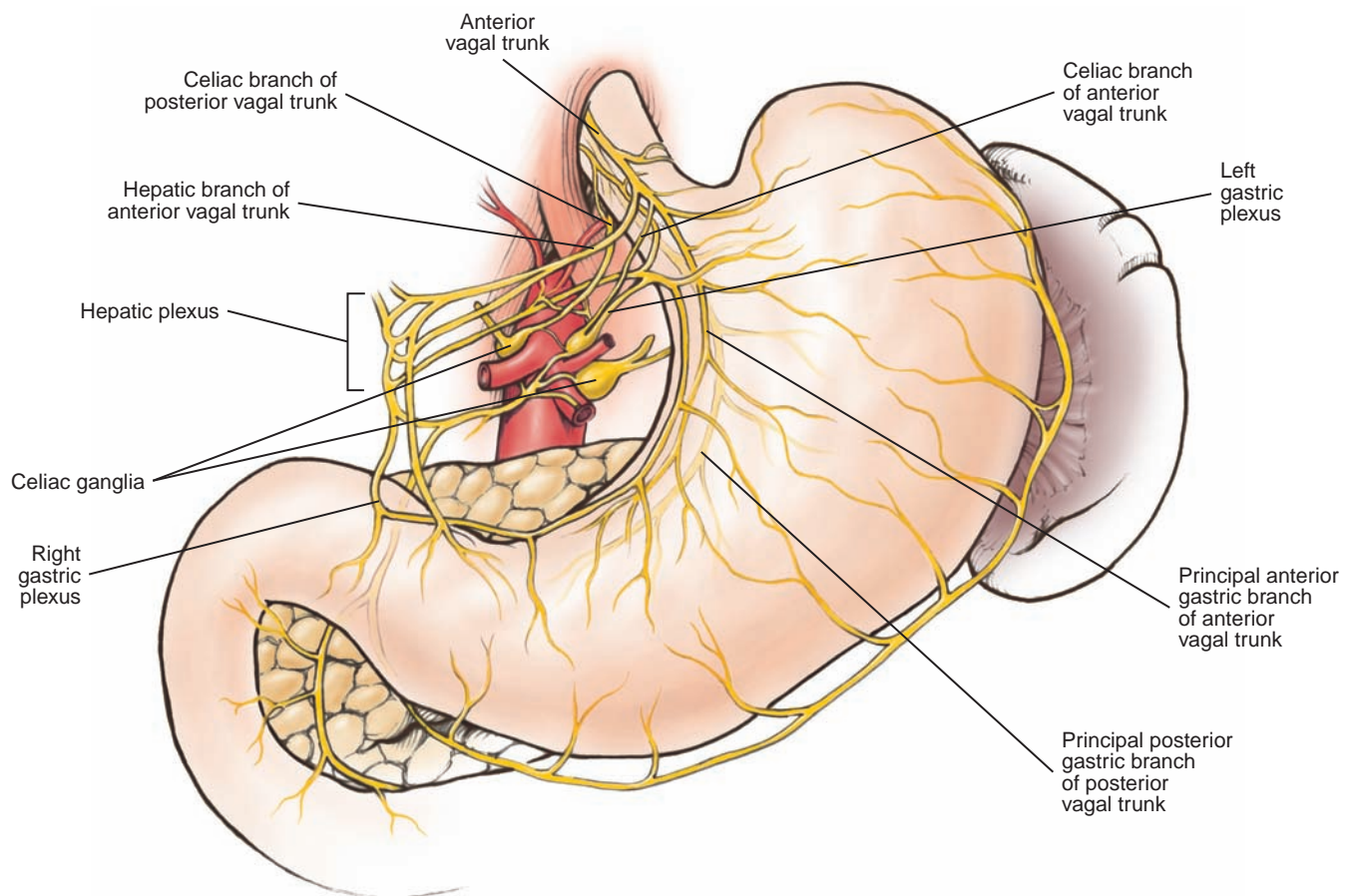


Figure 6.5

The right and left vagus nerves above the diaphragm coalesce to form the esophageal plexus. Just above the diaphragm the esophageal plexus divides into two nerve trunks that lie anterior and posterior to the esophagus, and then pass through the esophageal hiatus of the diaphragm and down the lesser curve of the stomach.

Both vagus nerves supply gastric branches to the stomach that arise at the cardiac end of the stomach. Each anterior and posterior vagal trunk gives off one long branch, the principal nerves of the lesser curvature, also known as the nerves of Latarjet, which descend on the anterior and posterior surfaces of the stomach and terminate as a “crow’s foot” on the pyloric antrum. In addition to the gastric branches, the anterior vagal trunk has a hepatic branch that passes from the stomach to the liver in the upper part of the hepatogastric ligament together with the hepatic branch of the left gastric artery. It also has a small branch that descends through the hepatogastric ligament to the pyloric portion of the stomach, duodenum, and pancreas. The posterior vagal trunk makes a major contribution to the celiac plexus by means of a celiac branch that follows the left gastric artery and vein.

The sympathetic nerve supply of the stomach is by perivascular plexuses (left gastric, hepatic, and splenic) that emanate from the celiac plexus. These are composed primarily of postganglionic sympathetic fibers, the cell bodies of which form the celiac ganglia. The preganglionic fibers reach the celiac ganglia by way of the greater thoracic splanchnic nerve from the fifth to the tenth thoracic cord segments.

The nerves to the stomach appear to have somewhat mixed functions. However, the parasympathetic innervation initiates or enhances muscular movements, and the sympathetic innervation is important in vasomotor control. The parasympathetic fibers exert the greater influence on the secretion of water and hydrochloric acid in the fundus and body; the sympathetic innervation has the major influence in the secretion of enzymes in the stomach.

Surgical Applications

There are a number of indications for operative placement of gastrostomy tubes, but they are generally used for gastric decompression or short-term external tube feedings. Long-term enteral feeding through a gastrostomy tube should be avoided because of increased risk for pulmonary aspiration. Patients with carcinomatosis or bowel obstructions requiring extensive lysis of adhesions or patients undergoing long elective abdominal operations may benefit from placement of a gastrostomy tube rather than prolonged use of a nasogastric tube. The advantages of a gastrostomy tube include the following: (1) it is vastly more comfortable than a nasogastric tube, (2) it allows the patient more mobility, and (3) it does not interfere with respirations or pulmonary toilet. In older patients with underlying pulmonary diseases, a gastrostomy tube may prevent some potentially lethal postoperative complications.

Gastrostomy

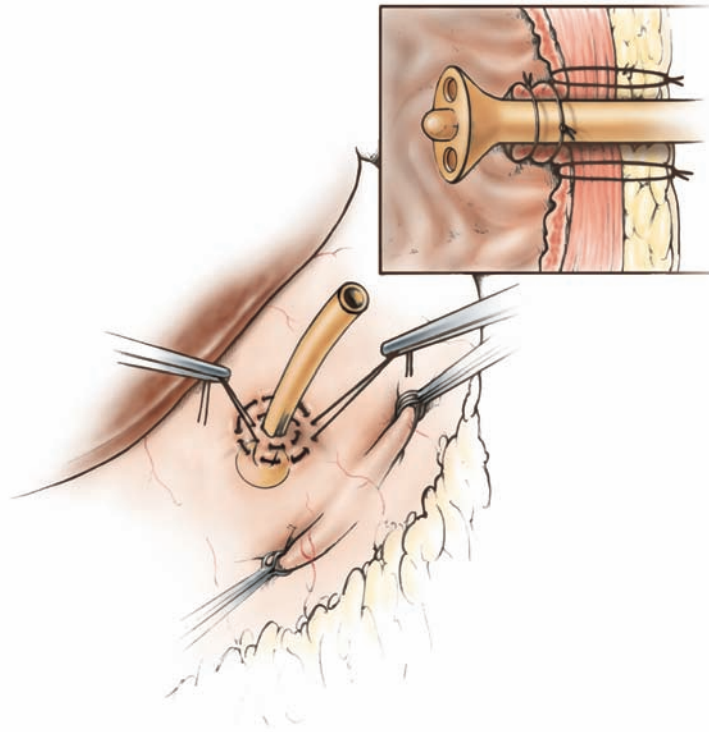


Figure 6.6

The most widely used temporary gastrostomy is the Stamm gastrostomy. It is performed quickly, easily, and safely and provides excellent venting of the stomach. The stomach is identified and grasped along the greater curvature with two Babcock clamps. A point is chosen on the middle anterior surface of the stomach where it will easily be sewn to the abdominal wall without any tension. A large (20–28 Fr) Malecot or Silastic Foley catheter is brought through a small puncture site in the left upper quadrant, away from the costal margin.

Two concentric 2–0 silk purse-string sutures are placed in the anterior body wall of the stomach. An opening is made in the stomach through the center of the inner purse-string suture using electrocautery. The gastrostomy tube is inserted into the stomach, and the inner purse-string suture is securely tied. While pushing down on the catheter or directly applying downward pressure on the ends of the inner purse-string suture, the outer purse string is tied. The two purse-string sutures form a snug seal and serosal lining for the tube tract. The gastric wall surrounding the tube is sutured to the abdominal wall in all four quadrants to prevent retraction and leakage. The catheter is secured to the skin with a 3–0 nylon suture.

In cases in which the stomach cannot come up to the abdominal wall because of severe adhesions or after a partial gastric resection, a Witzel gastrostomy can be done.

In this method, a single purse-string suture is placed, the tube is positioned through the gastric wall, and a tunnel is fashioned along the anterior gastric wall with 3–0 silk sutures. The gastrostomy tube penetrates the stomach at a distance from the point where it exits the abdominal wall to minimize leakage around the tube.

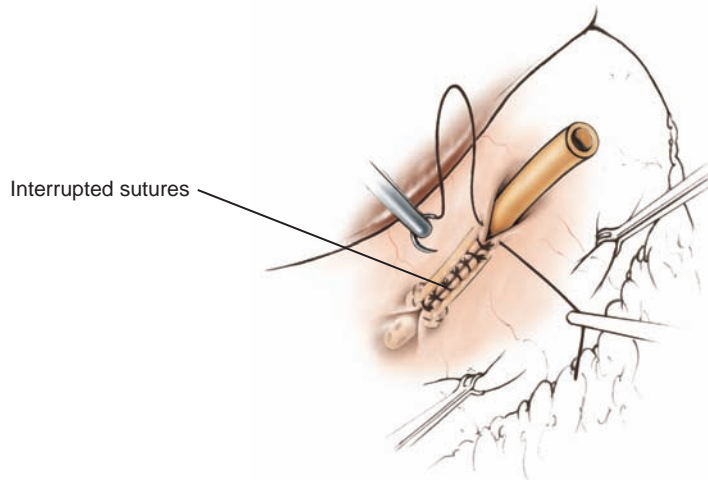


Figure 6.7

Postoperatively, the gastrostomy tube is placed to drain by gravity and is irrigated on every shift to avoid occlusion by mucus or other debris. The tube should be left in place for a minimum of 2–3 weeks to allow a tract to form between the stomach and the skin, thus preventing intra-abdominal leakage when removed.

Complications from gastrostomy placement are rare but can include leakage and retraction of the stomach from the abdominal wall. Small leaks can be treated conservatively with adequate drainage and nasogastric decompression of the stomach. Major leaks or retraction require repeat operation and repair.

Mesenchymal tumors are a rare group of benign or malignant neoplasms that can affect the gastrointestinal tract, particularly the stomach. They consist of three distinct neoplasms: smooth muscle neoplasms, including leiomyoma and leiomyosarcoma; rare peripheral nerve sheath tumors, and GIST. Overall, GIST accounts for at least 80% of gastrointestinal mesenchymal tumors of the stomach and small bowel.

Mazur and Clark first reported the existence of GIST as a separate entity from GI smooth muscle and nerve sheath tumors in 1983. GISTs are thought to originate from the interstitial cell of Cajal (ICC) which are located in and around the myenteric plexus and are thought to function as an intestinal pacemaker cell that regulates intestinal motility. In 1998, the pathological diagnosis of GIST tumors was simplified with the notable discovery of the immunohistological marker KIT (CD117). GIST tumors will have an overexpression of the c-Kit proto-oncogene in 85–90% of tumors. Based on data from the surveillance, epidemiology, and end results (SEER) program of the National Cancer Institute, the incidence of GIST tumors continues to increase every year. It is estimated that currently there are as high as 3,000–5,000 new cases of GIST tumors per year. GISTs can occur anywhere along the GI tract but are most commonly seen in the stomach (65%) or small intestine (25%). The median age of diagnosis is 60 years, and there is a slight male predominance. The clinical diagnosis varies widely, but the majority (70%) present with some vague abdominal symptoms,

Resection of Smooth Muscle Tumors

Table 6.3 Survival after complete resection (R0/R1) of gastrointestinal stromal tumors

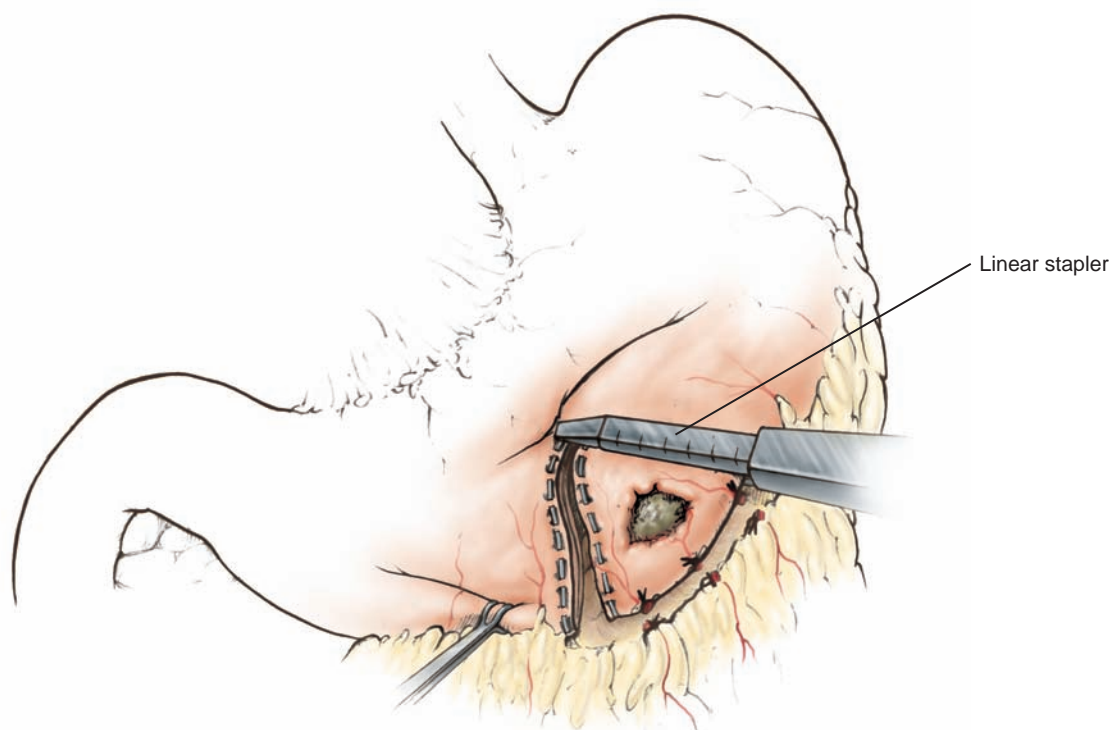
Study	Year	R0/R1 No. of patients	Survival after resections (%)	R0/R1 resection (%)
DeMatteo	2000	200	40	54 (5-year)
Crosby	2001	50	70	42 (5-year)
Pierie	2001	69	59	42 (5-year)
Langer	2003	39	90	87 (2-year)
Wu	2003	57	28	40 (2-year)
Carboni	2003	15	100	87 (2-year)
Besana-Ciani	2003	19	79	63 (5-year)

Source: Reproduced with permission from Raut CP, Morgan JA, Ashley SW. Current issues in gastrointestinal stromal tumors: incidence, molecular biology, and contemporary treatment of localized and advanced disease. *Current Opinion in Gastroenterology*, 23(2): p. 151, 2007. Lippincott Williams and Wilkins.

R0 = complete macroscopic resection with negative microscopic margins. R1 = complete macroscopic resection with positive microscopic margins.

whereas approximately 20% are asymptomatic. Asymptomatic GIST tumors are usually found incidentally on radiological exams or at the time of surgery and are usually of smaller size. Larger tumors can cause vague abdominal discomfort, pain, bloating, early satiety, or increased abdominal girth. More significantly, GIST tumors can erode into the lumen of the GI tract and cause significant hemorrhage.

Upper GI endoscopy and endoscopic ultrasound are helpful in the diagnosis of a gastric GIST tumor. Most often a submucosal mass will be seen on endoscopy occasionally with an associated ulcer. CT scan is useful in determining the size, location, and surgical strategy for the treatment of these GIST tumors. PET scans have an

**Figure 6.8**

important role in evaluating for metastatic disease and determining the success of treatment with Imatinib, a targeted agent against the c-Kit oncogene.

For patients with primary, localized GIST tumors, surgery represents the only potential chance for cure. The resection of small gastric GIST tumors can usually be accomplished with a wedge resection of the stomach. As opposed to adenocarcinoma, GIST tumors are well-encapsulated and only need a resection margin of 1 cm. Similarly, GIST tumors also do not usually metastasize to lymph nodes, such that a lymphadenectomy is not routinely indicated. For tumors along the greater curvature, the omentum is removed from the stomach near the tumor.

Resection can be done using a linear stapler or sharp resection with a hand-sewn two-layer closure. Lesions along the lesser curvature are resected in a similar manner. However, if the lesser curve resection is done with probable disruption of the vagal nerves supplying the pylorus, a pyloromyotomy should be performed to guard against gastric outlet obstruction.

A Heineke-Mikulicz pyloroplasty is perhaps the most commonly performed pyloroplasty and is begun by placing two silk stay sutures at the cephalad and caudal portions of the pylorus. With gentle traction upward on the stay sutures, the pylorus is opened longitudinally and closed transversely with a running absorbable suture and re-enforced with interrupted 3-0 silk Lembert sutures. In cases of prepyloric lesions, subtotal gastrectomy should be performed. When GISTs are densely adherent to adjacent organs, en bloc resections should be performed. For larger GIST tumors, full bowel prep should be done in case the mesentery of the left colon is involved and a colon resection is indicated. Laparoscopic resection of small GIST tumors can be done by an experienced laparoscopist, but should only be undertaken when it will not increase the chance of tumor rupture. Complete gross resection of a primary GIST tumor can be accomplished in approximately 85% of all patients. Unfortunately, about 50% patients will develop tumor recurrence after complete resection of their localized GIST tumors. Outcomes of surgical resection are listed in Table 6.3; 5-year survivals are about 50%.

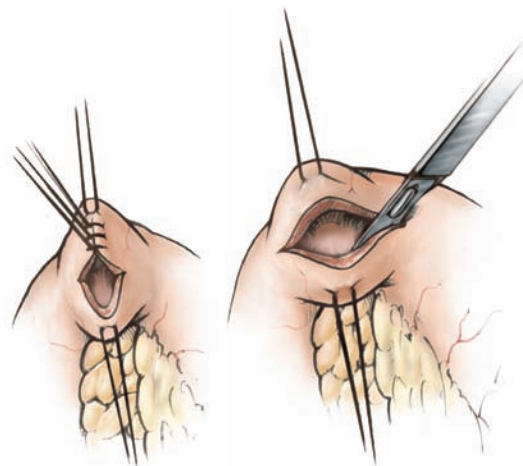


Figure 6.9

Table 6.4 Risk assessment for primary gastrointestinal stromal tumors.

Risk	Tumor size (cm)	Mitotic rate ^a
Very low	<2	<5
Low	2–5	<5
Intermediate	<5	6–10
	5–10	<5
High	>5	>5
	>10	Any mitotic rate
	Any size	>10

Source: Reproduced with permission from Raut CP, Morgan JA, Ashley SW. Current issues in gastrointestinal stromal tumors: incidence, molecular biology, and contemporary treatment of localized and advanced disease. *Current Opinion in Gastroenterology*, 23(2): p. 151, 2007. Lippincott Williams and Wilkins.

^aPer 50 high-power fields

Several prognostic factors have been determined to predict recurrence of GIST tumors. Tumor size and mitotic index are the two most important prognostic variables that estimate the risk of malignant potential. Based on these two factors, the probability of malignant potential and risk for recurrence are listed in Table 6.3. Gastric GISTs tend to have a more favorable clinical course compared to those in the small intestine. The ACOSOG has conducted two prospective trials for completely resected primary localized GIST tumors showing a benefit of adjuvant targeted therapy with Imatinib. The Z9000 trial which looked at the recurrence and survival of 106 patients who underwent complete resection of a high-risk GIST (>10 cm), intraperitoneal rupture or bleeding, or multifocal tumors has shown a benefit with the treatment of 1 year of Imatinib compared to historical controls. Z9001 trial was a randomized double-blinded trial in which patients who had undergone complete surgical resection of a GIST tumor >3 cm were given Imatinib or a placebo for 1 year. Those receiving Imatinib had a significant overall survival advantage.

Palliative Gastrojeunos- tomy

Gastrojejunostomy is indicated for patients with unresectable gastrointestinal cancers such as pancreatic, duodenal, or distal gastric cancers with evidence of impending or symptomatic mechanical gastric outlet obstruction. For patients with unresectable pancreatic or ampullary malignancies, a gastrojejunostomy is often combined with a biliary bypass. The procedure can be performed through either an upper midline or bilateral subcostal incision. Once exploration confirms unresectability of the primary tumor and near obstruction of the distal stomach or duodenum, the most dependent area of the greater curvature of the stomach is identified.

The omentum along this area is dissected from the greater curvature, and the lesser sac is entered. The next decision is whether to perform the anastomosis in an antecolic or retrocolic fashion. The retrocolic gastrojejunostomy generally empties better than the antecolic gastrojejunostomy but theoretically could be obstructed by tumors invading the transverse mesocolon. For these potentially obstructing tumors, an antecolic anastomosis is recommended.

To perform the retrocolic anastomosis, the ligament of Treitz is identified, and a proximal loop of jejunum is brought up through an incision in an avascular area of

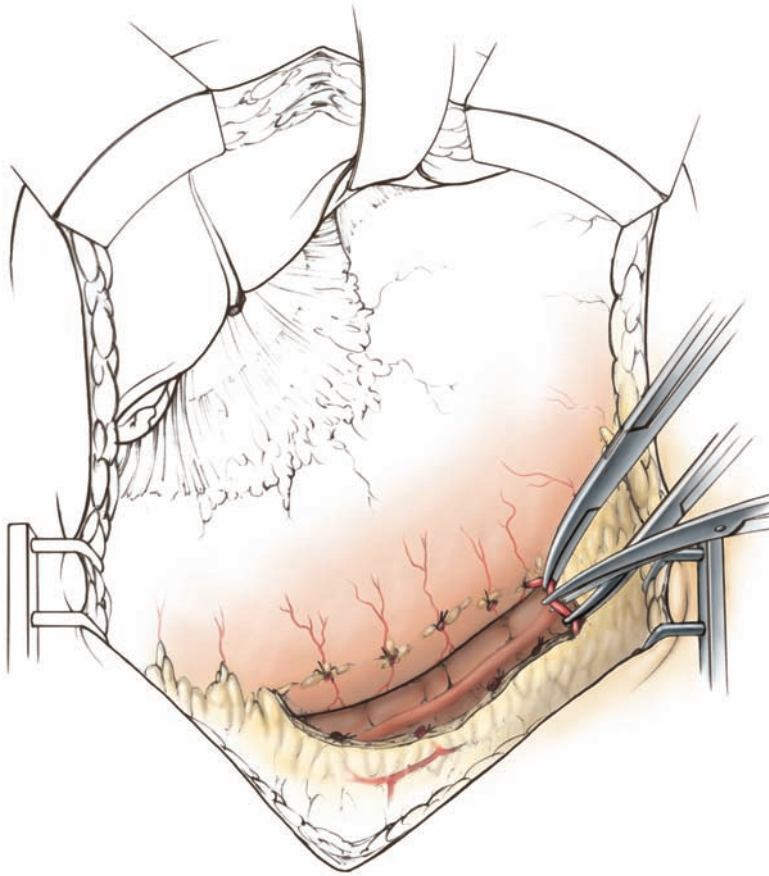


Figure 6.10

the transverse mesocolon. A side-to-side anastomosis is made with an inner layer of 3-0 absorbable sutures and an outer layer of Lembert 3-0 silk interrupted sutures. To minimize the risk for afferent loop syndrome or afferent loop herniation, the afferent loop is brought up to the more proximal stomach, minimizing the length of this segment of jejunum.

The gastrojejunostomy is then sutured to the rent in the transverse mesocolon on the gastric side to prevent obstruction of the anastomosis or bowel herniation.

An antecolic anastomosis is done in a similar fashion. However, the loop of jejunum is brought anterior to the colon, and the same side-to-side two-layer anastomosis is accomplished. A gastrostomy tube and feeding jejunostomy tube are placed distal to the anastomosis to aid in postoperative feeding and gastric decompression.

Subtotal gastrectomy with R2 lymph-node dissection can be performed through either an upper midline or a bilateral subcostal incision. A Goligher retractor is placed for exposure. The abdomen is completely explored to look for occult metastatic disease, and the primary tumor is assessed for resectability. The left lateral segment of the liver is mobilized by incising the left triangular ligament and folding the lobe underneath itself with gentle pressure from a self-retaining retractor.

The stomach is exposed, and the lesser sac is entered by dissecting the greater omentum from the transverse colon. This dissection is facilitated by gentle opposing traction of the omentum and colon and is easier to begin over the left transverse colon.

Subtotal Gastrectomy

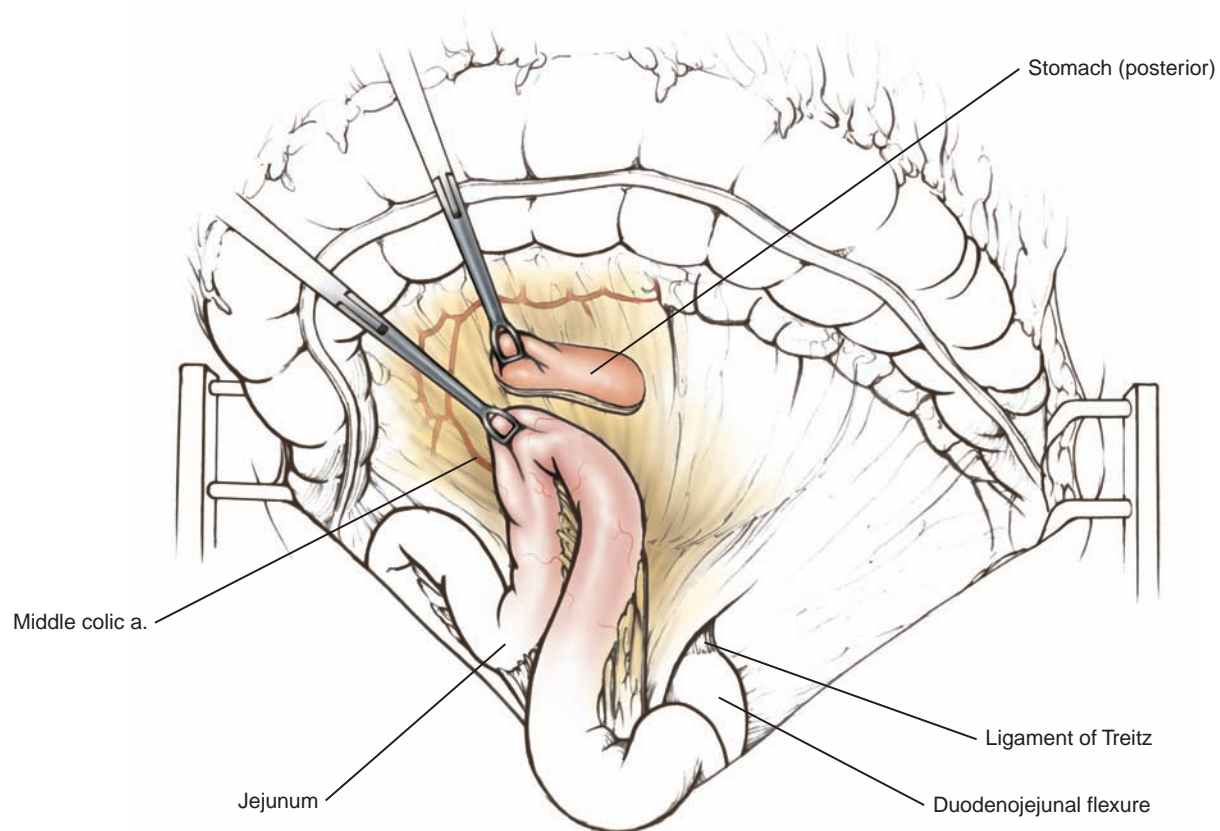


Figure 6.11

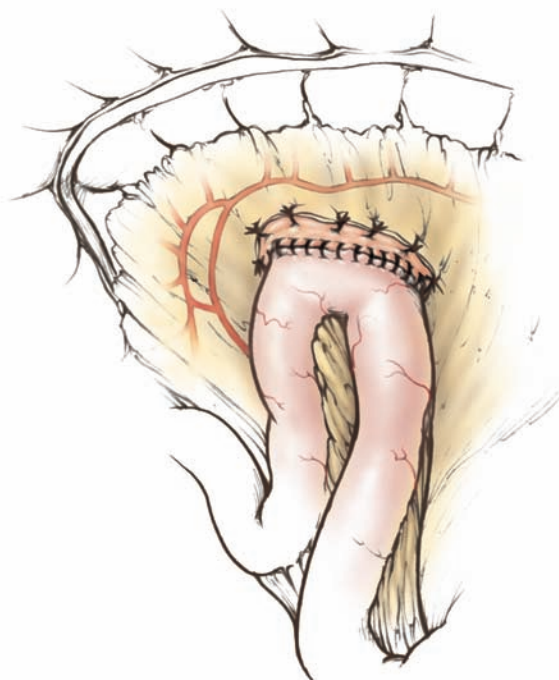


Figure 6.12

Figure 6.13

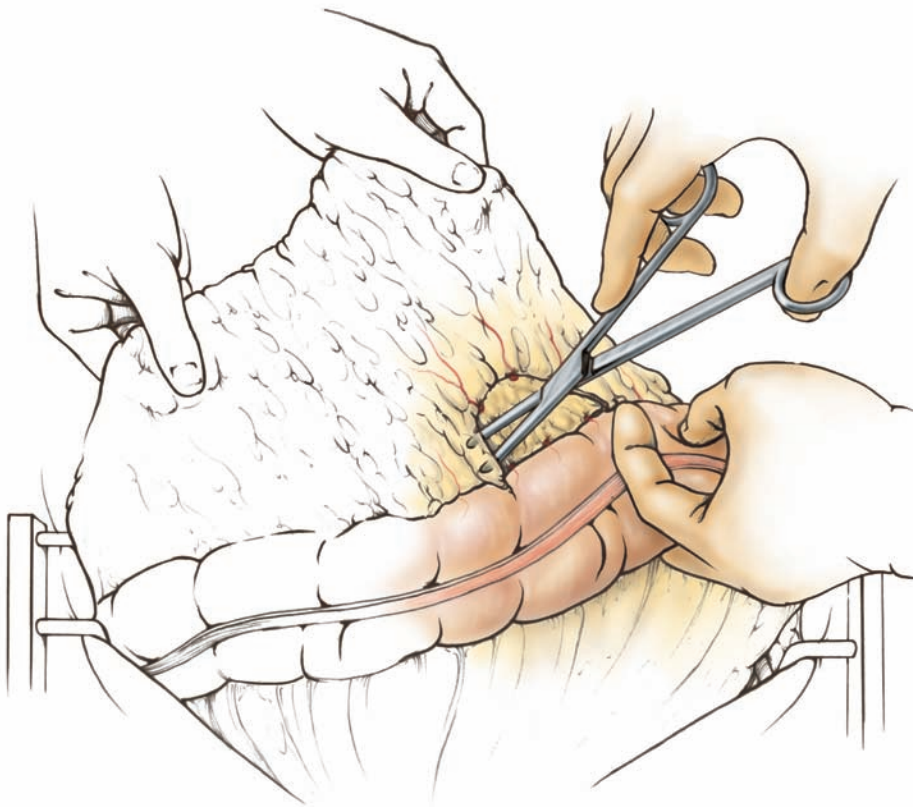
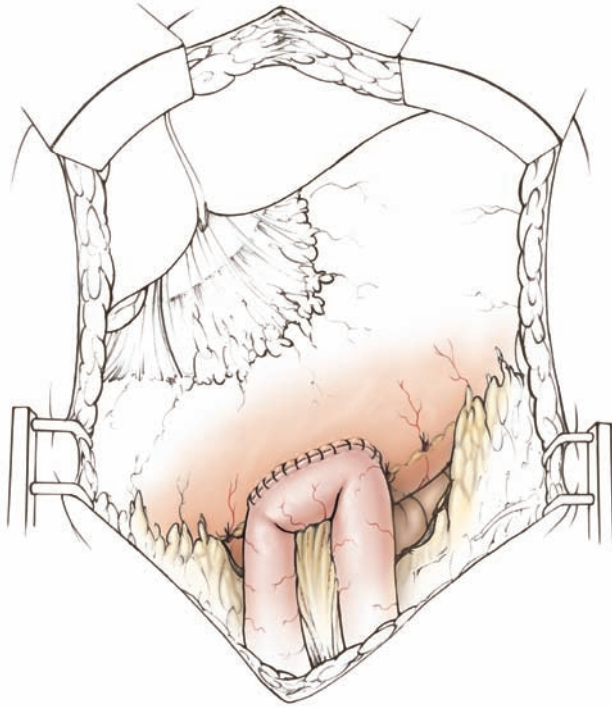


Figure 6.14

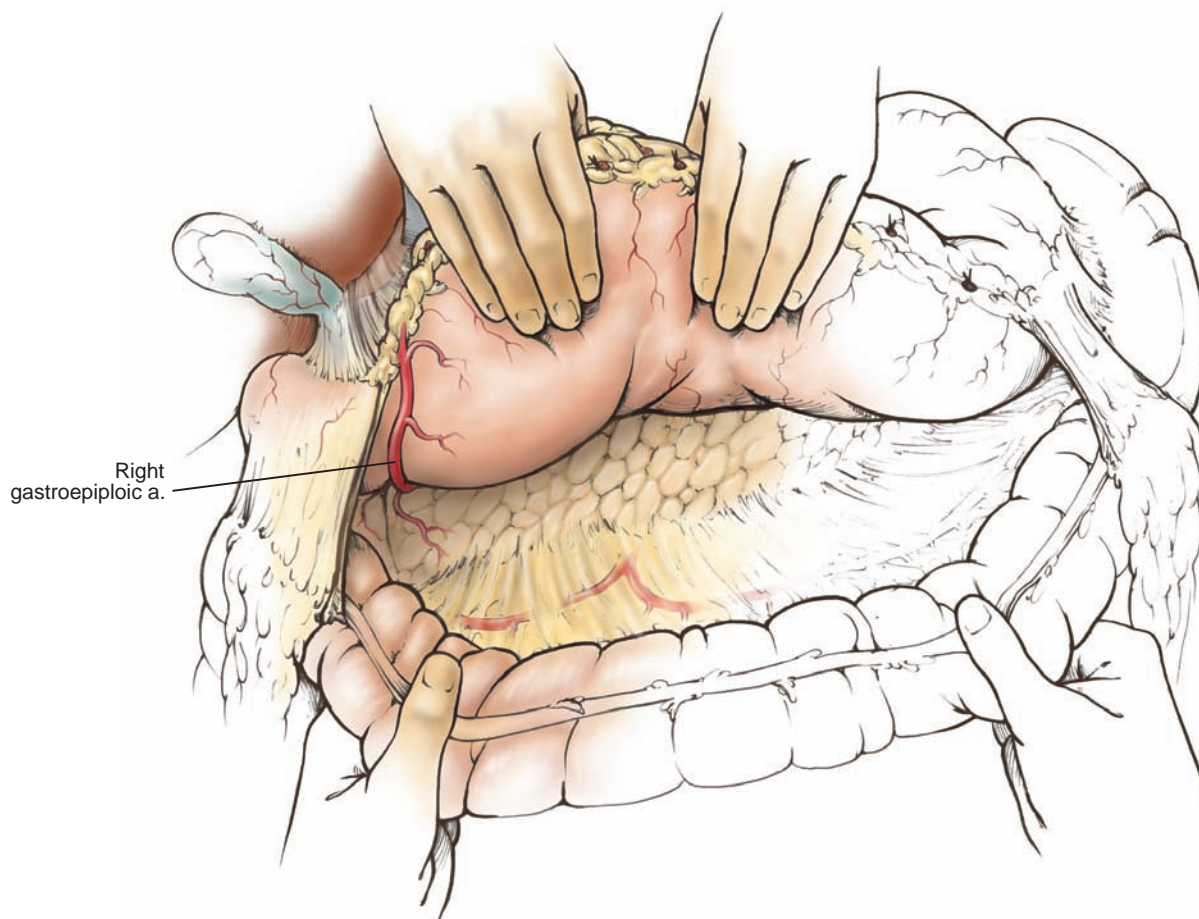


Figure 6.15

The peritoneum overlying the cephalad portion of the transverse mesocolon is dissected up, with care not to injure the middle colic vessels. In some patients this plane of dissection is not possible because of fusion of the peritoneum. When possible, this plane of dissection is continued past the base of the mesocolon to the inferior edge of the pancreas. The peritoneum and fatty tissue over the pancreas are dissected in a cephalad fashion.

Once the lesser sac is entered, the dissection continues along an avascular plane, moving to the patient's right until the right gastroepiploic vessels are identified and ligated. To mobilize the duodenum and pylorus, a Kocher maneuver is performed by dividing the retroperitoneal attachments to the duodenum. The attachments between the gallbladder and duodenum are released and the hepatoduodenal ligament is transected, exposing the porta hepatis.

The right gastric vessels are identified and ligated. The pylorus and the first portion of the duodenum are mobilized just enough to achieve a tumor-free margin and safe closure of the duodenum.

The duodenum is transected with a stapling device just 2 cm distal to the pylorus. The staple line is oversewn with a row of interrupted 3-0 silk Lembert sutures.

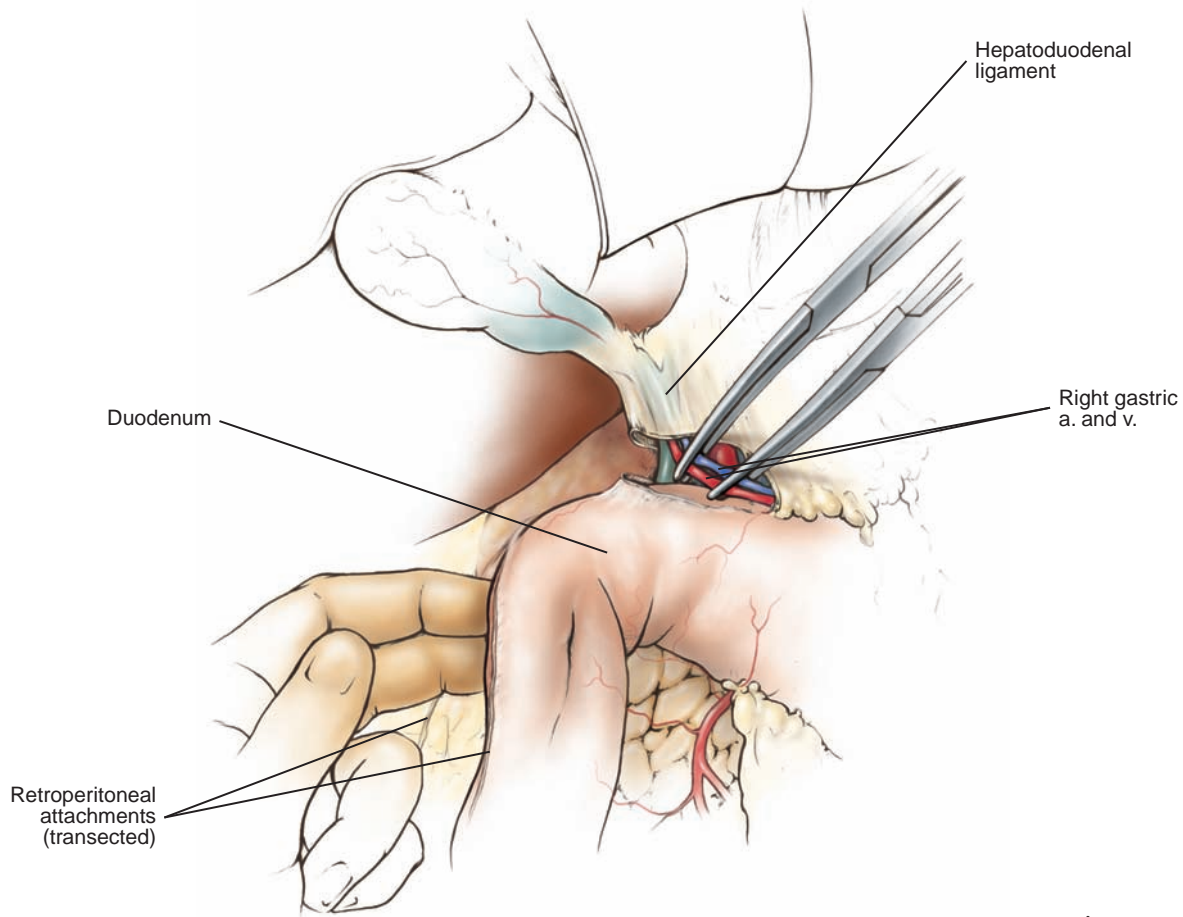


Figure 6.16

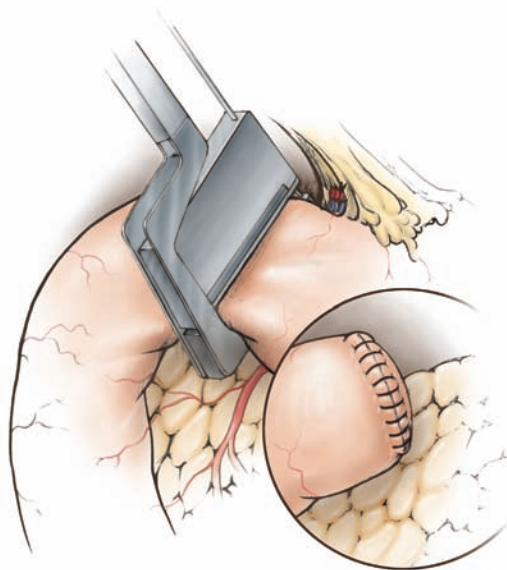


Figure 6.17



Figure 6.18

The lesser omentum is taken down from its attachments to the liver along with the lymph-node tissue inferior to the hepatic artery and along its course down to the celiac trunk. It is important to remember that an aberrant or accessory left hepatic artery may originate from the left gastric artery and reside in the lesser omentum. The aberrant artery should be preserved along with the main left gastric artery.

The stomach and omentum are then retracted cephalad, exposing the left gastric artery, which is doubly ligated at its origin and divided. The R2 nodes around the celiac axis are dissected with the specimen along the aorta from the celiac trunk to the superior border of the pancreas to the left along the splenic vessels. The proximal line of gastric transection is chosen about 5 cm from the tumor. The lesser and greater omentum are dissected from the stomach at the proximal transection site.

The proximal stomach is transected with a 90-mm stapling device. Studies have shown no benefit of total gastrectomy compared with subtotal gastrectomy as long as a tumor-free margin is achieved. After histologic confirmation of disease-negative resection margins, reconstruction is begun.

To prevent tension on the anastomosis, I prefer to use a retrocolic or anticolonic Roux-en-Y gastrojejunostomy. A loop of proximal jejunum is identified and transected with a stapling device at about 20 cm from the ligament of Treitz. The jejunal limb is mobilized so that the distal limb reaches the proximal stomach. A 50-cm distal

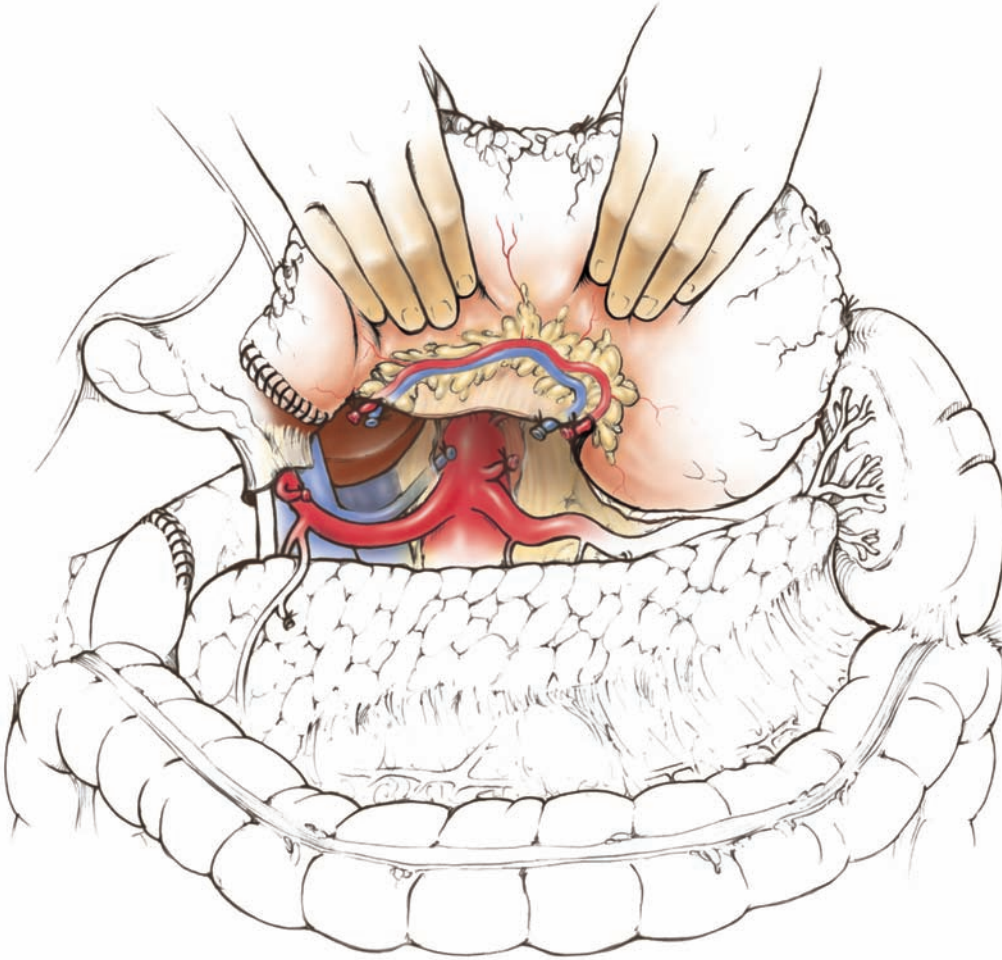


Figure 6.19

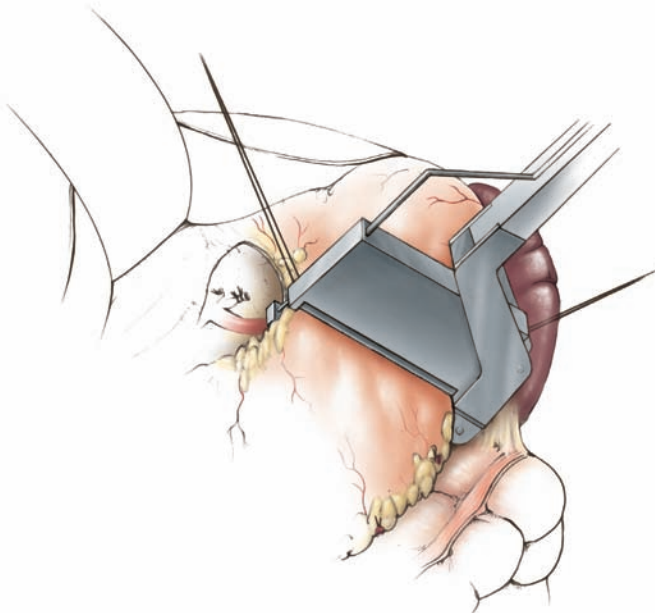


Figure 6.20

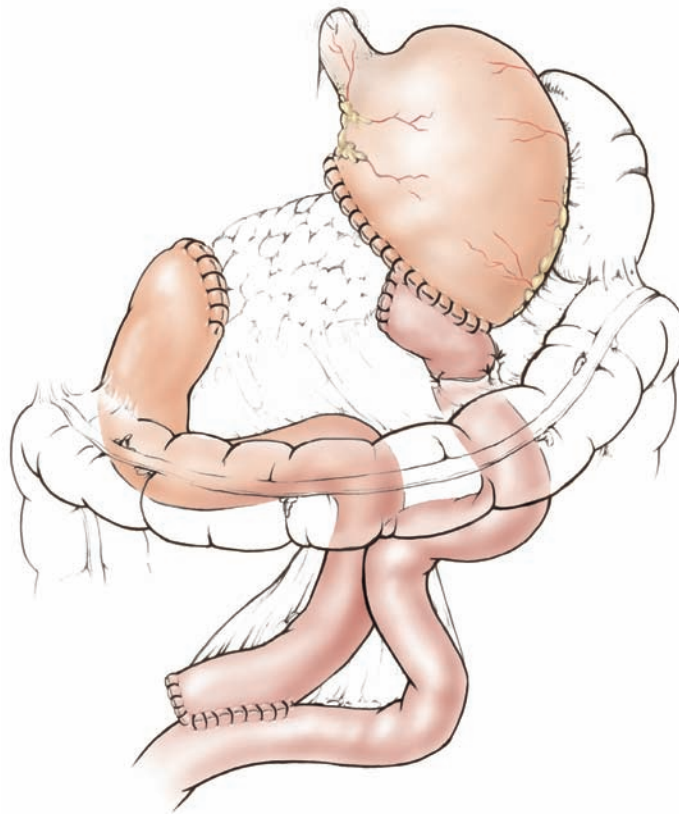


Figure 6.21

limb is measured and marked with a stitch. A side-to-side jejunojejunostomy is performed with either a two-layer hand-sewn or stapled method. The distal limb is either brought up through the mesocolon or in front of the colon, and an end-to-side gastrojejunostomy anastomosis is made using a two-layer technique of 3-0 running absorbable sutures for the inner layer and interrupted 3-0 silk Lembert sutures on the outside. An alternate technique is to use either an anticolonic or retrocolic Billroth II loop gastrojejunostomy. However, with a large subtotal resection, many times there is not enough length on the loop for a tension-free anastomosis.

For a loop gastrojejunostomy, either a Polya or Hofmeister technique can be performed on the basis of personal preference. Whether the jejunal loop is placed isoperistaltic or antiperistaltic is not important functionally, but, more important, the jejunal loop should be oriented for the anastomosis in a way that minimizes tension, angulation, or undesirable twisting of the small bowel. Difficult duodenal closures should be drained with a closed suction drain. A feeding jejunostomy is placed for early postoperative feeding.

Potential complications after subtotal gastrectomy include intra-abdominal bleeding, delayed gastric emptying, pancreatitis, duodenal stump leakage, and anastomotic leakage. After the perioperative period, some of the so-called postgastrectomy syndromes can be devastating to the patient. These syndromes include afferent loop syndrome, bile gastritis, and dumping syndrome.

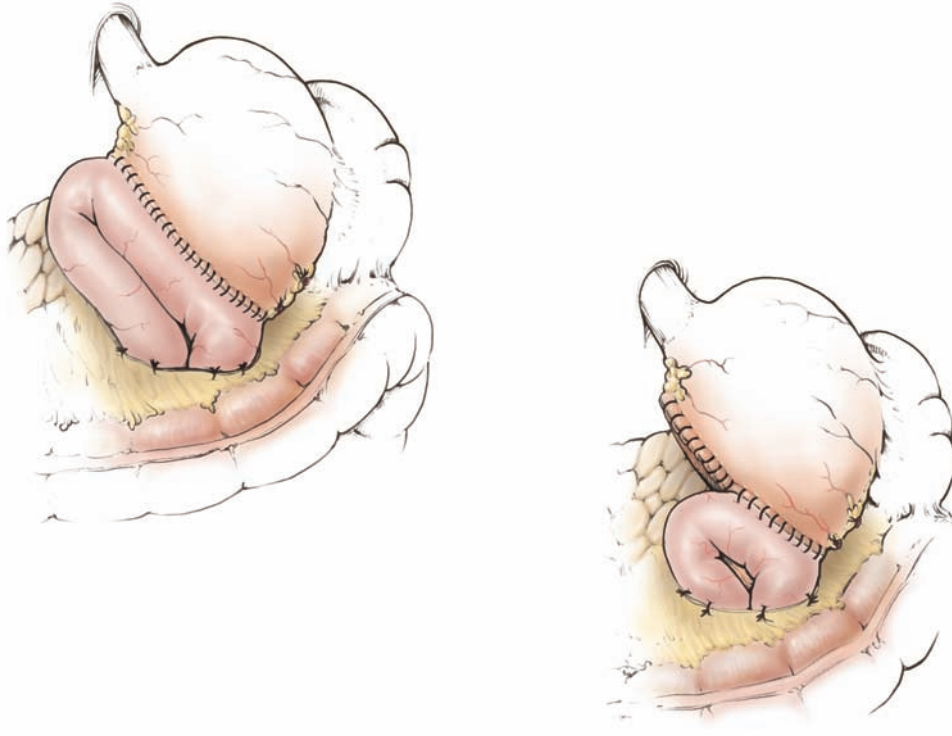


Figure 6.22

The role of radical lymphadenectomy in gastric cancer has been very controversial over the past few decades but is based on the principle that a radical resection, including extensive removal of lymph-node tissue, could result in improved outcomes. In Japan, where gastric cancer is far more common than in Western countries, the standardized radical lymph-node dissection has been developed and used with a therapeutic benefit and improved long-term survival rates compared to Western centers. The Japanese classification for gastric carcinoma (JCGC) shown in Table 6.5 has categorized the regional lymph nodes into various anatomical regions for lymph-node stations, identified by numbers.

These lymph-node stations are classified into three groups that correspond to the location of the primary tumor and reflect the likelihood of harboring lymph-node metastases. Most perigastric lymph nodes (# 1–6) are defined as Group 1 and lymph

Radical Lymphadenectomy

Group	Location of primary tumor			
	Entire stomach	Lower third	Middle third	Upper third
Group 1 (N ¹ or perigastric nodes)	1–6	3–6	1, 3–6	1–4
Group 2 (N ²)	7–11	1, 7–9	2, 7–11	5–11
Group 3 (N ³)	12–14	2, 10–14	12–14	12–14

Table 6.5 Anatomic grouping of lymph nodes according to site of primary tumor

¹ right cardial, 2 left cardial, 3 along the lesser curvature, 4 along the greater curvature, 5 suprapyloric, 6 infrapyloric, 7 along the left gastric artery, 8 along the common hepatic artery, 9 around the celiac artery, 10 at the splenic hilus, 11 along the splenic artery, 12 in the hepatoduodenal ligament, 13 at the posterior aspect of the pancreas, 14 at the root of the mesentery

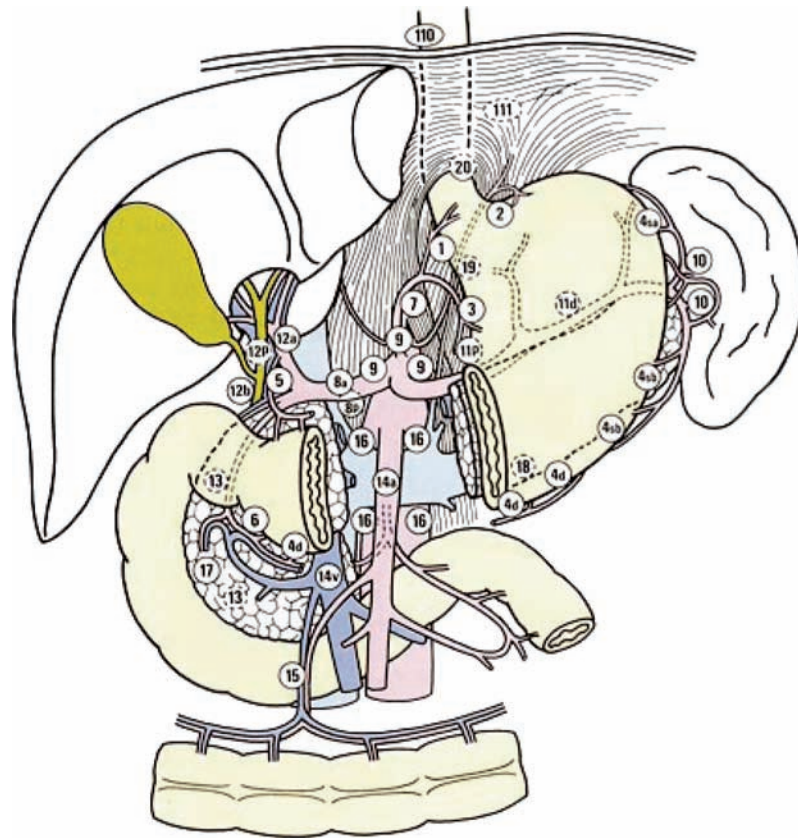


Figure 6.23

Source: Reproduced with permission from the Japanese Gastric Cancer Association. Japanese classification of gastric cancer, 2nd English edition. Gastric Cancer, 1:16, 1998, Springer.

nodes at the base of the left gastric artery (# 7) along the common hepatic (# 8), splenic (# 11), and proper hepatic (# 12) arteries and along the celiac axis (# 9) are defined as Group II. The periaortic lymph nodes (# 16) are defined as Group III. The extent of elective lymph-node dissection has been classified as D categories in the JCGC. D1 corresponds to dissection of Group 1 lymph nodes and D2 denotes dissection of Group 2, in addition to the Group 1 lymph nodes. D3 represents D2 lymph nodes plus resection of the periaortic lymph nodes (Group 3). In 1981, Kodama et al. showed that patients undergoing a D2 lymphadenectomy compared to those with a D1 lymphadenectomy had a significant improved overall survival.

In order to resolve the controversy about the benefit of D2 lymphadenectomy, several large, randomized studies were conducted in Western centers. In 1989, the Medical Research Council (MRC) in the United Kingdom conducted a trial that accrued 737 patients with histologically proven gastric adenocarcinoma. They randomized 400 resectable patients to equal groups of gastrectomy with either D1 or D2 lymphadenectomy. Patients undergoing a D2 resection had significantly higher post-operative mortality and complication rates compared to those who underwent a D1 resection. However, the excess morbidity, mortality, and prolonged hospital stay was associated with the routine use of pancreaticosplenectomies done in D2 dissections in this study. Both the overall survival and recurrence-free survival were similar

between the two groups. The authors concluded that the standard D2 lymphadenectomy offered no survival advantage over D1 resection. A second large multicenter prospective randomized trial was conducted in the Netherlands and again compared the outcome of D1 and D2 lymph-node dissections for gastric cancer. Seven hundred and eleven patients were randomized to either a D1 or a D2 lymphadenectomy after a curative gastrectomy. The D2 resections were done by one of eight specially trained, regional surgeons who had been instructed by an expert Japanese gastric surgeon. Despite efforts to maintain quality control, there was significant noncompliance of lymph-node basins resected. More specifically, noncompliance occurred in 51% of D2 dissections in which no lymph nodes were obtained from at least two of the lymph-node stations to have been dissected. Similar problems with noncompliance in the D1 dissections also occurred. Patients undergoing D2 dissections also had higher postoperative mortality and significant more postoperative complications. Similar to the MRC trial, D2 dissections in this study also required a pancreaticosplenectomy for proximal tumors and morbidity and mortality were increased in this group. The lack of benefit of D2 lymphadenectomy in these randomized trials has been challenged by many authors. First, the inadequate pretrial training in these studies was associated with a much higher mortality rate than reported in contemporary nonrandomized studies conducted in high-volume centers. Second, obligatory resection of the spleen and distal pancreas during total gastrectomy was specified in both trials and in most cases is not necessary. Third, efforts to validate the different extent of lymph-node dissection between D1 and D2 operations, in fact, indicated a considerable degree of overlap between the treatment groups. The effects of such contamination and noncompliance errors reduce the estimated difference in survival between the groups. In the United States in general, low postoperative morbidity and mortality have been universally observed in centers with high volume and surgeons trained and experienced in D2 dissections. Several nonrandomized trials done in specialized high-volume centers have shown similar morbidity and mortality between D1 and D2 lymphadenectomy. The same nonrandomized specialized series have suggested and associated improved survival in subgroups of patients undergoing D2 lymphadenectomy compared with limited D1 resections. In a prospective nonrandomized multicenter study, Seiwert et al. found equivalent morbidity (30%) and mortality (5%) rates for standard and radical lymph-node dissections performed on 1,654 patients with operable gastric cancer. D2 lymphadenectomy was an independent, prognostic factor associated with improved survival on multivariate analysis in Stage II and Stage IIIa patients. In a similar retrospective study of 320 patients, Pacelli et al. compared limited D1 with extended D2/D3 dissections. Postoperative morbidity and mortality were similar between the two groups. The authors reported a significant benefit in patients who had D2/D3 dissections with improved overall 5-year survival rates in all patients. The role of D2 dissections in the United States remains controversial, but the mortality and morbidity of patients undergoing a D2 lymphadenectomy in high-volume centers is similar to those undergoing a D1 dissection. Surgeons experienced in D2 lymphadenectomies should be able to provide patients with acceptable morbidity and mortality, better cancer staging, and perhaps better long-term survival. Several recent studies looking at the role of D3 lymphadenectomy compared to D2 lymphadenectomy

have been completed. Universally, these have shown no statistical survival advantage and most surgeons have abandoned D3 periaortic lymph-node dissections.

Total Gastrectomy

Total gastrectomy can be performed by extending the proximal dissection of the subtotal gastrectomy described previously.

After the omentum is mobilized off the transverse colon, and dissection of the duodenal region and R2 lymphadenectomy are complete, the dissection is continued along the greater curvature, dividing the gastrosplenic ligament and each of the short gastric vessels. During this dissection, the surgeon needs to avoid excessive traction, which could result in a capsular tear of the spleen. Studies have shown no benefit to removing the spleen during gastrectomy unless there is direct tumor invasion. The dissection along the lesser omentum is extended up to the esophagus.

With the left lateral lobe of the liver retracted medially, the esophagus is identified by palpation of the nasogastric tube, and the peritoneum along its intra-abdominal portion is divided. A Penrose drain is placed around the esophagus to aid in the dissection. The vagus nerves are identified and divided above the esophagogastric junction.

The esophagus is divided, and frozen-section pathologic evaluation is done because of the frequency of unsuspected proximal lymphatic infiltration of tumor.

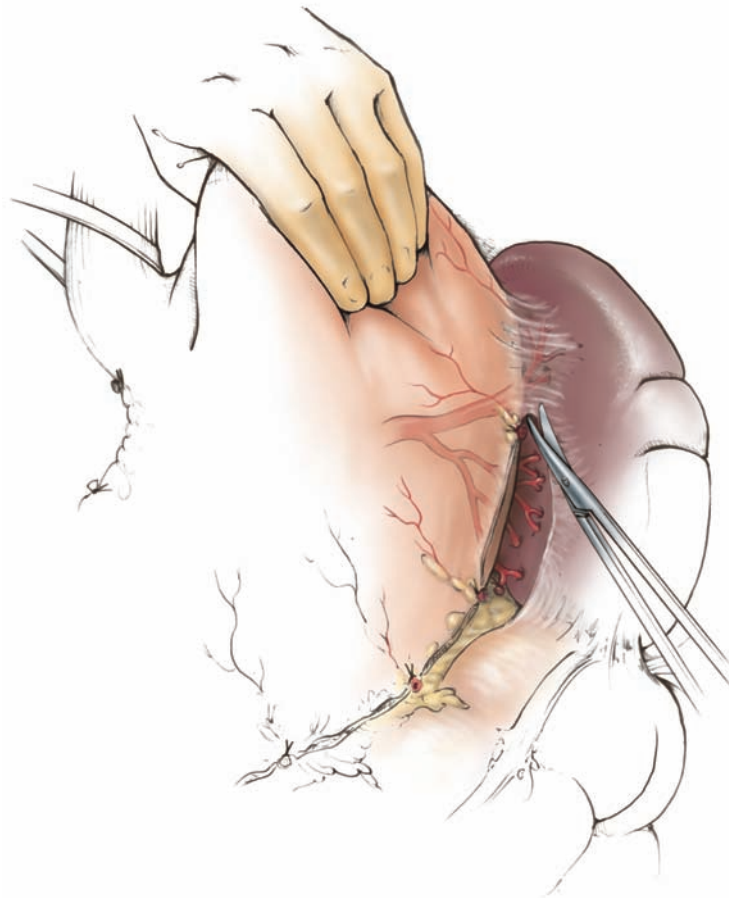


Figure 6.24

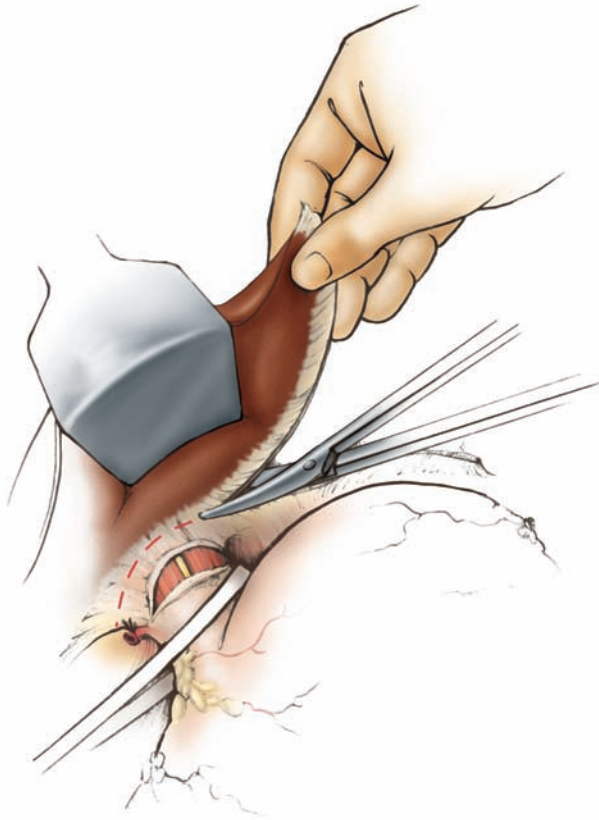


Figure 6.25

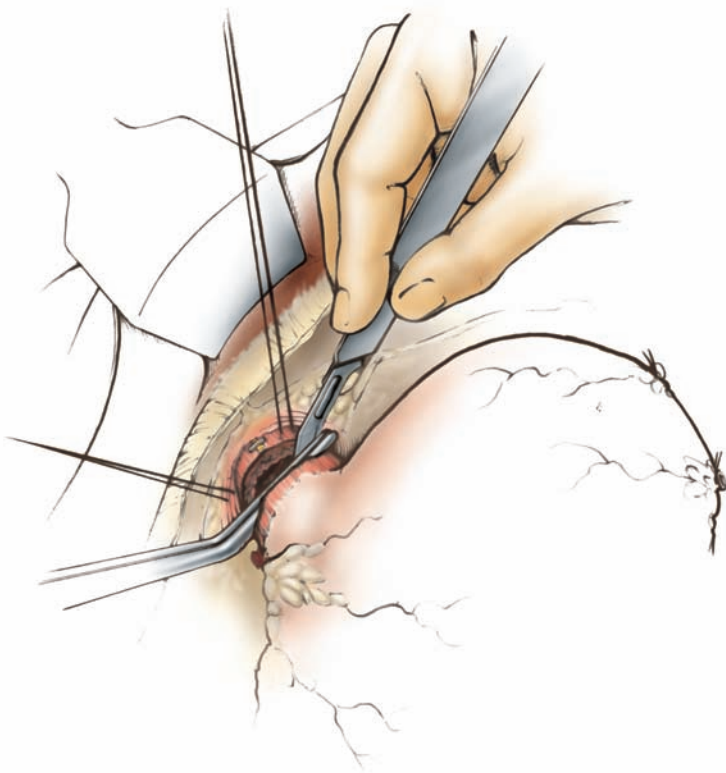


Figure 6.26

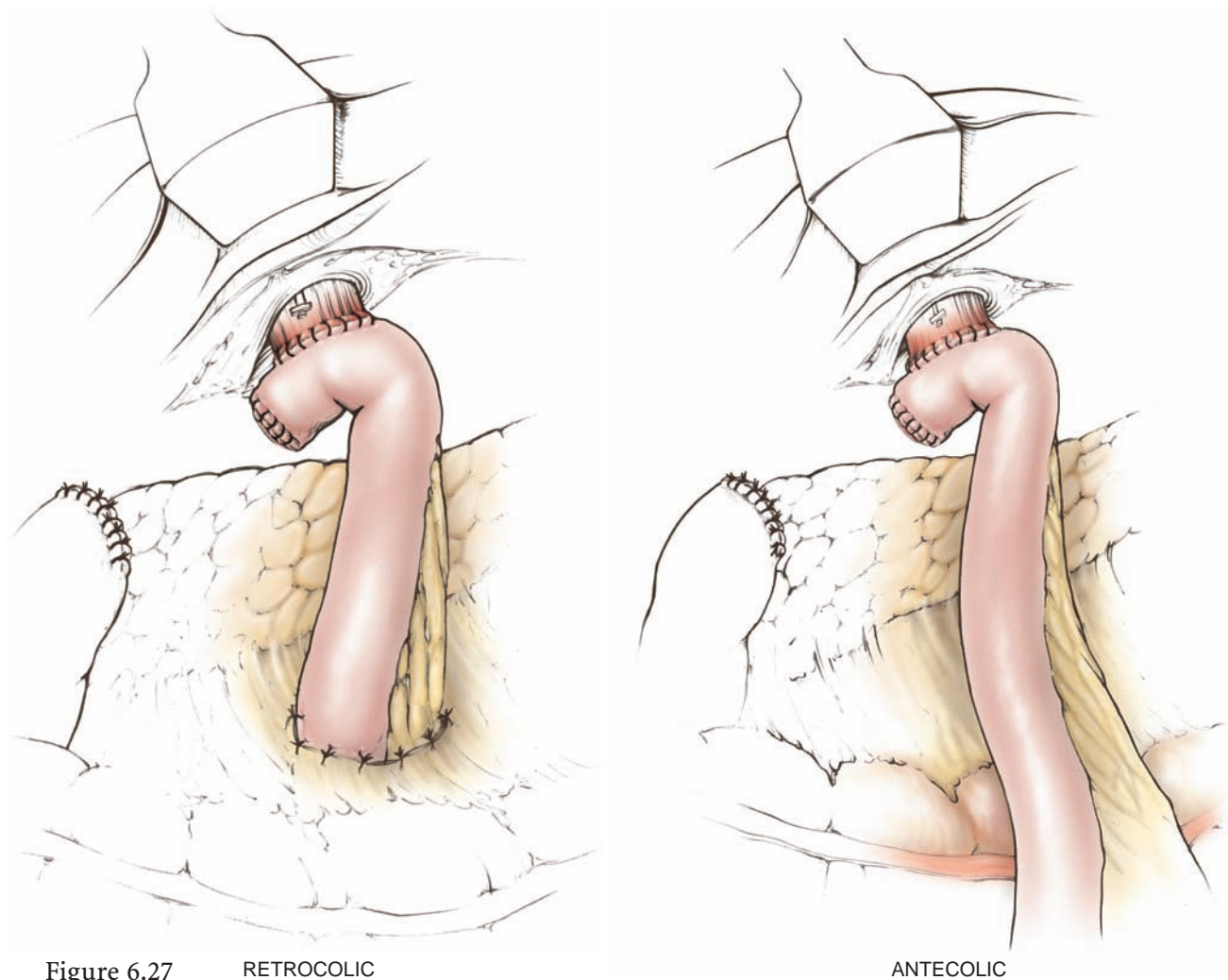


Figure 6.27 RETROCOLIC

ANTECOLIC

After removal of the specimen and disease-free margins are confirmed histologically, a Roux-en-Y end-to-side esophagojejunostomy is performed. Stay sutures are placed on the lateral aspects of the esophagus. The Roux limb is then brought up either retrocolic or antecolic. A point 8–10 cm from the end of the Roux limb is then used for the end-to-side anastomosis, which can be done either with the circular stapling device or a two-layer hand-sewn anastomosis.

For the stapled anastomosis, the staple line at the end of the Roux limb is removed.

The appropriate-sized circular stapler is introduced through the Roux limb.

A 2–0 Prolene purse-string suture is placed in the end of the esophagus, and the anvil of the circular stapler is inserted into the esophagus. The purse-string suture is tightened and the stapler engaged.

After removing the stapler, the end of the jejunal limb is closed with a linear stapler. The nasogastric tube is placed down the efferent limb.

There are many modifications of the reconstruction of a total gastrectomy. Some surgeons have advocated the use of a jejunal pouch (Hunt-Lawrence pouch), which can

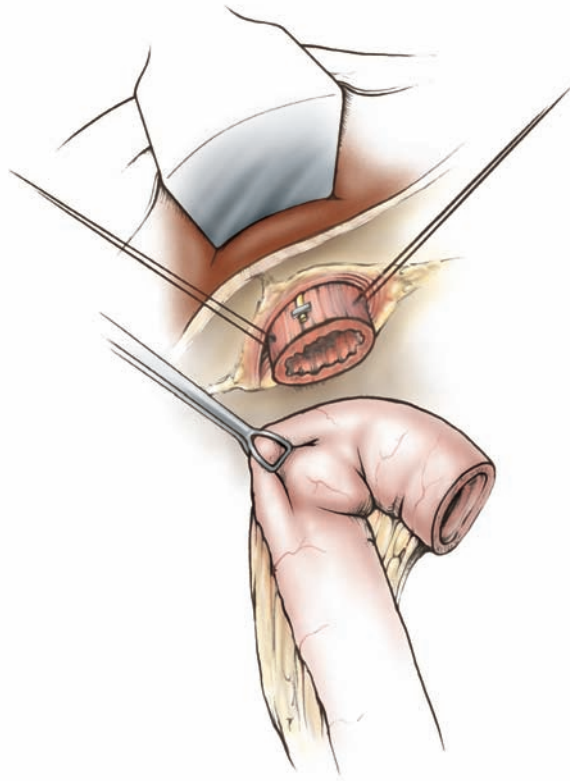


Figure 6.28

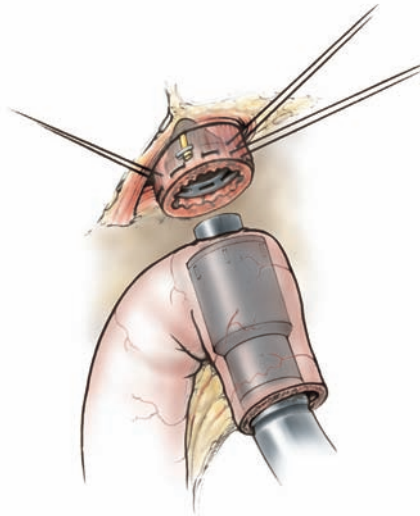


Figure 6.29

be created by performing a side-to-side jejunojunostomy just below the esophagojejunostomy to act as a food reservoir. This pouch can be created using either a hand-sewn or stapled technique. However, there is no objective evidence that these pouches provide nutritional benefits over a standard Roux-en-Y esophagojejunostomy. A

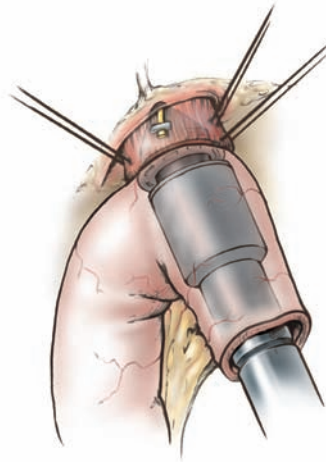


Figure 6.30

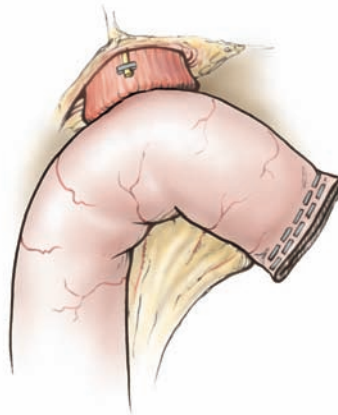


Figure 6.31

feeding jejunostomy is placed for early postoperative feeding. A closed suction drain is placed near the esophagojejunostomy.

Extended Gastrectomy

Large gastric tumors may locally invade adjacent organs, and the operating surgeon must be prepared to resect these organs en bloc if necessary. Bulky tumors along the posterior wall of the antrum or body may extend into the pancreas or retroperitoneal structures. When this occurs, the distal pancreas and spleen should be removed en bloc with the stomach. The splenic flexure of the colon is mobilized to gain better exposure of the spleen. The retroperitoneal and colonic attachments to the spleen are divided. The spleen and distal pancreas are elevated and brought to the midline.

The splenic vein and artery are ligated. The pancreas is divided at the level of the mesenteric vessels. The residual pancreas requires ligation of the pancreatic duct

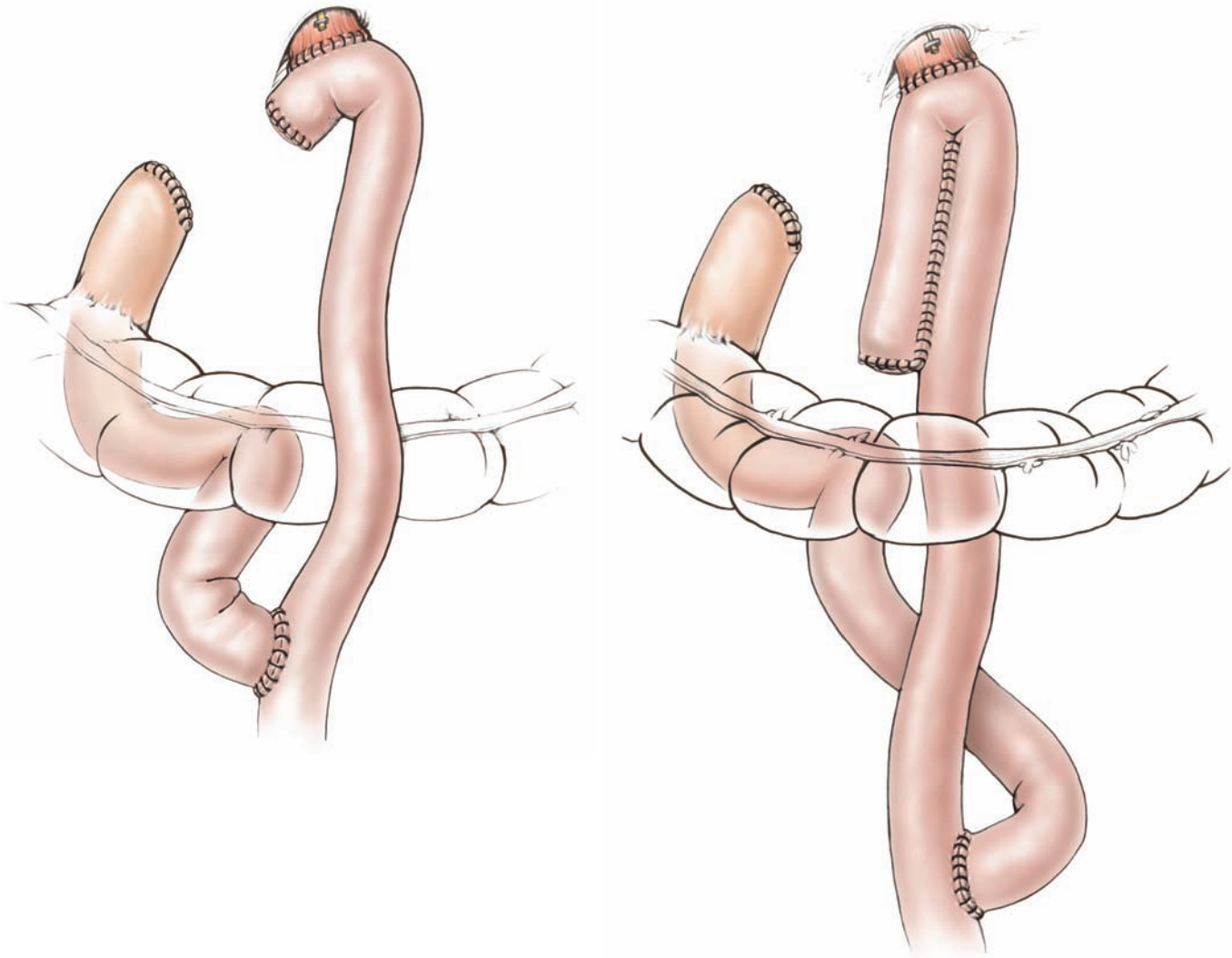


Figure 6.32

with a 5–0 Prolene suture and closure of the pancreatic stump with 3–0 Prolene mattress sutures. A closed suction drain is placed near the pancreatic closure.

On occasion gastric carcinoma can locally also invade the left lateral lobe of the liver. This represents direct tumor invasion, not metastatic disease. An umbilical tape is placed around the porta hepatis if inflow occlusion is needed.

Overlapping large 0 chromic liver sutures are used for hemostatic control along the liver transection line. The liver tissue is then divided with at least a 1-cm gross margin using the ultrasonic dissector or the electrocautery unit. The remainder of the gastrectomy is done in the standard fashion.

Large tumors along the greater curve of the stomach may invade either the transverse colon mesentery or the transverse colon itself, and may require en bloc resection of the stomach and transverse colon. Given an adequate mechanical and antibiotic bowel preparation, a primary colon resection is performed with reanastomosis of the colon.

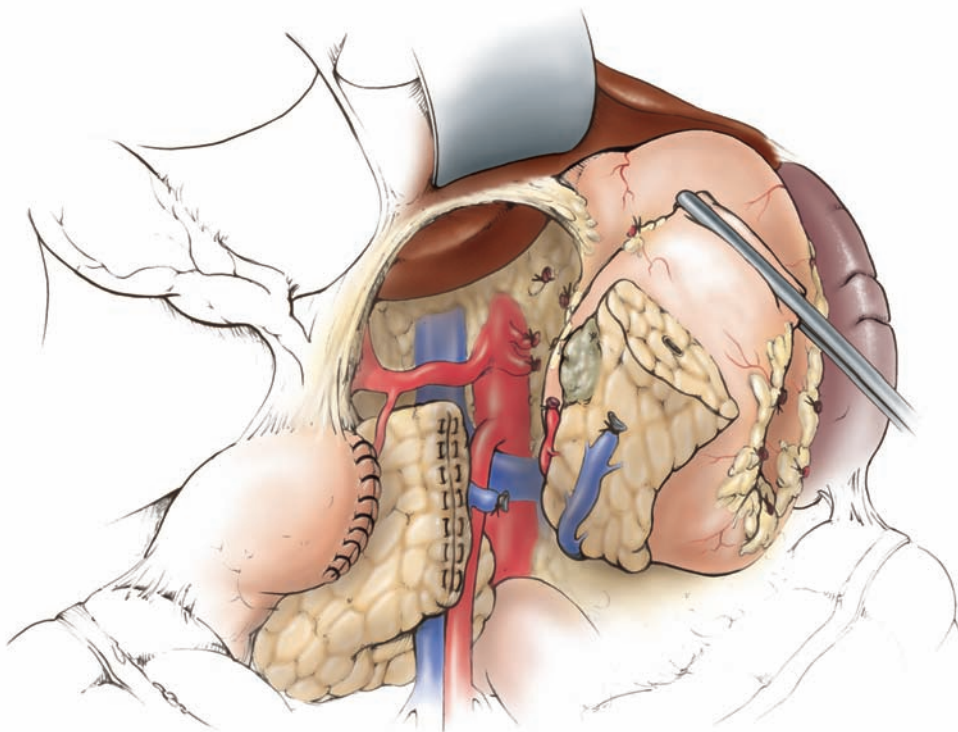


Figure 6.33

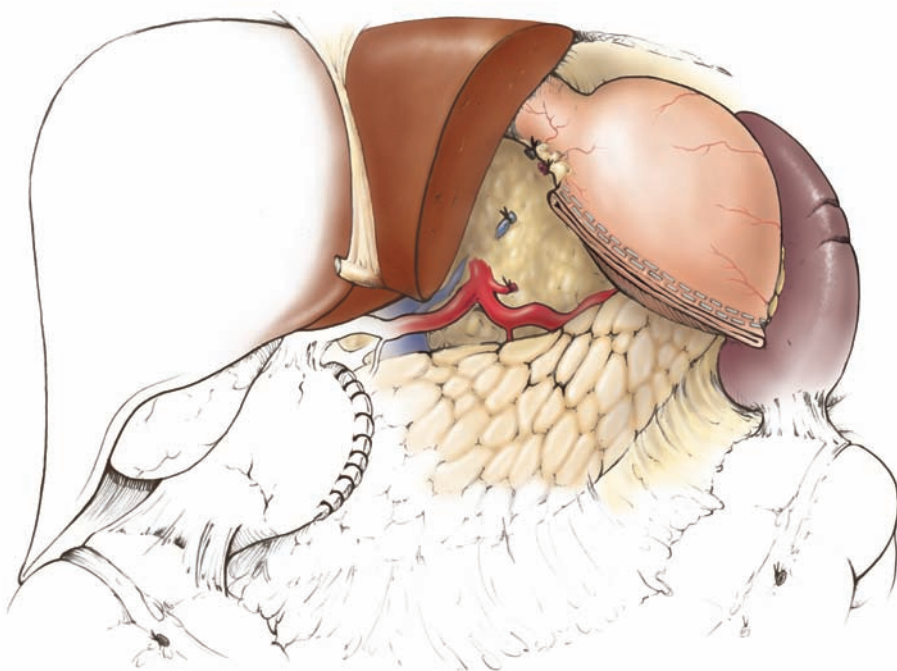


Figure 6.34

Anatomic Basis of Complications

- Too much traction on the gastrosplenic ligament may result in splenic injury, requiring splenectomy. **Major**
- Division of an aberrant left hepatic artery in the lesser omentum from the left gastric artery may cause ischemia or necrosis of the left lobe of the liver.
- Breakdown of the duodenal stump closure will result in intra-abdominal abscess formation and sepsis.
- Pancreatitis can develop from dissection along the gland. **Minor**
- Delayed gastric emptying will result in intermittent nausea and vomiting.
- Afferent loop syndrome can develop due to mechanical obstruction of an afferent loop of jejunum.

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These authors review Japanese and Western staging systems for gastric cancer. Through screening programs the Japanese identify more early gastric cancer, and their overall survival rate is better than that for the United States. The value of extended lymph-node dissection has not been clearly defined.

Cady B, Rossi R, Silverman M, et al Gastric adenocarcinoma. *Arch Surg.* 1989;124:303–08

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Gouzi J, Huguier M, Fagniez P, et al Total versus subtotal gastrectomy for adenocarcinoma of the gastric atrium. A French prospective controlled study. *Ann Surg.* 1989;209:162–6

This multicenter trial compares postoperative mortality and 5-year survival of patients undergoing total gastrectomy vs. subtotal gastrectomy. Postoperative mortality was low in both groups; overall survival was the same in both groups. Total gastrectomy offers no benefit over subtotal gastrectomy.

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Abdominal Wall

William S. Richardson, and Charles A. Staley

The anatomy of the abdominal wall is significant for the planning and performance of abdominal incisions and for placement of endoscopes and trocars.

Surgical Anatomy

Landmarks

The abdomen is defined as that region of the trunk between the diaphragm above and the inlet of the pelvis below. The xiphoid process is the cartilaginous lower part of the sternum that is easily palpated in the depression where the costal margins meet in the upper part of the anterior abdominal wall. The costal margin is the curved lower margin of the thoracic wall that is formed in front by the cartilages of the seventh, eighth, ninth, and tenth ribs and behind by the cartilages of the eleventh and twelfth ribs. The iliac crest can be palpated along its entire length and ends in front at the anterior iliac spine and behind at the posterior superior iliac spine. The inguinal ligament, the rolled edge of the aponeurosis of the external oblique muscle, extends laterally to the anterior superior iliac spine and curves downward and medially to the pubic tubercle. The pubic tubercle is the small protuberance along the superior surface of the pubis. The symphysis pubis is the cartilaginous joint that lies in the midline between the bodies of the pubic bones. The midline of the abdominal fascia is called the linea alba and is formed by the fusion of the aponeuroses of the muscles of the anterior abdominal wall. The umbilicus lies in the linea alba and is the site of attachment of the umbilical cord in the fetus. The linea semilunaris is the lateral edge of the rectus abdominis muscle and crosses the costal margin at the tip of the ninth costal cartilage.

Topography

Abdominal Regions

For clinical purposes, it is customary to divide the abdomen into nine regions by two vertical and two horizontal lines. Each vertical line (midinguinal) passes through the midpoint between the anterior superior iliac spine and the symphysis pubis. The upper horizontal line, referred to as the subcostal plane, joins the lowest point of the costal margin on each side. The lowest horizontal line, referred to as the intertubercular plane, joins the tubercles on each iliac crest.

The upper abdomen includes the right hypochondric, epigastric, and left hypochondric regions. The middle abdomen includes the right lumbar, umbilical, and left lumbar regions. The lower abdomen includes right iliac, hypogastric, and left iliac areas.

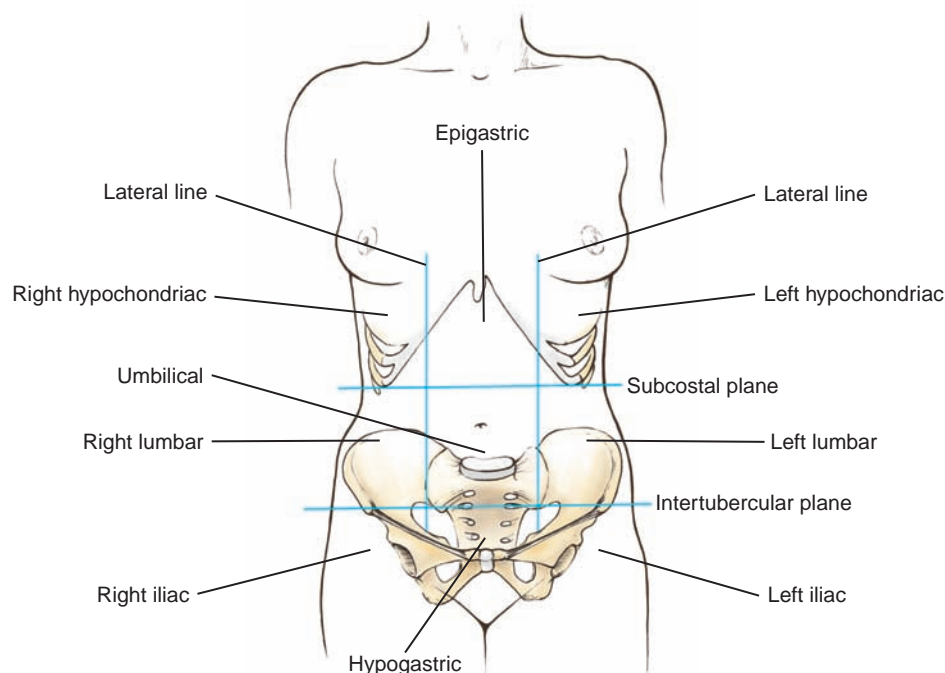


Figure 6.35

Structure of Abdominal Wall

Superiorly, the abdominal wall is formed by the diaphragm, which separates the abdominal cavity from the thoracic cavity. Inferiorly, the abdominal cavity is continuous with the pelvic cavity through the pelvic inlet. Anteriorly, the abdominal wall is formed above by the lower part of the thoracic cage and below by the rectus abdominis, external oblique, and transversus abdominis muscles. Posteriorly, the abdominal wall is formed in the midline by the lumbar vertebrae and their intervertebral disks. Posterolaterally, the abdominal wall is formed by the twelfth ribs, the upper part of the body pelvis, the psoas muscles, the quadratus lumborum muscles, and the aponeuroses of the transversus abdominis muscles. Laterally, the abdominal wall is formed above by the lower part of the thoracic wall, including the lungs and pleura, and below by the external oblique, internal oblique, and transversus abdominis muscles.

Anterior and Lateral Abdominal Wall

The general layers of the anterolateral abdominal wall from the outside in are the skin, superficial fascia, deep fascia, abdominal muscles with their fascia, transversalis fascia, extraperitoneal fat, and parietal peritoneum.

Skin

The skin is the outermost layer. The course of the connective bundles of the corium form lines of cleavage (Langer's lines of minimal tension) in the skin. These natural lines of cleavage in the skin are constant and run almost horizontally around the

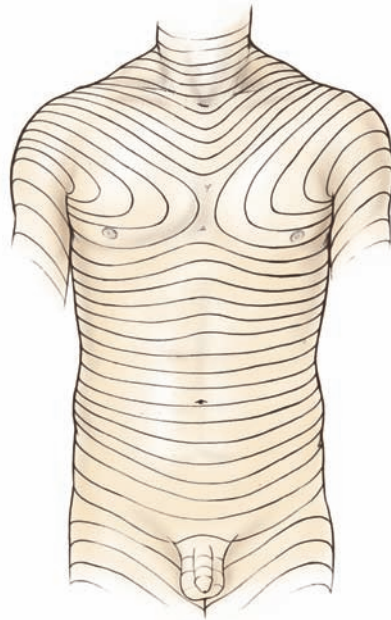


Figure 6.36

trunk. This is important clinically because an incision along a cleavage line will heal as a narrow scar, whereas one that crosses these lines will heal as a wide scar.

Superficial Fascia

The superficial fascia may be divided into a superficial fatty layer and a deep membranous layer. The fatty layer of superficial fascia is called Camper's fascia. The deeper portion of the subcutaneous tissue contains more fibrous elements and forms a membranous fascial layer called Scarpa's fascia.

Muscles of Anterior and Lateral Abdominal Walls

The muscles of the anterior and lateral abdominal walls include the external oblique, the internal oblique, the transversus, the rectus abdominis, and the pyramidalis muscles.

External Oblique

The external oblique muscle is a broad, thin, muscular sheet that arises from the outer surfaces of the lower eight ribs and fans out to insert into the xiphoid process, the linea alba, the pubic crest, the pubic tubercle, and the anterior half of the iliac crest. A triangular defect in the external oblique aponeurosis, known as the superficial inguinal ring, lies immediately above and medial to the pubic tubercle. The spermatic cord (or round ligament of the uterus) passes through this opening and carries the external spermatic fascia (or the external covering of the round ligament

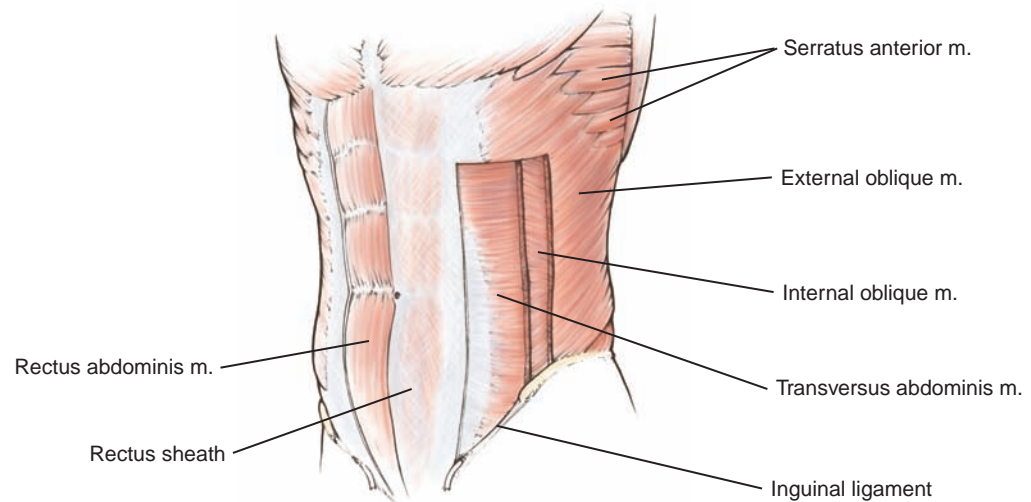


Figure 6.37

of the uterus) from the margins of the ring. Between the anterior superior iliac spine and the pubic tubercle, the lower border of the aponeurosis is folded backward on itself, forming the inguinal ligament. The external oblique aponeurosis is different from the fascia of Gallaudet.

Internal Oblique

The internal oblique muscle is a broad, thin, muscular sheet that lies deep to the external oblique muscle. The majority of its fibers run at right angles to those of the external oblique muscle. It arises from the lumbar fascia, the anterior two thirds of the iliac crest, and the lateral two-thirds of the inguinal ligament. The muscle fibers radiate as they pass upward and forward. The muscle is inserted into the lower borders of the lower three ribs and their costal cartilages, the xiphoid process, the linea alba, and the symphysis pubis. The internal oblique muscle has a lower free border that arches over the spermatic cord (or round ligament of the uterus) and then descends behind it to be attached to the pubic crest and the pectineal line.

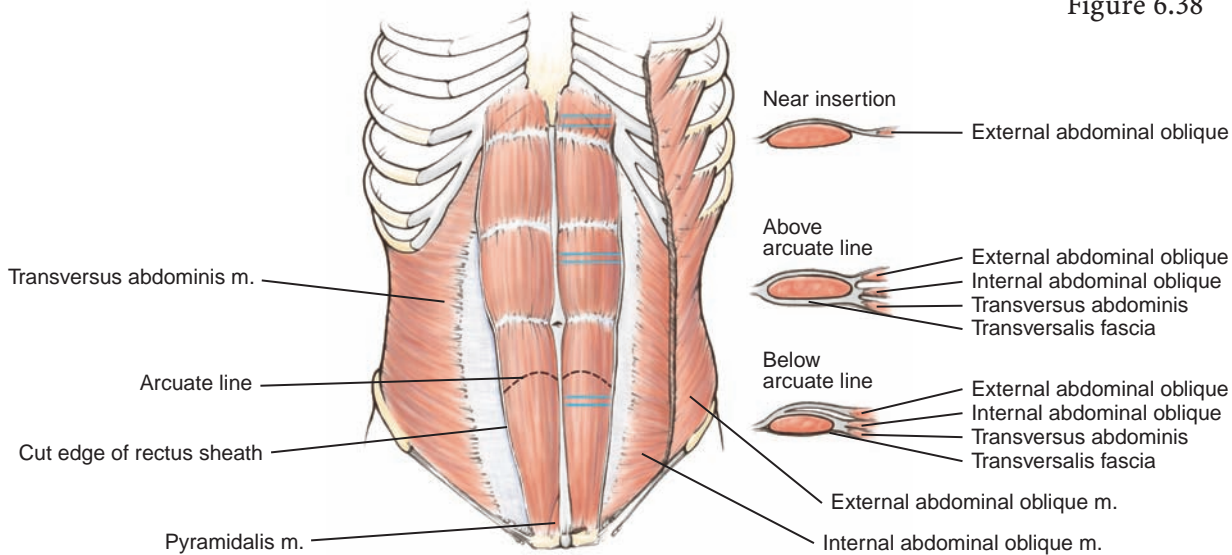
Near their insertion, the lowest tendinous fibers are joined by similar fibers from the transversus abdominis muscle to form the conjoint tendon.

As the spermatic cord passes under the lower border of the internal oblique muscle, it carries with it some of the muscle fibers that are called the cremaster muscle.

Transversus

The transversus abdominis muscle is a thin sheet of muscle that lies deep to the internal oblique muscle, and its fibers run horizontally forward. It arises from the deep surface of the lower six costal cartilages, lumbodorsal fascia, anterior two thirds of the iliac crest, and lateral third of the inguinal ligament. The muscle inserts into the xiphoid process, the linea alba, and the symphysis pubis.

Figure 6.38



Rectus Abdominis

The rectus abdominis muscles are paired long strap muscles that extend vertically along the whole length of the anterior abdominal wall. They are broader above and lie close to the midline, separated from each other by the linea alba. The rectus abdominis muscle arises from two heads, from the front of the symphysis pubis and from the pubis crest. It inserts into the fifth, sixth, and seventh costal cartilages and the xiphoid process. When the rectus abdominis muscle contracts, its lateral margin forms a palpable and visible curved ridge known as the linea semilunaris. The anterior surface of the muscle is crossed by three tendinous intersections, at the tip of the xiphoid, at the umbilicus, and halfway between the two. These intersections are strongly attached to the anterior wall of the rectus sheath. The rectus abdominis muscle is enclosed between the aponeuroses of the external oblique, the internal oblique, and the transversus abdominis muscles, which form the rectus sheath.

The pyramidalis muscle is a triangular muscle, and many a time, it is absent. When present, the muscle arises from the anterior surface of the pubis and inserts into the linea alba. It lies in front of the lower part of the rectus abdominis muscle.

Rectus Sheath

The rectus sheath is a long sheath that encloses the rectus abdominis muscle and pyramidalis muscle (if present) and contains the anterior rami of the lower six thoracic nerves and the superior and inferior epigastric vessels and lymphatic vessels. It is formed largely by the aponeuroses of the three lateral abdominal muscles.

Between the costal margin and the level of the anterior superior iliac spine, the aponeurosis of the internal oblique splits to enclose the rectus muscle; the external oblique aponeurosis is directed in front of the muscle, and the transversus aponeurosis

is directed behind the muscle. Between the level of the anterior superior iliac spine and the pubis, the aponeuroses of all three muscles form the anterior sheath. The posterior sheath is absent, and the rectus muscle lies in contact with the fascia transversalis. Finally, in front of the pubis, the origin of the rectus muscle and the pyramidalis (if present) is covered anteriorly by the aponeuroses of all three muscles. The posterior wall is formed by the body of the pubis.

At the point the aponeuroses forming the posterior wall pass in front of the rectus at the level of the anterior superior iliac spine, the posterior wall has a free, curved lower border called the arcuate line. At this site the inferior epigastric vessels enter the rectus sheath and pass upward to anastomose with the superior epigastric vessels. The rectus sheath is separated from the rectus muscle on the opposite side by the linea alba.

Transversalis Fascia

The next layer of the abdominal wall is the transversalis fascia, which lines the abdominal cavity somewhat like the peritoneum. The transversalis fascia is thicker in the lower half of the abdomen, especially below the arcuate line, where the posterior rectus sheath is absent. The portion of the fascia beneath the rectus muscle is so closely attached to the overlying posterior rectus sheath that the rectus sheath, peritoneum, and the transversalis fascia form one layer. Lateral to the posterior rectus sheath the transversalis fascia is loosely attached to the transversus abdominis, quadratus lumborum, and psoas muscles. Thus, this extraperitoneal plane can be dissected to expose the kidney, ureters, vena cava, and aorta.

Extraperitoneal Fat

This layer consists of loose areolar fibrous fatty tissue that lies between the overlying transversalis fascia and the underlying parietal peritoneum. The falciform ligament is a fold of the parietal peritoneum, which contains extraperitoneal fat and paraumbilical blood vessels.

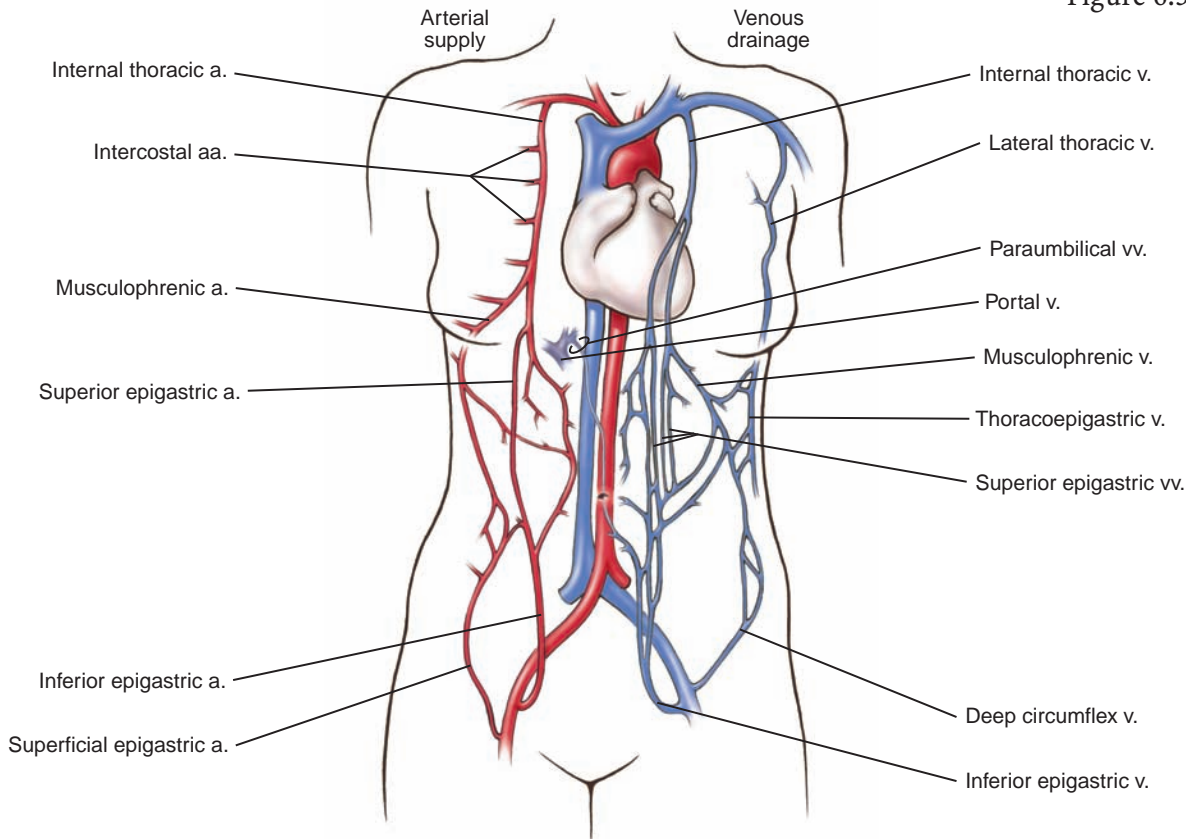
Peritoneum

The parietal peritoneum is the innermost layer of the abdominal wall and is reflected onto the various viscera to form the visceral peritoneum. The peritoneum has little strength and can tear easily.

Blood Supply

Cutaneous arteries, which are branches of the superior and inferior epigastric arteries, supply the area near the skin in the midline. Branches from the intercostal, lumbar, and deep circumflex iliac arteries supply the skin over the flank.

Figure 6.39



The venous blood is collected into a network of veins that radiates out from the umbilicus. The network is drained above into the axillary vein via the lateral thoracic vein and below into the femoral vein via the superficial epigastric vein. The lumbar veins drain the midabdominal and flank areas. A few small veins, the paraumbilical veins, connect the network through the umbilicus and along the ligamentum teres to the portal vein. They form an important portosystemic venous anastomosis.

The anterolateral abdominal wall receives its arterial blood supply from the last six intercostal and four lumbar arteries, the superior and inferior epigastric arteries, and the deep circumflex iliac arteries. The lower six intercostal arteries and the four lumbar arteries pass forward between the muscle layers and supply the lateral part of the abdominal wall.

The superior epigastric artery, one of the terminal branches of the internal thoracic (mammory) artery, enters the upper part of the rectus sheath between the sternal and costal origins of the diaphragm. It descends behind the rectus muscle, supplying the upper central part of the anterior abdominal wall, and anastomoses with the inferior epigastric artery.

The inferior epigastric artery is a branch of the external iliac artery just above the inguinal ligament. It runs upward and medially along the medial side of the deep inguinal ring and passes through the transversalis fascia to enter the rectus sheath anterior to the arcuate line. After ascending behind the rectus muscle to supply the

lower central part of the anterior abdominal wall, the inferior epigastric artery anastomoses with the superior epigastric artery.

The deep circumflex iliac artery is a branch of the external iliac artery just above the inguinal ligament. It runs upward and laterally toward the anterior superior iliac spine and then continues along the iliac crest to supply the lower lateral part of the abdominal wall.

Lymphatic Drainage

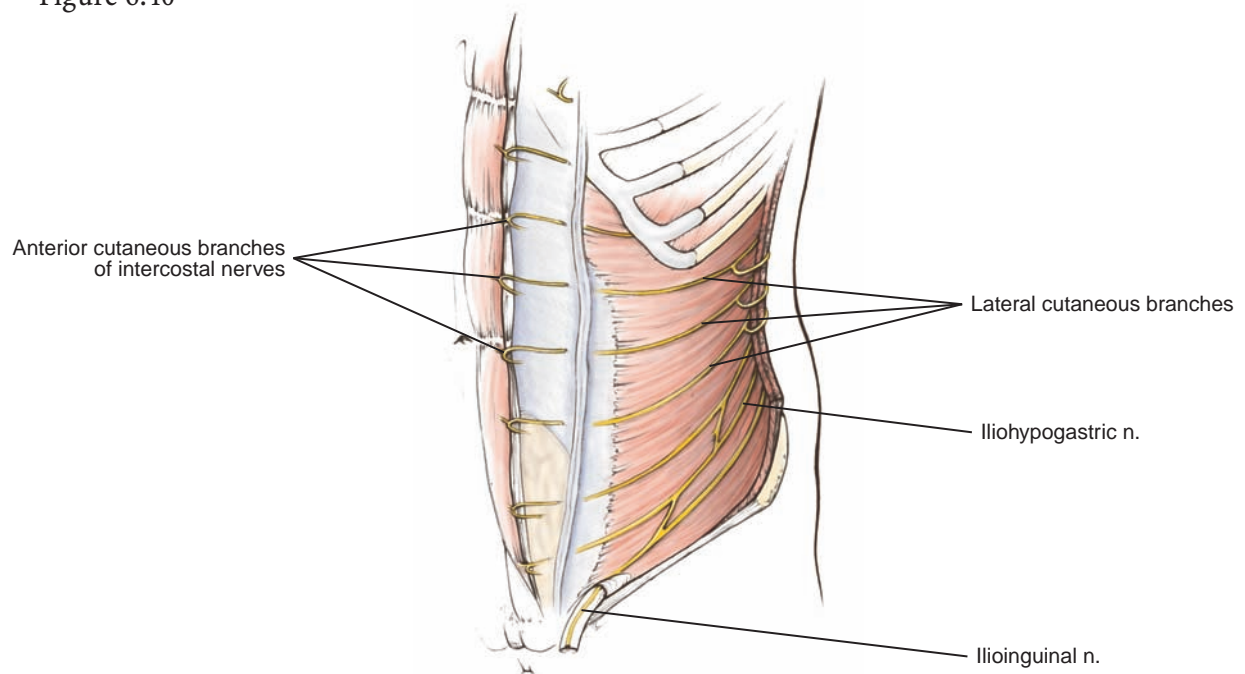
The cutaneous lymph vessels above the level of the umbilicus drain upward into the anterior axillary lymph nodes. The vessels below this level drain downward into the superficial inguinal nodes. The deep lymph vessels follow the arteries and drain into the internal thoracic, external iliac, posterior mediastinal, and para-aortic (lumbar) nodes.

Nerve Supply

The cutaneous nerve supply to the anterior abdominal wall is derived from the anterior rami of the lower six thoracic and first lumbar nerves. The dermatome of T7 is situated in the epigastrium just over the xiphoid process, T10 includes the umbilicus, and L1 lies just above the inguinal ligament and the symphysis pubis.

Each nerve passes forward in the interval between the internal oblique and transversus abdominis muscles to supply the skin of the anterior abdominal wall, the muscles, and the parietal peritoneum. The lower six thoracic nerves then pierce the posterior wall of the rectus sheath to supply the rectus muscle and the pyramidalis. Each nerve then terminates by piercing the anterior wall of the rectus sheath

Figure 6.40



and supplies the skin. The first lumbar nerve does not enter the rectus sheath but gives off contributions to both the iliohypogastric nerve, which pierces the external oblique aponeurosis above the superficial inguinal ring, and the ilioinguinal nerve, which emerges through the inguinal ring. Both the ilioinguinal and iliohypogastric nerves end by supplying the skin just above the inguinal ligament and the symphysis pubis.

Surgical Applications

The importance of selecting the proper incision for a cancer operation cannot be underestimated. A badly placed incision without the option for extension may compromise the ability for a complete and margin-free tumor resection. The incision must give ready and direct access to the anatomy to be investigated and provide adequate space to perform the indicated operation. Once the proper incision is made, exposure of the operative field is maximized by carefully placed retractors and correct positioning of the operative table. The incision should be extendible in the direction that will allow for the possible enlargement of the scope of the operation.

Abdominal incisions can be roughly divided into vertical and transverse incisions. All abdominal incisions have some degree of pulmonary physiology impairment. In the 1940s it was noted that pulmonary complications occurred four times more frequently in patients with a vertical, compared with transverse, abdominal incisions. Also, upper abdominal incisions were shown to have marked effects on pulmonary physiology. However, with the use of epidural catheters and patient-controlled anesthesia for postoperative pain, the effect of the various incisions on pulmonary function has been minimized.

Incisions

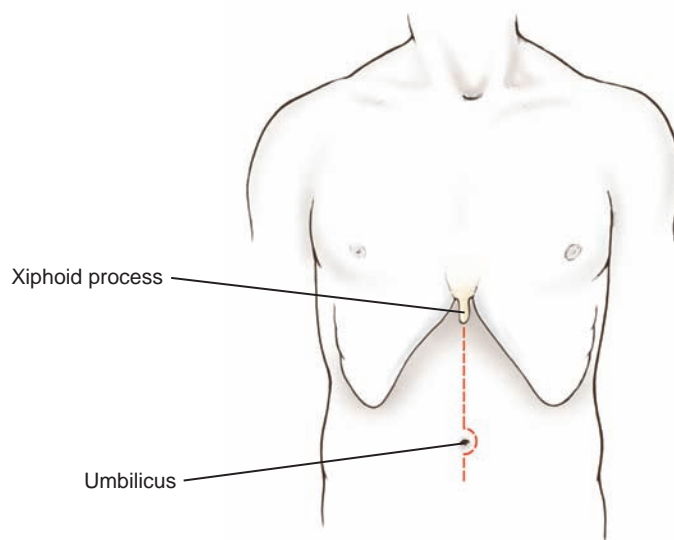


Figure 6.41

Upper Midline Incision

An upper midline incision is a preferred approach of some surgeons for operations involving the stomach. The incision can be extended upward to remove the xiphoid process and provides an excellent operative field for total or partial gastrectomy. It can be extended downward around the umbilicus if necessary. The incision can be made quickly, destroys no nerves, transects no muscles, and is easy to close. The incision is made through the skin from the xiphoid to a few centimeters above the umbilicus. The linea alba is identified, and the decussation of fibers indicates the midline. Dividing the linea alba exposes the extraperitoneal fat, which can be thinned out to reveal the peritoneum. Two clamps are placed on the peritoneum, and upward traction is applied while it is divided to avoid injury to underlying bowel. The falciform ligament is divided and tied.

After the intended operation is completed, the incision is closed. There are many acceptable ways to close this abdominal incision. We generally close this incision with a No. 1 nonabsorbable running suture approximating the linea alba and peritoneum in one layer. Stitches are traditionally placed at least 1 cm in from the edge of the linea alba and move along at a distance of 1 cm. If there is any question about the integrity of the fascia, large interrupted nylon retention sutures can be placed to prevent evisceration.

Lower Midline Incision

A lower midline incision is commonly used for operations to resect pelvic tumors and for surgery on the rectosigmoid colon and other viscera in the pelvis. A urinary bladder catheter is placed before making an incision to prevent injury to the bladder.

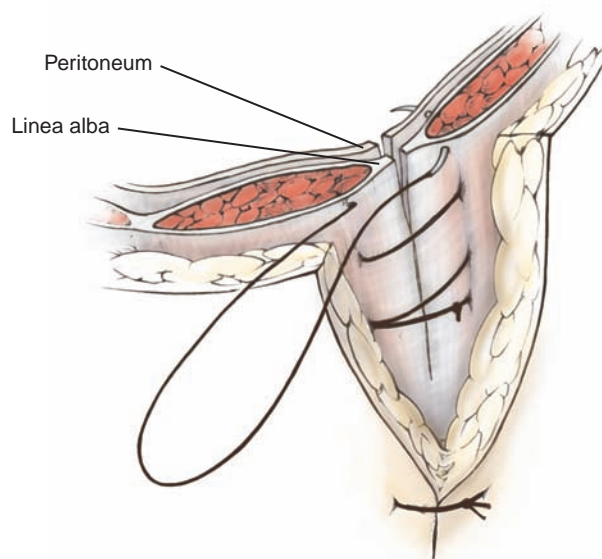


Figure 6.42

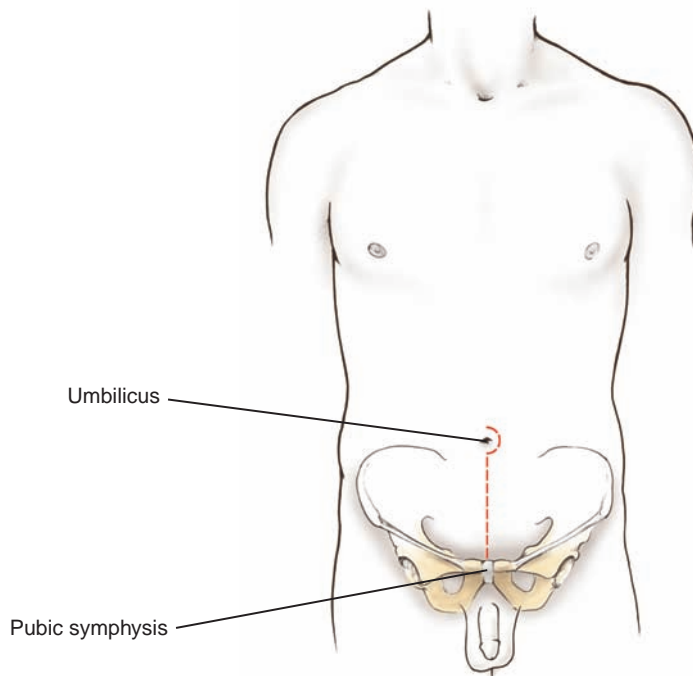


Figure 6.43

An incision is made through the skin and subcutaneous tissue to expose the linea alba, which is narrow below the umbilicus. Often it is easier to divide the fascia in the midline high near the umbilicus and then continue inferiorly to the symphysis pubis. The peritoneum is carefully opened, making sure not to injure underlying bowel. The perivesicle fat is divided out laterally to prevent damage to the bladder. After the operative procedure is completed, the anterior fascia is closed with a No. 1 nonabsorbable suture in a continuous method, which distributes the tension along the suture line evenly.

Transverse Abdominal Incision

A transverse abdominal incision may be used at any level on the abdominal wall and may be made on the right or left. It takes longer to make and is more tedious to close. A transverse midabdominal incision can be used as an alternative to a vertical midline incision for colon surgery. The skin incision is made either 2 cm above or below the umbilicus, depending on where the lesion is located. Dissection is carried down through the subcutaneous tissue to expose the anterior rectus sheath and the external oblique muscle aponeurosis. The anterior rectus sheath is incised and the muscle transected. The external oblique muscle is split in the direction of its fibers. The epigastric vessels are clamped within the rectus muscle to prevent postoperative bleeding. The posterior rectus sheath and peritoneum are incised transversely to open the abdominal cavity. Moving out laterally, the internal oblique and transversus abdominis muscles are split in the direction of their fibers. The incision can be extended either way for more exposure. After the operation the peritoneum,

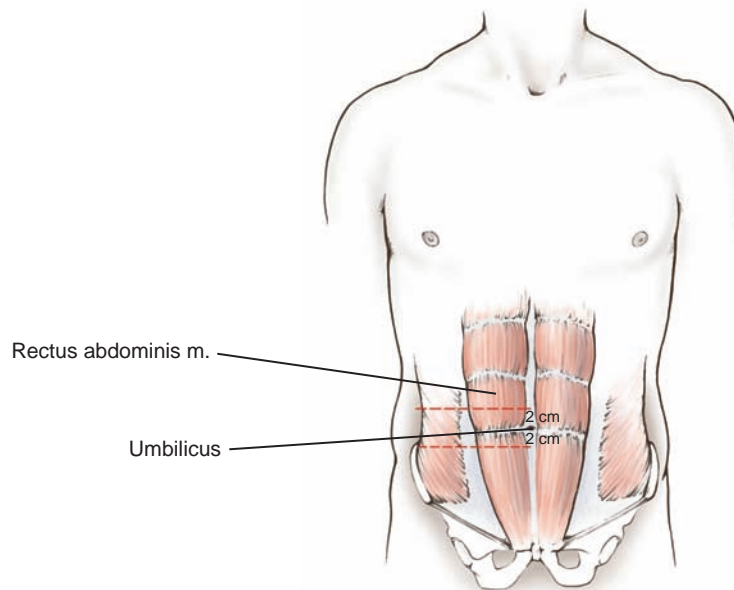


Figure 6.44

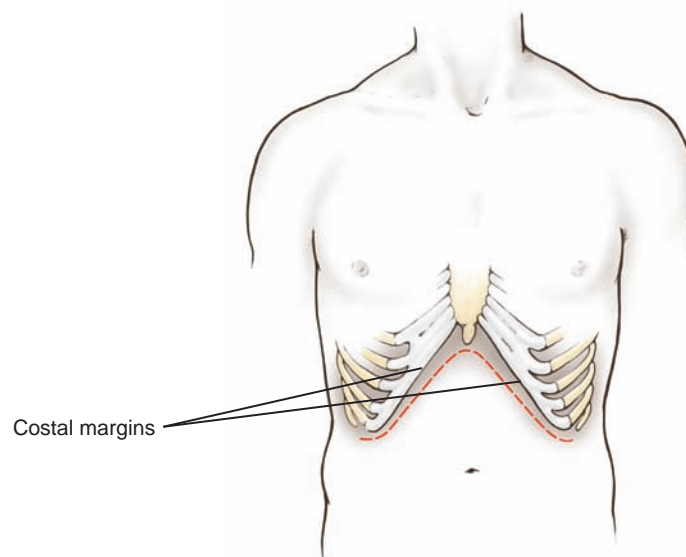


Figure 6.45

transversalis fascia, internal oblique, and posterior rectus fasciae are closed with a continuous 0 absorbable suture. Finally, the external oblique fascia and the anterior rectus fasciae are closed in the same layer with No. 1 nonabsorbable suture.

The bilateral subcostal incision gives excellent exposure to the pancreas, liver, and stomach. An incision is made two fingerbreadths below the right and left costal margins. The right external oblique and right anterior rectus fasciae are incised. The right rectus muscle is transected. The posterior rectus fascia and peritoneum are incised to enter the abdomen. The falciform ligament is divided and ligated. The remaining abdominal wall muscles on the right are divided from medial to lateral.

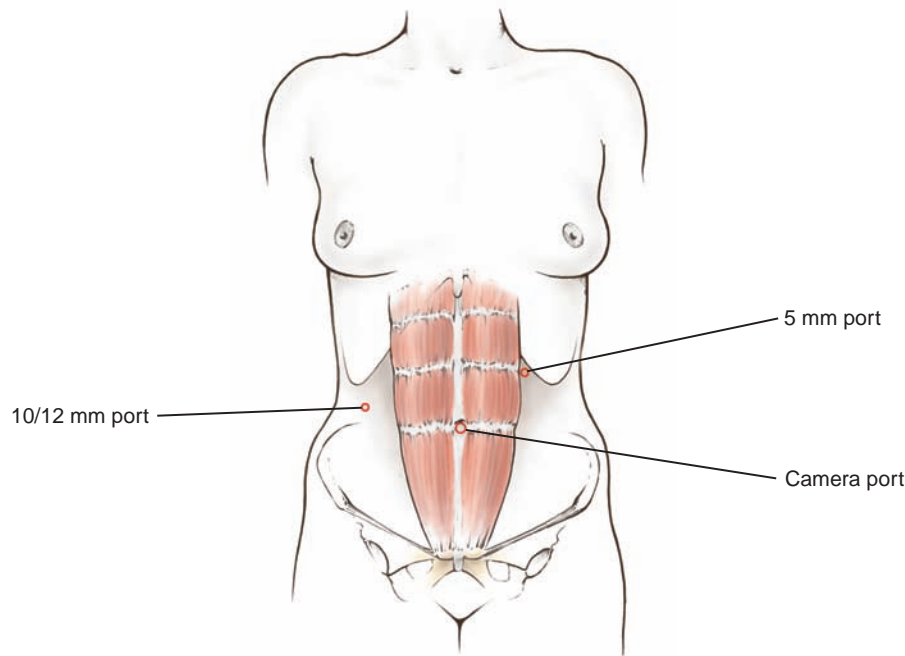


Figure 6.46

The left rectus muscle and left abdominal wall muscles are divided from medial to lateral. After the operation is completed, the abdomen is closed in two layers. The transversus, internal oblique, and posterior rectus sheathes are closed with No. 1 nonabsorbable suture in a continuous fashion. The external oblique and anterior rectus fasciae and the linea alba are closed in another layer in the same continuous fashion.

Laparoscopy is being increasingly used as an important staging modality in a variety of abdominal malignancies. Recent reports have demonstrated that laparoscopy enhances clinical staging for gastric, hepatobiliary, and pancreatic cancer. Laparoscopy can help assess the stage of the primary tumor and detect low-volume peritoneal disease unappreciated on CT scans. The ability of laparoscopic staging to avoid unnecessary exploration clearly identifies its role in gastric and pancreatic cancer. At laparoscopy, 20–25% of patients will be found to have advanced unresectable disease. Patients with gastric cancer without symptoms of obstruction or bleeding who are found to have unsuspected peritoneal disease at laparoscopy are spared open laparotomy. With the success of endoscopic biliary stent placement, a patient with pancreatic cancer found to have unsuspected peritoneal disease at laparoscopy is spared open laparotomy if there are no symptoms of gastric outlet obstruction.

A diagnostic laparoscopy is performed with general anesthesia. It is our personal preference to use an open technique to gain access to the abdomen with a 10-mm Hasson cannula. Both 0 and 30° laparoscopes are used to explore the abdomen. About 250 mL of normal saline solution is instilled into the peritoneal cavity and then

Diagnostic Laparoscopy

aspirated for cytologic examination. If present, intraperitoneal adhesions are divided. One or two 5 mm operating ports may be necessary for biopsy and for taking down adhesions. Any peritoneal nodules are biopsied. The liver is inspected while placing the patient in the reverse Trendelenburg position. A 10/12 mm port can be placed in the right upper quadrant for laparoscopic ultrasonography if it is available. For gastric tumors, the degree of wall penetration, local extension, volume, and fixation can be assessed. Currently trials are under way to examine the role of laparoscopic ultrasonography for detection of small liver lesions and assessment of resectability of pancreatic cancers. Diagnostic laparoscopy is a safe, sensitive, and cost-effective method for detecting occult metastatic disease in patients with gastric, hepatobiliary, or pancreatic cancer.

Laparoscopic Jejunostomy and Gastrostomy

For patients without extensive previous abdominal surgery and who need only a gastrostomy or feeding jejunostomy, a laparoscopic approach may spare them an open procedure. Many companies make laparoscopic gastrostomy and jejunostomy kits.

There are many methods of placing a feeding jejunostomy. One method is to place a Hasson cannula through a small incision below the umbilicus. The patient is placed in the Trendelenburg position. A 5-mm working port is placed in the right middle quadrant. The omentum is reflected superiorly to expose the ligament of Treitz.

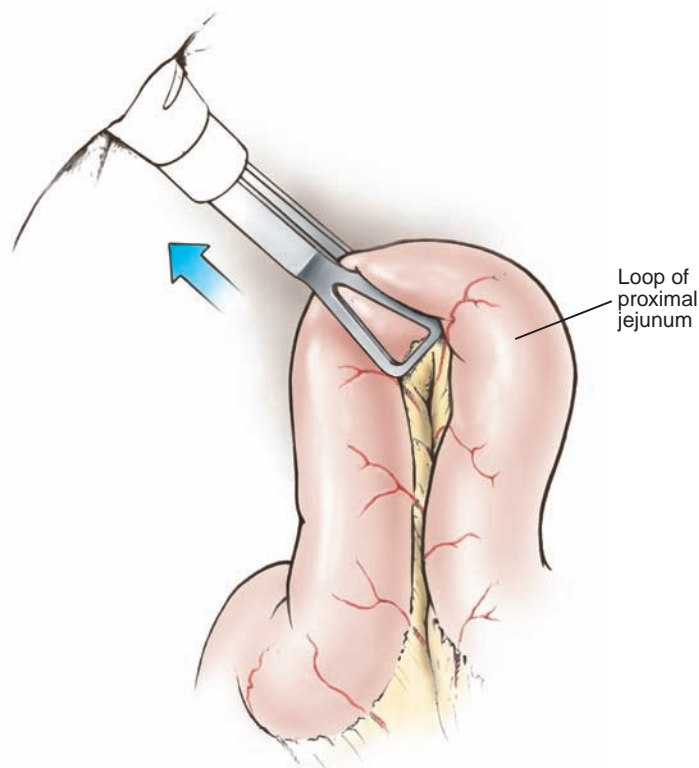


Figure 6.47

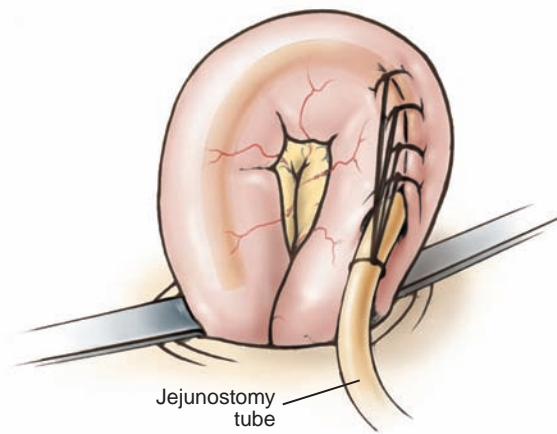


Figure 6.48

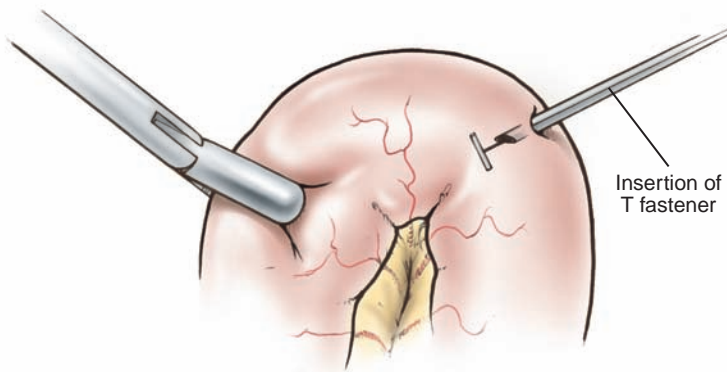


Figure 6.49

The proximal jejunum is followed until a loop of bowel is identified that will easily come up to the abdominal wall.

A small transverse incision is made in the abdominal wall and the jejunum is exteriorized. The jejunostomy tube is brought through the skin just below the skin incision and inserted into the jejunum in the standard fashion. The jejunum is tacked to the abdominal wall, and the incision is closed.

Another method, described by Way et al., is to use a percutaneous technique with T fasteners to pull the jejunum up to the abdominal wall.

A percutaneous introduction needle is then used to cannulate the jejunum, and a wire is passed into the bowel. Air can be insufflated into the bowel to confirm intraluminal placement of the needle before passing the wire. A series of dilators are passed under direct vision. The peel-away dilator is placed and the wire and dilator removed.

The jejunostomy is placed, and the balloon is inflated with 3–5 mL of saline solution. The jejunostomy is pulled snug to the abdominal wall. The T fasteners are tied securely to each other. The tube is irrigated to check its patency.

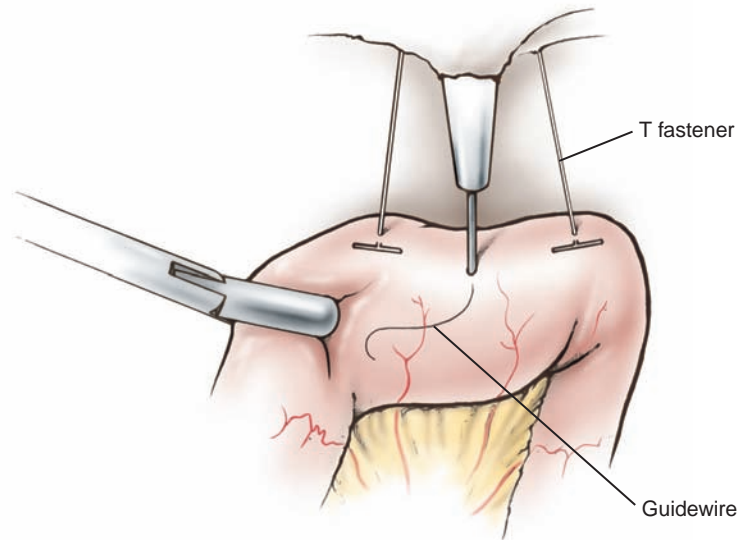


Figure 6.50

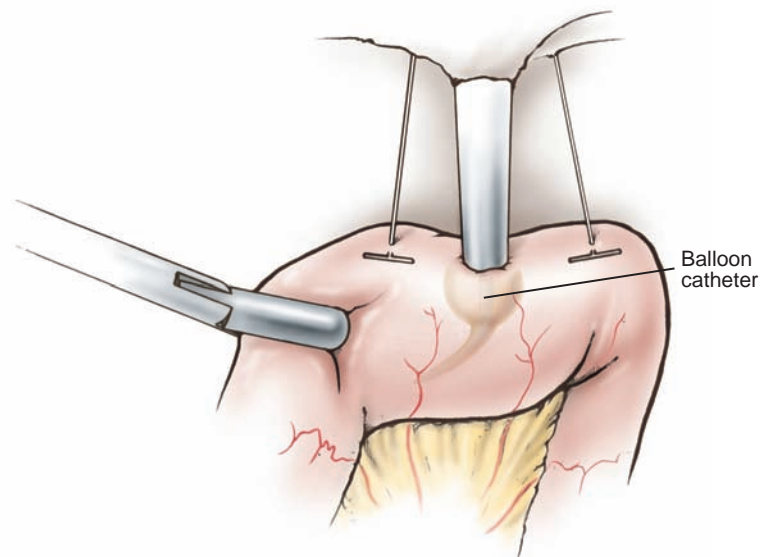


Figure 6.51

To perform a gastrostomy a Hasson cannula is placed through a small incision at the umbilicus. The laparoscope is placed through this cannula and the stomach is identified. A 5-mm working port is placed under direct vision in the right middle quadrant. The body of the stomach is brought up to the abdominal wall with a grasper to identify placement of the tube. A needle is placed percutaneously through the identified point for the tube and then into the anterior wall of the body of the stomach. Using the Seldinger technique, a wire is placed through the needle and into the body of the stomach. A series of dilators are inserted over the wire, followed by the gastrostomy tube. The balloon is inflated in the gastrostomy tube. The stomach is

then tacked up to the abdominal wall with 3-0 silk intracorporeal sutures or with T fasteners, as described for the jejunostomy. Another option to secure the stomach to the abdominal wall is to take a 3-0 nylon suture on a Keith needle, place it through the skin, grasp it with a needle holder inside the abdomen, and place it through the stomach wall near the tube and then back out through the skin. The suture is tied extracorporeally over a cotton roll.

Laparoscopic Ileostomy and Colostomy

One hundred thousand patients undergo stoma surgery in the United States annually. Complications can be minimized by carefully selecting the stoma site, through adequate mobilization, avoiding tension on the bowel and maintaining the blood supply to the exteriorized segment. Many of these patients have end-stage cancer, and sparing them an open procedure could decrease their chances for complications. An ileostomy and transverse or sigmoid colostomy can all be done using a laparoscopic technique.

For optimal placement of stomas, enterstomal nurses mark the sites before surgery.

The operative technique for ileostomy involves placing a Hasson cannula in the usual periumbilical position after the induction of general anesthesia and placement of a Foley catheter and nasogastric tube. A laparoscopic Babcock clamp is used to grasp the small intestine through a 10-mm port placed through a preoperatively marked stoma site. A 5-mm port can be placed in the left lower quadrant if further dissection is required. The ileocecal valve is identified, and the distal ileum is followed proximally until a loop of bowel is identified that can be exteriorized without tension.

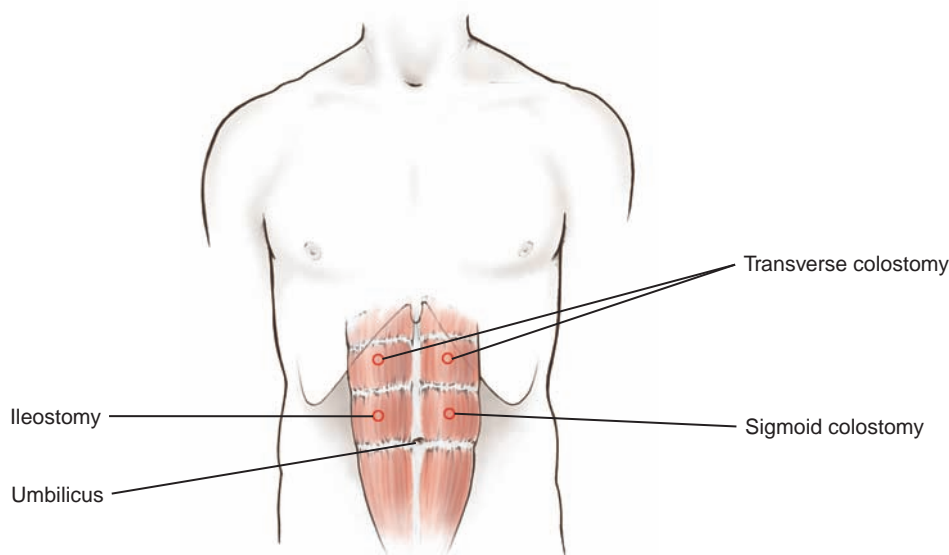


Figure 6.52

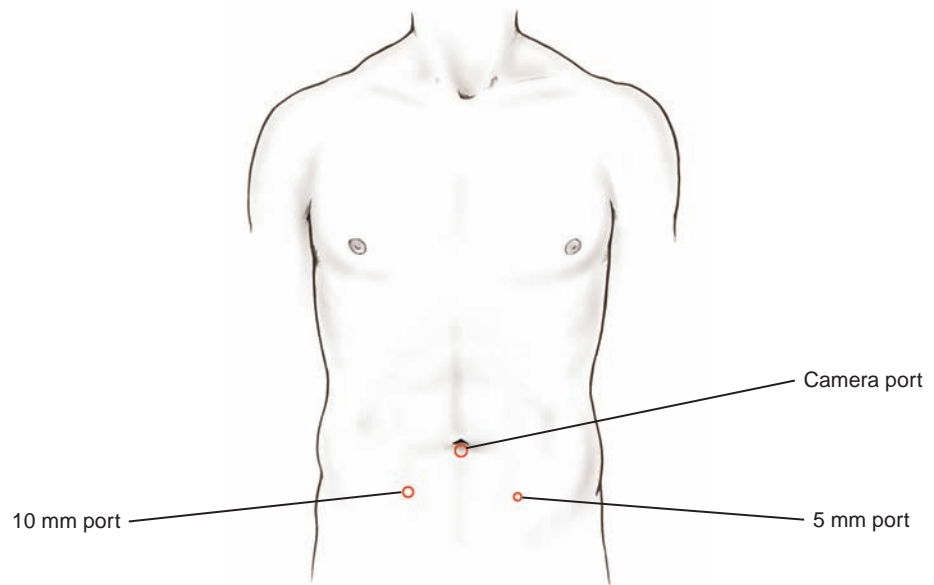


Figure 6.53

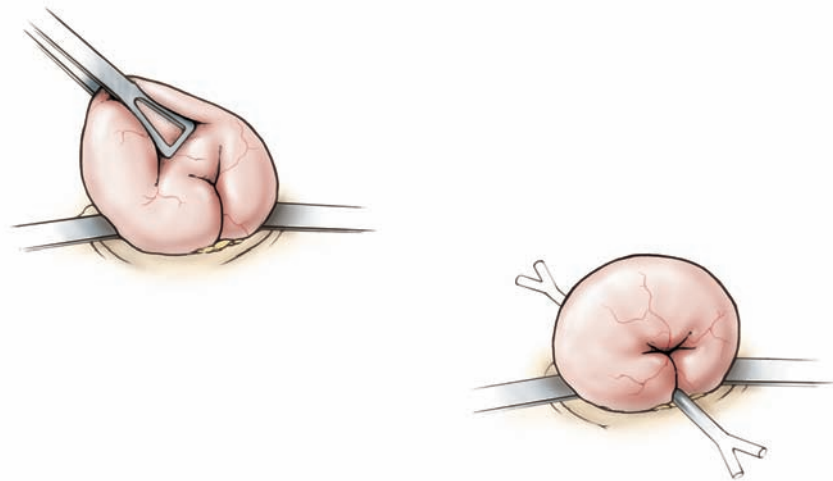


Figure 6.54

The bowel is brought out through a small incision, and the stoma is matured using the standard open Brooke method.

A transverse or sigmoid colostomy can be accomplished using a laparoscopic approach. Most of these are loop colostomies done for palliation of downstream obstruction.

For a transverse colostomy, the laparoscope is placed through a 10-mm Hasson cannula in the middle right quadrant. One or two 5-mm ports are placed to enable grasping the greater omentum in a cephalad direction.

With the weight of the transverse colon acting as countertraction, the omentum is dissected off the colon and brought up as the colostomy. This dissection is done through a 10-mm port placed through the stoma site.

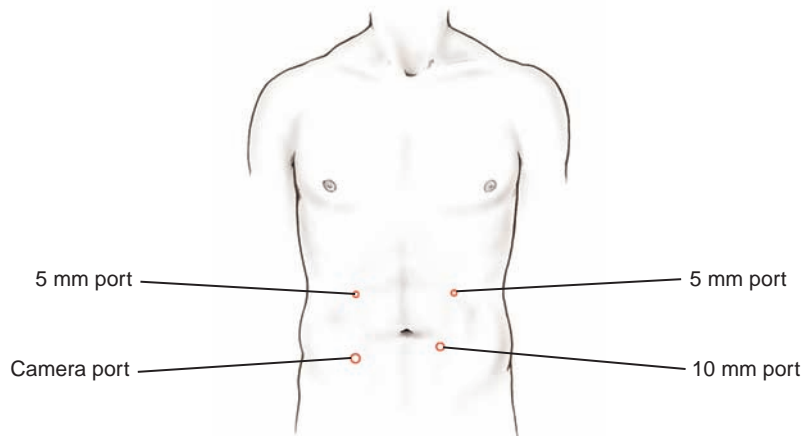


Figure 6.55

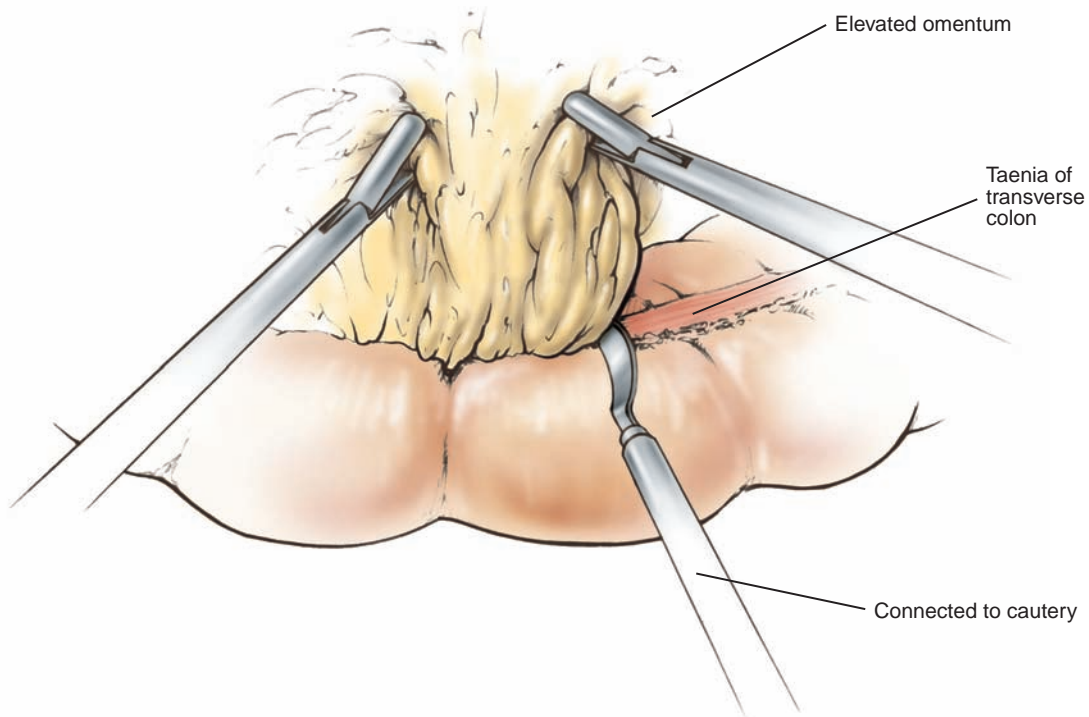


Figure 6.56

When the bowel has been sufficiently mobilized, it is brought up through the port site for the stoma. A similar technique is used for sigmoid colostomy. The Hasson cannula is placed in the umbilicus or middle right quadrant. The sigmoid colon is identified and mobilized along the white line of Toldt. A 10-mm port is placed through the stoma site for retraction of the colon.

Once the mobilization is complete, a small incision is made around the port, the bowel is externalized, and the colostomy is matured.

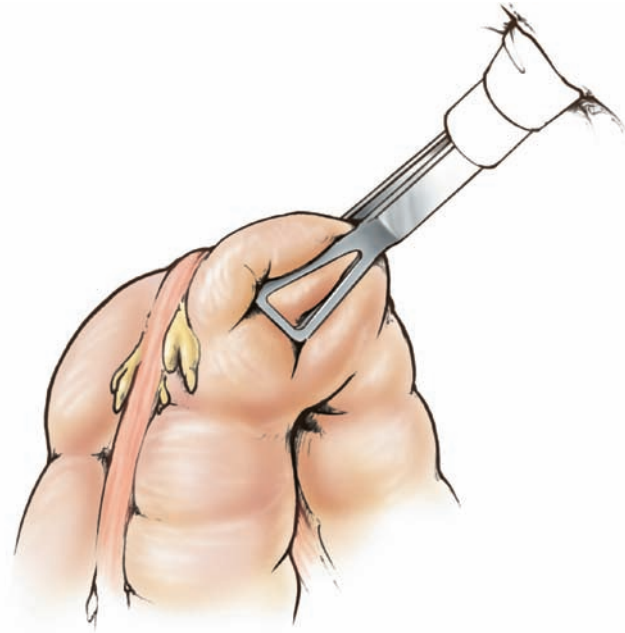


Figure 6.57

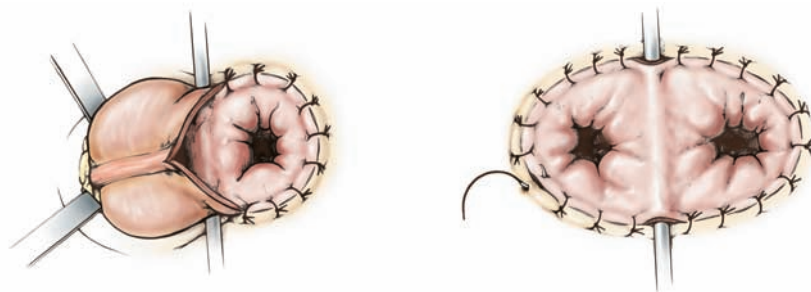


Figure 6.58

Anatomic Basis of Complications

- Major** • Inadequate closure of the anterior fascia may result in a dehiscence or evisceration.
- Minor** • Inadequate ligation and identification of the epigastric blood vessels during a transverse abdominal incision may result in a postoperative rectus sheath hematoma.

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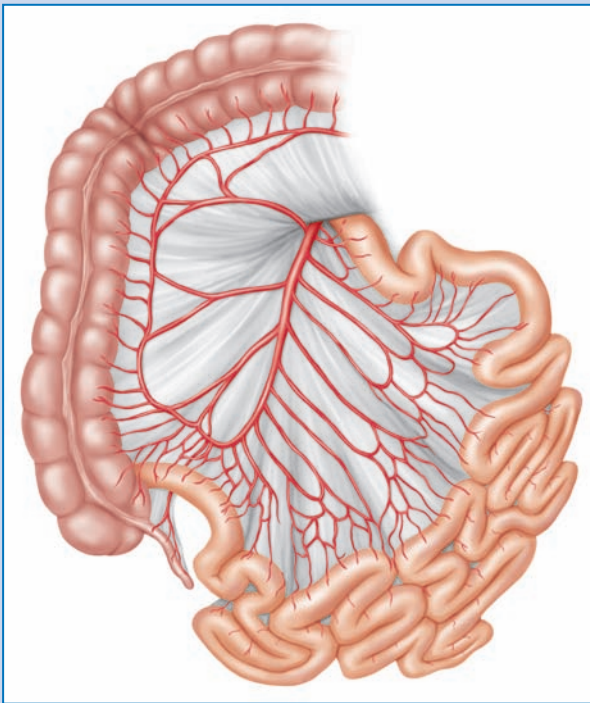
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Small Bowel and Mesentery

John E. Skandalakis



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Small Bowel and Mesentery

Benign and malignant tumors of the jejunum are rare (Turner and Bass). Despite its length and large absorptive mucosal stroma (more than 90% of the mucosal surface area of the gastrointestinal tract), only 5% of all gastrointestinal neoplasms (Evers) and 1–2% of all gastrointestinal malignancies develop in the small bowel and mesentery (Whang et al.). However, approximately two-third of these neoplasms are malignant (Rustgi). An annual estimate of 5,100 cases of small intestine cancer, with 1,340 deaths, was issued for the United States in 2006 by the American Cancer Society (Gore et al.).

Zeh stated, “Cancer arising in the small intestine presents significant diagnostic and therapeutic challenges to the cancer clinician because (1) it is not a single pathologic entity but rather a diverse group of histologically benign and malignant tumors; (2) it is relatively rare, making collection, collation, and analysis of epidemiologic data, as well as treatment outcomes, difficult; and (3) it usually presents with vague or non-specific symptoms, making early diagnosis difficult.”

Both benign and malignant leiomyomas and leiomyosarcomas occur, and primary lymphomas and metastatic melanomas to the small bowel are other neoplastic sources of bleeding, intussusception, or obstruction. Metastases account for approximately 50% of all small bowel neoplasms.

Surgical Anatomy

Topography

The intestinal wall is composed of a serosa of visceral peritoneum (muscularis obliquus externa) with longitudinal and circular muscle, a submucosa of connective tissue, and a mucosa of connective tissue, smooth muscle (lamina muscularis mucosae), and epithelium. The plicae circulares of the small intestine are the most obvious in the jejunum. The jejunal villi are more distinct when compared with the ileal villi; they are long, tongue-shaped, or finger-like projections, while the ileal villi are shorter and blunter and disappear gradually toward the ileocecal valve.

Almost a century ago, Halsted pointed out the importance of the submucosal connective tissue in holding sutures. Fear of perforating the mucosa with a stitch makes seromuscular sutures seem safer, but the integrity of an anastomosis is greater if the submucosa is included.

The serosa surrounds the jejunum and ileum completely. Together with the muscular coat, the serosa is the well-known stroma for the application of seromuscular sutures during surgical procedures. The muscular coat is formed by the inner circular and outer longitudinal layers. It should be considered, at least surgically, one layer. It is responsible for intestinal motility and contains the myenteric plexus of Auerbach as well as the ganglia for non-myelinated nerve fibers.

The submucosa is the home of the very rich network of the neuronal elements of Meissner's plexus, as well as arteries, veins, and lymphatic vessels. It also hosts Peyer's patches of isolated and confluent masses of lymphatic nodules in the antimesenteric side of the ileum.

Sixty percent of the length of the gastrointestinal tract is composed of the small bowel. This small intestine performs 90% of the absorption.

The superior mesenteric artery arises from the aorta below the origin of the celiac trunk. About 1% of persons have a combined celiacomesenteric trunk (Yi et al.). The celiac, superior, and inferior mesenteric arteries are the remnants of the paired vitelline arteries of the embryo. The superior mesenteric artery continues beyond the ileal border to supply Meckel's diverticulum, if one is present.

On average, the left side of the superior mesenteric artery gives origin to five intestinal arteries above the origin of the ileocolic artery and 11 arteries below that level. The intestinal vessels branch a few centimeters from the border of the intestine to form a series of arterial arcades. These arcades connect the intestinal arteries with

Blood Supply

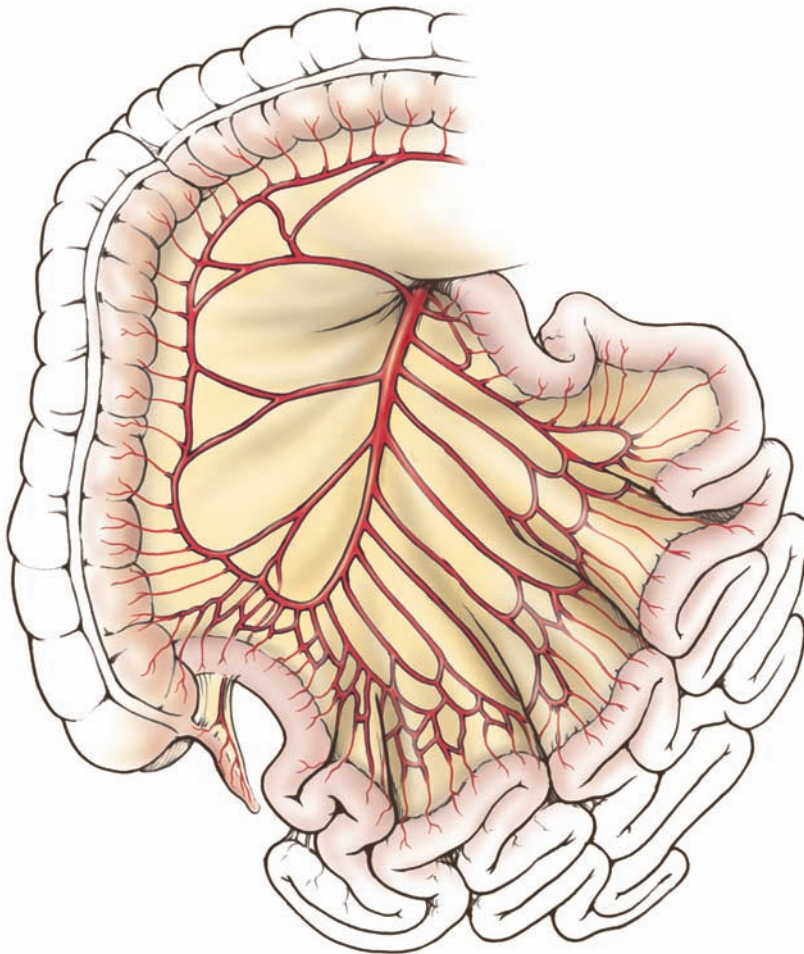


Figure 7.1

one another. Their number increases from one to three in the proximal jejunum to three to five in the ileum. From the arches of these arcades, the vasa recta arise and pass without branching into the intestinal wall. There they branch but do not anastomose before piercing the muscularis externa. This provides the most oxygenated blood to the mesenteric side of the bowel wall and the least to the antimesenteric border. There is a plexus of vessels in the submucosa from which short vessels reach the mucosa and villi. This is the only area of anastomosis distal to the arcades in the mesentery.

The vascular arches form the primary anastomoses of the arterial supply. A complete channel may exist from the posteroinferior pancreaticoduodenal artery, which is parallel with the intestine and joins the marginal artery (of Drummond) of the colon. In some persons the pathway is incomplete, usually at the end of the ileum. From the arches of the arcades, numerous arteries (the vasa recta) arise and pass (without cross-communication) to enter the intestinal wall.

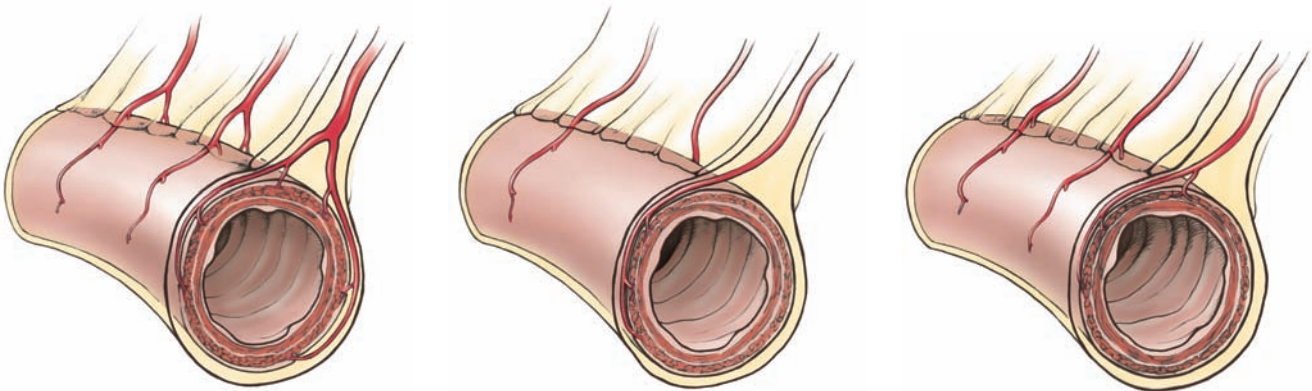
The vasa recta may divide into two short vessels to the mesenteric side of the intestine and two long vessels that supply the rest of the intestinal wall. More frequently, a single long vessel supplies one side of the intestine, alternating with a vessel supplying the other side. A single long and short vessel may serve one side only. Other combinations of paired or single, and long and short vessels are possible.

The vasa recti branch, but do not anastomose, beneath the serosa before piercing the muscularis externa. There is no collateral circulation between the vasa recti or their branches at the surface of the intestines. This configuration provides the best supply of oxygenated blood to the mesenteric side of the intestine and the poorest supply to the antimesenteric border.

If we accept that there is no collateral circulation beyond the terminal arcades (in other words, no communication between the vasa recti or within the intramural network), the blood supply of the antimesenteric border of the small bowel is relatively poor.

Within the intestinal wall, the arteries form a large plexus in the submucosa. From this plexus, short vessels reach the lamina propria to supply a network of capillaries around the intestinal crypts, and longer arteries supply the cores of the

Figure 7.2



intestinal villi. Thus, there are two regions of anastomoses of intestinal arteries: the extramural arches between the intestinal arteries and the intramural submucosal plexus.

One or more small veins originate near the tip of each intestinal villus and travel outward, receiving contributions from a plexus of veins around the intestinal glands. They enter the submucosal plexus. This is drained through the muscular layer by larger veins traveling with the arteries in the mesentery to reach the superior mesenteric vein. These intestinal veins are interconnected by venous arcades that are similar to, but less complex than, the accompanying arterial arcades.

The innervation of the jejunum and ileum is by the autonomic system. However, pain secondary to small bowel disease is referred to the ninth, tenth, and eleventh thoracic nerves, and usually is periumbilical.

Lymphatic vessels (lacteal vessels) arise in the cores of the intestinal villi and form plexuses at the base of the villi, the base of the crypts, the muscularis mucosa, the submucosa, and between the circular and longitudinal layers of the muscularis externa. This series of plexuses is drained by large lymphatic vessels that travel in the mesentery with the arteries and veins. The lymph flows to nodes residing between the leaves of the mesentery. More than 200 small mesenteric nodes lie near the vasa recta and along the intestinal arteries. Drainage from these is finally to the large, superior mesenteric lymph nodes at the root of the mesentery. Efferent vessels from these and the celiac nodes form the intestinal lymphatic trunk. This trunk passes beneath the left renal artery and ends in the left lumbar lymphatic trunk (70%) or the cisterna chyli (25%).

Intramural

- Lacteal vessels
- Mucosal vessels
- Submucosal plexus
- Subserosal plexus

Extramural

- Vasa recti
- Lymph nodes along the mesenteric vessels
- Lymph nodes along superior mesenteric artery and celiac artery
- Cisterna chyli

From the gastroduodenal junction to the ileocecal junction, the small bowel is the home of rare, benign and malignant tumors. Because of the differences in anatomic topography of the duodenum and the jejunoileum, the surgical techniques for treatment of duodenal and jejunoileal tumors are discussed separately.

Nerve Supply

Lymphatic Drainage

Small Bowel Lymphatic Pathways

Neoplasms

Comparison of Jejunum and Ileum

Jejunum	Ileum
Wall thicker	Wall thinner
Lumen larger	Lumen smaller
Fat on mesentery	Fat on ileum and mesentery
Prominent plicae circulares	Less prominent plicae
Single line of arterial arcades	Several lines of arterial arcades
Aggregate lymph nodules (Peyer's patches) sparse	Aggregate lymph nodules frequent

Zeh commented on current knowledge of gastrointestinal stromal tumors (GIST): “[A] paradigm shift has occurred in our understanding and treatment of mesenchymal tumors arising in the small intestine. It is now recognized that a vast majority of the tumors that had been previously identified as leiomyoma and leiomyosarcoma are actually CD 117-positive GIST. In fact, GISTs are now thought to be the most

Table 7.1 Distribution of malignant tumors of the small bowel by site in 10 case series

Tumors by anatomic site (<i>n</i>)				
Tumor type	Duodenum	Jejunum	Ileum	Total (<i>n</i>)
Adenocarcinoma	177	111	54	342
Carcinoid	14	33	132	179
Lymphoma	13	61	56	130
GIST	13	34	32	79
Total	217	239	274	730

GIST gastrointestinal stromal tumor

From Horton KM, Fishman EK. Clinical aspects and management of small bowel and appendiceal cancers: diagnostic and staging procedures. In: Abbruzzese JL, Evans DB, Willet CG, Fenoglio-Preiser C, editors. *Gastrointestinal oncology*. New York: Oxford; 2004. p. 570

Table 7.2 Distribution of benign tumors of the small bowel by site in 17 case series

Tumors by anatomic site (<i>n</i>)				
Tumor Type	Duodenum	Jejunum	Ileum	Total (<i>n</i>)
Leiomyoma	31	74	57	162
Adenoma	59	19	18	96
Lipoma	20	15	36	71
Hemangioma	2	10	27	39
Fibroma	5	7	13	25
Hamartoma	3	9	6	18
Brunner's gland	14	0	0	14
Other	45	13	17	75

From Horton KM, Fishman EK. Clinical aspects and management of small bowel and appendiceal cancers: diagnostic and staging procedures. In: Abbruzzese JL, Evans DB, Willet CG, Fenoglio-Preiser C, editors. *Gastrointestinal oncology*. New York: Oxford; 2004. p. 570

Table 7.3 Tumors entering the differential diagnosis of GIST: Summary of distinguishing anatomic features

Tumor	Most frequent anatomic site	Most frequent layer of gut
GIST	Stomach (60%) Small bowel (30%)	Muscularis propria
Fibromatosis	Mesentery (most frequent mesenteric tumor)	Serosa and muscularis propria
Leiomyoma	Esophagus Colorectum	Esophagus: muscularis propria Rectum: muscularis mucosae
Schwannoma	Stomach	Muscularis propria
Inflammatory fibroid polyp	Antrum of stomach Small bowel	Antrum: submucosa Small bowel: often submucosal and often transdural
Inflammatory myofibroblastic tumor	Mesentery and omentum	When involving the walls of the gut, the muscularis propria is frequently infiltrated
Solitary fibrous tumor	Peritoneum, retroperitoneum	Serosa
Reactive nodular fibrous pseudotumor	Small and large bowel	Serosa (may extend transmurally)
Perineurioma	Colorectum (occasional mass lesion at other sites)	Colorectal polyps: lamina propria Mass lesions: submucosa
Calcifying fibrous tumor	Mesentery and omentum Visceral	Subperitoneal (but occasionally intramural)
Benign fibroplastic polyp	Colorectum	Mucosa (lamina propria)
Sclerosing mesenteritis	Mesentery	May extend into base of small bowel with constriction
Sclerosing peritonitis	Peritoneum	Serosal surface of small bowel
Retroperitoneal fibrosis	Usually lower lumbar	Occasionally may be peripancreatic or periduodenal
Melanoma	Metastatic: small bowel most frequent Primary: anorectum, esophagus	Metastatic: any layer of bowel wall; often polypoid/ nodular Primary: often involves mucosa and submucosa
Spindle cell carcinoma	Any site in GI tract; esophagus most frequent	Can be transmural; primary tumors often centered mucosa and submucosa
Leiomyosarcoma	Retroperitoneum, esophagus, small bowel, colon	Often transmural or intraluminal polypoid masses
Malignant peripheral nerve sheath tumor	Stomach most frequent (also esophagus, small bowel, colon, and rectum)	Thought to arise from Auerbach plexus in muscularis propria
Clear cell sarcoma	Nil particular	Nil particular
Follicular dendritic cell sarcoma	Nil particular	Nil particular
Endometrial stromal sarcoma	Primary: rectosigmoid Metastases: any site	Nil particular
Sarcomatoid adult granulosa cell tumor	Nil particular	Nil particular
Angiosarcoma	Nil particular	Nil particular
PEComa	Nil particular	Nil particular

(continued)

Table 7.3 (continued)

Tumor	Most frequent anatomic site	Most frequent layer of gut
Glomus tumor	Stomach, antrum	Intramural with variable involvement of serosa, submucosa, and mucosa
Neuroendocrine tumor	Stomach, small bowel, and colon	Mucosal origin with variable mural spread
Paraganglioma	Duodenum	Submucosa mainly
Epithelioid schwannoma	Colorectum	Mucosa
Pseudosarcomatous proliferations	Esophagus frequent but any site in GI tract	Ulcers, usually interface between visible tissue and overlying slough/fibrin

GIST gastrointestinal stromal tumor

Modified from Kirsch R, Gao Z-H, Riddell R. Gastrointestinal stromal tumors. *Adv Anat Pathol*. 2007; 14:265–8

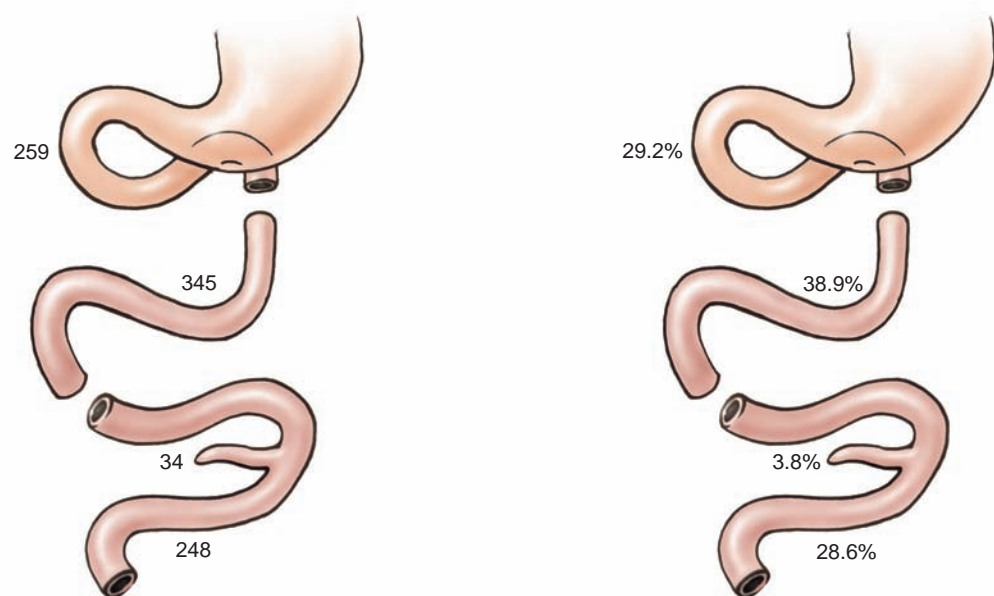
common mesenchymal tumors arising from the small intestine. True leiomyomas and leiomyosarcomas are rare in the GI tract, with the exception of the esophagus.” Most GISTs are centered in the muscularis propria; they may extend into the serosa, submucosa, or mucosa (Kirsch et al.).

In our own reviews of benign and malignant tumors (Skandalakis et al. and Blanchard et al.) we found that malignant tumors of the small bowel were adenocarcinoma (30–50%), leiomyosarcoma (10–20%), and lymphoma (10–15%). Carcinoid (neuroendocrine) tumors were found in association with other tumors in 15–30%.

Of the 1,052 cases of intestinal leiomyomas, the sites were specified in 886 cases (as noted above) and could not be determined in 166 cases.

Of the 1,655 cases of intestinal leiomyosarcoma, the sites were specified in 1,268 cases (as noted above) and could not be determined in 387 cases.

Figure 7.3



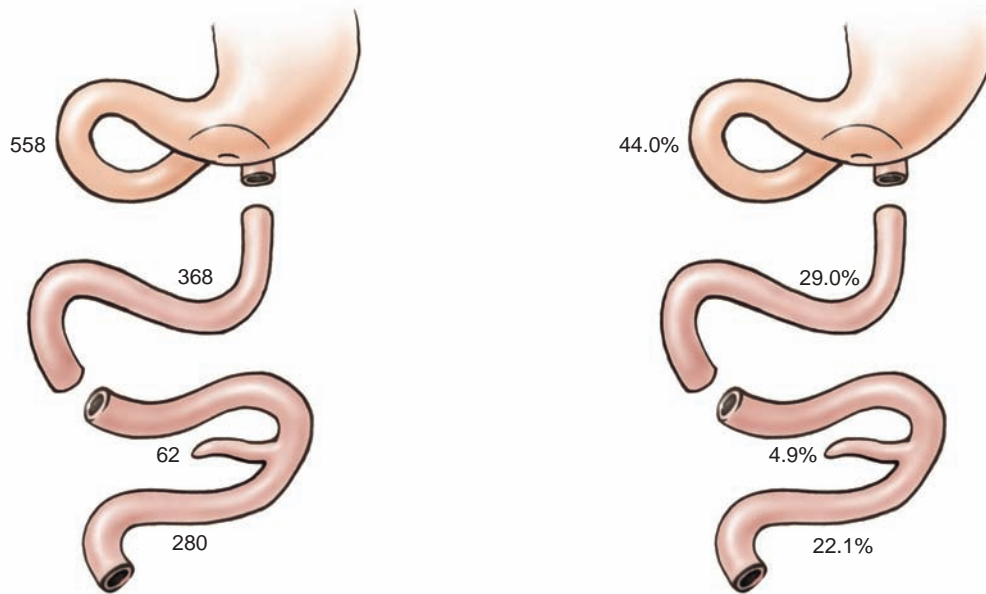


Figure 7.4

We join other authors in strongly advising that leiomyoma of the gastrointestinal tract be treated as a malignant tumor because of the difficulty of diagnosis by frozen- or permanent-section analysis. This enigmatic presentation dictates radical surgery, even though the disease may be benign. Similarly, because of the possibility of malignancy, sessile villous adenoma should be treated with segmental resection, not enterotomy and excision.

Like adenomas, adenocarcinomas are found primarily in the duodenum, with a marked decrease in frequency moving axially along the small bowel (Turner and Bass). About 46–55% of small bowel adenocarcinomas occur in the duodenum (Wayne and Talamonti).

From duodenum to ileum, the distribution of neuroendocrine (carcinoid) tumors increases along the length of the small bowel, with the greatest concentration in the distal ileum (Erbil et al.). Duodenal carcinoids may behave in a benign fashion, while carcinoid tumors of the jejunum and ileum are characteristically malignant (Bass). Patients with midgut tumors (distal duodenum, jejunum, ileum, appendix, ascending colon) are more likely than those with carcinoids in other locations to exhibit carcinoid syndrome, and to develop noncarcinoid primary tumors of the GI tract.

The numbers of carcinoid tumors from several locations in our studies have been compared in Table 8–4. It will be seen that per inch, many more tumors were found in both the appendix and Meckel's diverticulum than in the duodenum and small intestine.

Tumors of the appendix are rare and usually detected incidentally after appendectomy. While carcinoids are the most common tumors of the appendix, a decrease from 31.8% (1973–1979) to 12% (1990–1997) was noted in National Cancer Institute (NCI) studies (Stinner and Rothmund). In our world literature review from 1875 to 1996 of smooth muscle (stromal) tumors, we found only five cases of leiomyosarcoma of the appendix (Blanchard et al.).

Table 7.4 Site-specific characteristics of gastrointestinal carcinoid tumors

	Fraction of all Carcinoids (%)	Regional Spread ^a (%)	Distant Metastases ^a (%)	5-Year Survival ^r (%)
All gastrointestinal carcinoids	67	21	16	68
Stomach	6	3	7	63
Small intestine	28	36	22	61
Appendix	2	29	10	71
Colon	8	27	25	62
Rectum	19	2	2	87

* Surveillance Epidemiology and End Results (SEER) data 1992–1999 from Modlin IM, Lye KD, Kidd M. A 5-decade analysis of 13,715 carcinoid tumors. Cancer 2003; 97:934

^a At presentation

From Anthony T, Kim L. Gastrointestinal carcinoid tumors and the carcinoid syndrome. In: Feldman M, Friedman LS, Brandt LJ, editors. Sleisenger & Fordtran's gastrointestinal and liver disease: pathophysiology/diagnosis/management. 8th ed. Philadelphia: Saunders, Elsevier; 2006. p. 605–23

Table 7.5 Relative frequency of carcinoid tumors reported in the intestinal tract

Organs	Length (in.)	No. of tumors*	Tumors per in. of length
Duodenum	10	43	4.3
Jejunum	96	49	0.5
Ileum	144	813	5.6
Meckel's diverticulum	2	33 (1,650) ^a	16.5 (8,250.0) ^a
Appendix	3	1,340	446.6

* Number reported up to 1966

^a The diverticulum is present in 2% of patients; hence, $33 \times 50 = 1,650$ for those patients with a diverticulum. From Singhabhandhu B, Gray SW, Krieger H, Gerstmann KE, Skandalakis JE. Carcinoid tumor of Meckel's diverticulum: report of a case and review of literature. J Med Assoc GA. 1973;62:84–9

Table 7.6 Incidence of carcinoid tumors of Meckel's diverticulum by age and sex^a

Age (year)	Male	Female
20–29	1	–
30–39	2	–
40–49	3	1
50–59	13	5
60–69	10	2
70–79	7	1
80–89	1	–
Not stated	2	1
Total	39	10

^aIn one case, sex was not stated

From Singhabhandhu B, Gray SW, Krieger H, Gerstmann KE, Skandalakis JE. Carcinoid tumor of Meckel's diverticulum: report of a case and review of literature. J Med Assoc GA. 1973;62:84–9

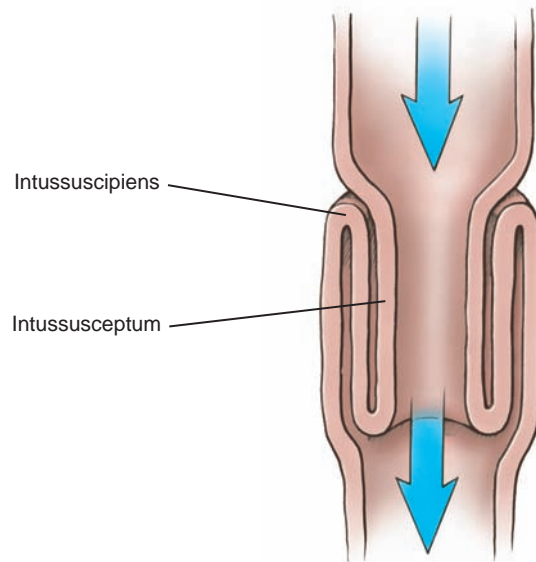


Figure 7.5

An intussusception is created when a proximal segment of intestine (the intussusciens) invaginates into the portion of intestine immediately distal to it (the intussusceptum). In adults, our “two-thirds” rule can be applied:

- Two-thirds are from known causes.
- Of these, two-thirds are due to neoplasms.
- Of those caused by neoplasms, two-thirds of the neoplasms will be malignant.

Intussusception and Its Relationship to Neoplasia

Surgical Applications

Most of the small bowel remains inaccessible to routine endoscopic examination. Wireless capsule endoscopy, a noninvasive diagnostic technique that visualizes the entire small bowel during normal peristaltic movement, has been used to diagnose patients with obscure GI bleeding. Accurate localization of intraluminal small bowel tumors has been obtained through intraoperative laparoscopic sonography. Gore reported on differential diagnosis: “A polypoid or constricting annular mass in the duodenum suggests adenocarcinoma. A mesenteric mass with calcifications and spiculations suggests carcinoid tumor. A large, homogenous mass with mural thickening and lumen dilation in the ileum suggests lymphoma. Lymphoma, metastases and GIST can cause large masses.”

With benign or malignant lesions, segmental resection is preferable to wedge resection as performed for simple diverticulum. Benign lesions seem to be more common in the distal small bowel (perhaps due to the relative shortness of the duodenum); however, per unit area, duodenal tumors are most frequent. Benign neoplasms

may be resected either by endoscopy or laparotomy, depending on their size, growth pattern, and location.

Most patients with adenocarcinoma undergo surgical exploration and resection. The same author stated the following about sarcomas: “Gross inspection cannot distinguish a benign from a malignant smooth muscle neoplasm; so if any such neoplasm undergoes surgery, wide excision is required. Lymph node resection, however, is usually not necessary for leiomyosarcomas because they metastasize only rarely to lymph nodes. Hence, most of these tumors can be resected. ... For patients with unresectable disease, doxorubicin-based regimens offer the best tumor response, although the median duration of the benefit is short, and the prognosis remains poor.”

Adenocarcinomas of the duodenum usually are treated by pancreaticoduodenotomy. Demetri commented on surgical treatment of GIST:

Definitive expert surgery remains the mainstay of treatment for patients with localized, primary GIST. It is important to recognize that surgical resection of GIST should probably be undertaken only if there is a very low risk of functional deficit. If a very large GIST were to be detected, it might be judicious to consider such a lesion unresectable for cure, which could be done without causing unacceptable risk for morbidity; in such a case, preoperative administration of imatinib could be given, with follow-up at close intervals to ensure appropriate response to therapy. ...The surgical approach to resection of primary disease must take into account the specific growth and behavior characteristics of GIST. GIST rarely involves the locoregional lymph nodes, and so extensive lymph node exploration or resection is rarely indicated. ...The margins of resection from the tumor specimen should be carefully oriented and examined, and biopsy samples from several different areas of the tumor should be evaluated by the surgical pathologist.

Resection of Small Bowel

The nature of the pathology dictates the extent of resection. Inspect the entire length of the small bowel for disease and incidental developmental anomalies (Scott-Connor). Remember to measure and record the remaining small bowel after resection.

Resection of the Duodenum

We quote from Arber and Weinstein: “For tumors located in the duodenum, most physicians favor radical excisions. Pancreaticoduodenectomy is advocated for lesions of the first and second portions of the duodenum, and segmental resection (pancreatic sparing duodenectomy) for tumors in the third and fourth parts of that organ. ... Unresectable ampullary tumors should be treated by a palliation procedure of biliary bypass and gastrojejunostomy.”

Resection of Jejunum and Ileum

Jejunal or ileal resection may be done in response to pathologic entities of the small bowel, such as benign or malignant tumors with or without intestinal obstruction or intussusception. In resecting a segment of the proximal part of the jejunoileum, remove 20 cm of healthy small bowel on each side of the lesion, as well as a V-like mesenteric excision. In performing a resection of the terminal ileum, a right-sided colectomy is the appropriate procedure, because of the anatomic lymphatic pathway.

A midline vertical incision is made, and the area is explored. The intestinal segment is isolated, and the loop of intestine with the tumor is brought out of the abdomen

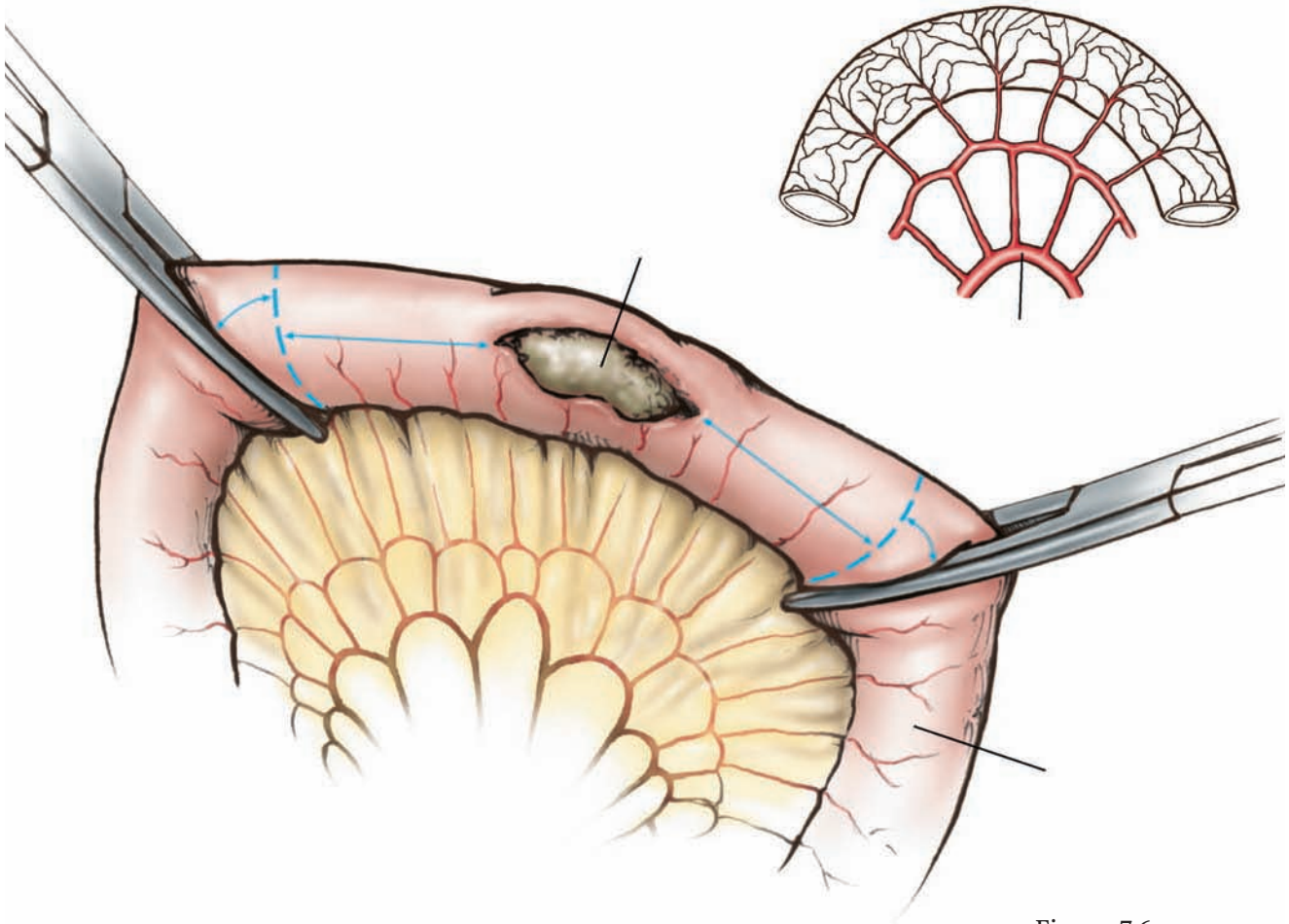


Figure 7.6

together with sufficient length proximal and distal to the area to be resected. The exposed segment and the general peritoneal cavity are protected with warm laparotomy pads. Noncrushing clamps are applied obliquely 20 cm from the tumor on each side. In addition, straight Kocher clamps are applied on each side on the specimen side. A V-type incision is made with a knife in the mesentery, incising only the visceral peritoneum.

The mesenteric vessels are isolated with care, and the intestinal segment with the tumor is transected proximally and distally. The specimen is removed, and both cut edges are covered with warm laparotomy pads to prevent possible contamination. The anastomosis may be end-to-end, side-to-side, or any appropriate variation.

To prepare a long loop of jejunum for anastomosis, the following steps can be used, after securing the duodenojejunal junction and drawing the proximal jejunum out of the abdomen:

Anastomosis

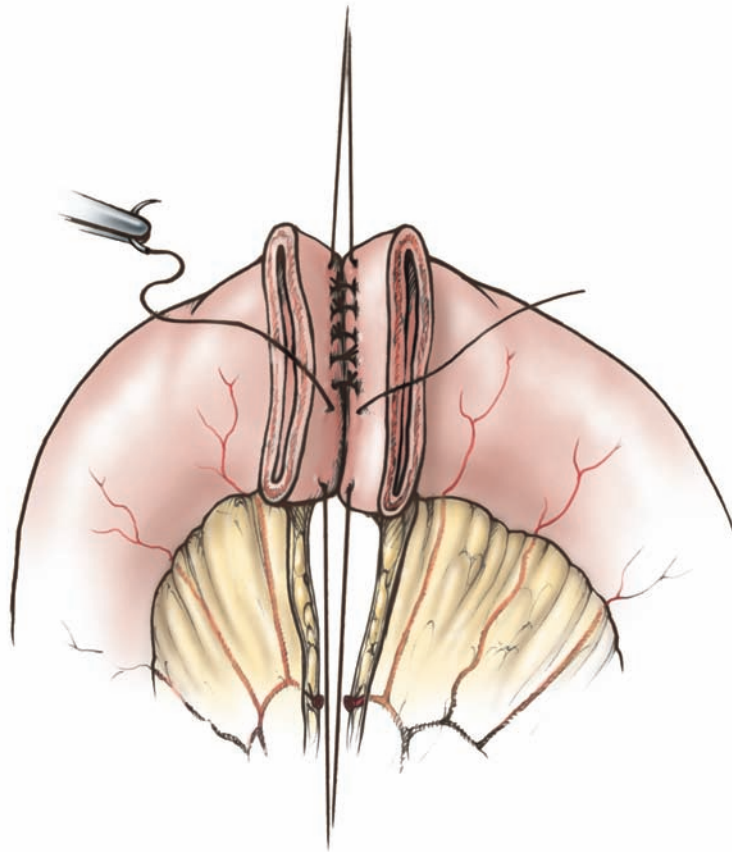


Figure 7.7

1. The peritoneum is incised halfway between the root and the mesenteric border. It is elevated from the selected loop. Fat and lymph nodes are removed to within 1–2 cm from the wall of the intestine.
2. The jejunal vessels are skeletonized of connective tissue, nerve fibers, and lymphatic vessels, separately freeing the arteries and veins, with careful exposure of the vascular arcades.

The exposed blood vessels are again covered with peritoneum. At the same time, the anatomy of the jejunal arteries and their arcades is examined to determine the feasibility of dividing the necessary number of arteries (usually three or four) required for mobilization of a loop of adequate length. If needed, the root of the mesentery is divided as necessary to gain length.

The anastomosis is performed on the antimesenteric border with a GIA 55 or 75 stapler. Traction sutures are placed at the mesenteric and antimesenteric borders of both bowel lumina. The antimesenteric borders of the proximal and distal bowel loops are approximated. GIA forks are inserted into proximal and distal lumens. The bowel ends should be aligned evenly on the GIA forks. The instrument is then closed and the staples fired. The knife in the GIA divides between two double staple lines, creating a stoma.

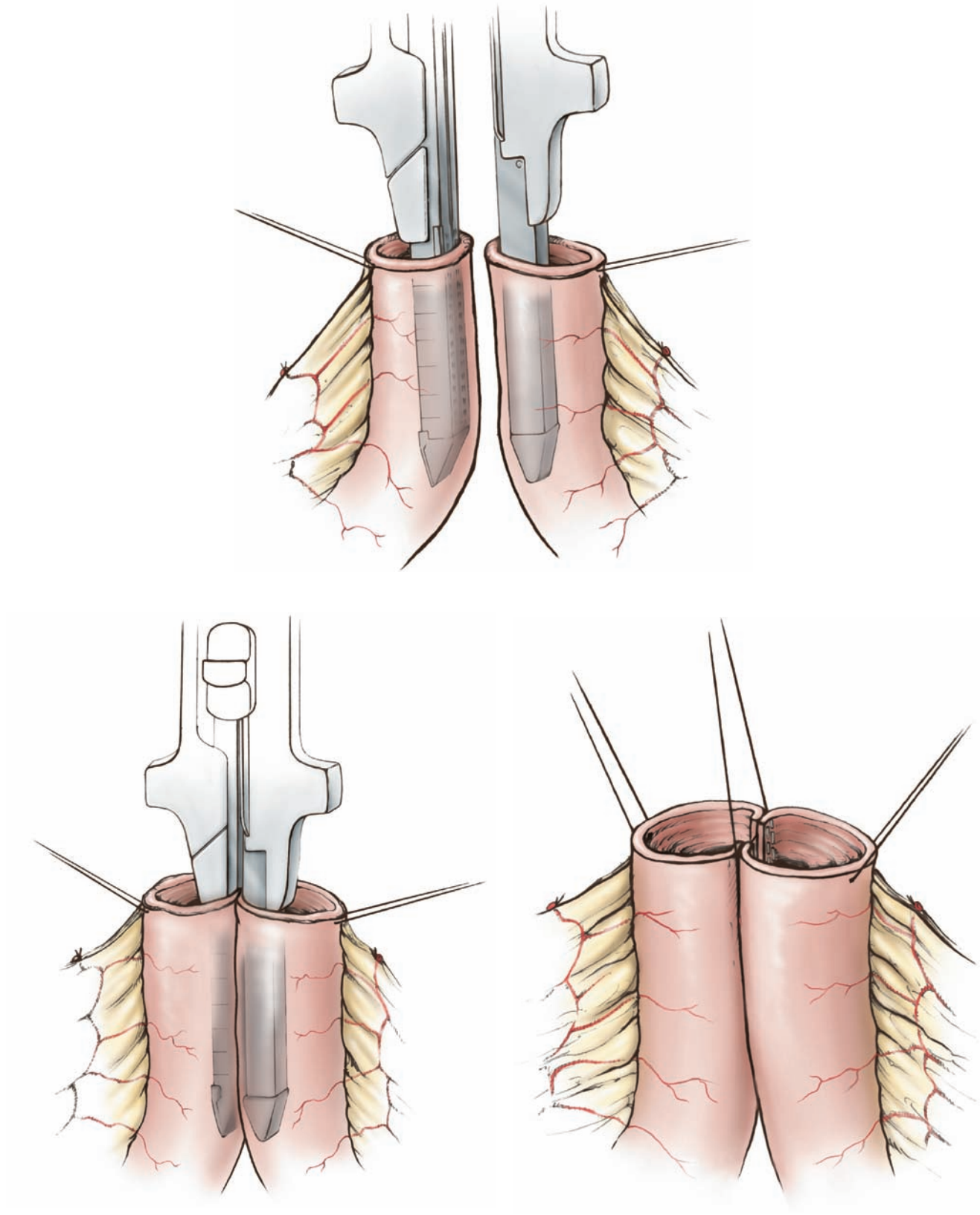


Figure 7.8

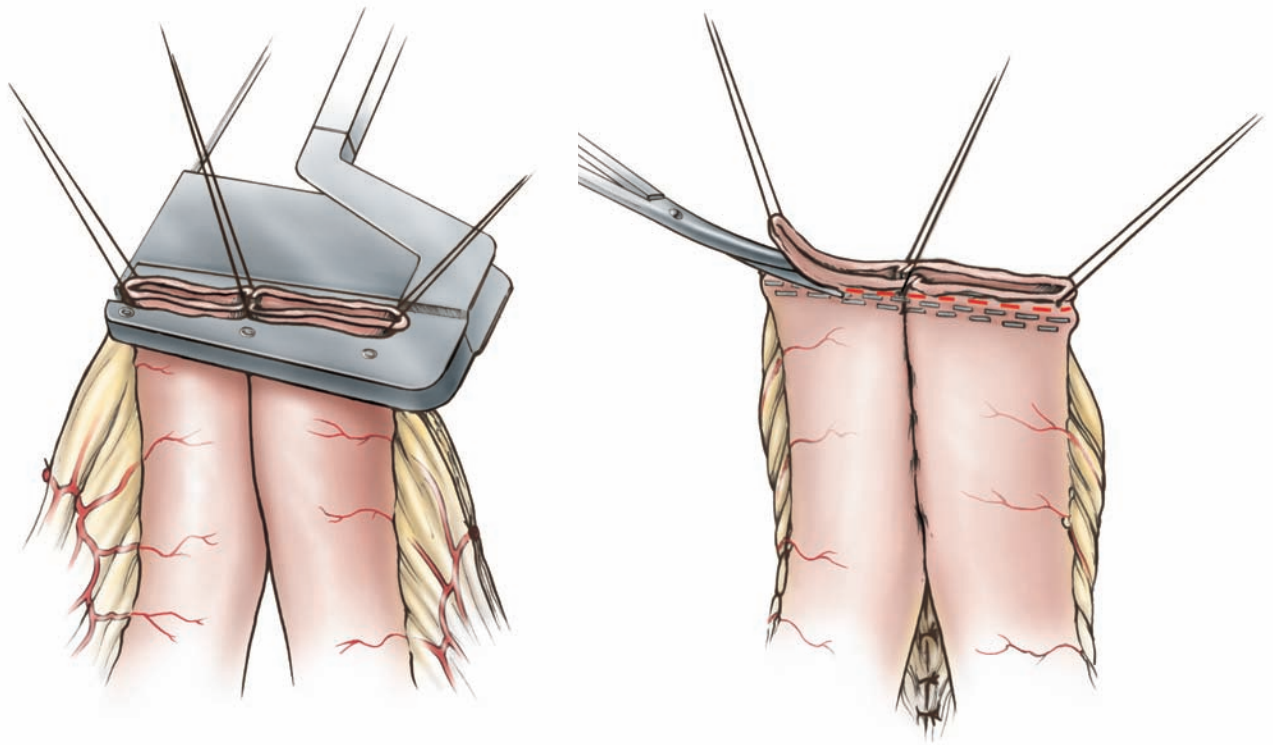


Figure 7.9

Allis clamps or through-and-through sutures including all the layers of the stomas of the proximal and distal loop are now placed. The apposition of the walls of the proximal and distal limb should be complete. A TA-55 device is used to close the opening between the two limbs by carefully incorporating all the layers of the loops. The redundant bowel is excised with a knife or scissors before removing the device.

Resection of Mesentery

Primary tumors of the mesentery are uncommon. The most common tumors of the mesentery and omentum are metastatic, arising from primary malignant tumors of anatomic entities within the peritoneal cavity (e.g., ovaries).

The primary treatment for mesenteric tumors is surgical excision. The radicality of the operation depends on whether the tumor is benign or malignant, its size, its location, and the degree of invasion to neighboring anatomy. A V-like excision of the mesentery, including the corresponding loop or loops of the small bowel, is the treatment of choice. When resection is not possible, radiation therapy is an alternative.

Anatomic Basis of Complications

Vascular Injury

- Vascular injury to the superior mesenteric artery must be repaired at once. Injury to the mesentery and one or more of the intestinal arteries requires ligation. It will also add to the length of devitalized segment of intestine and hence the length of

resection needed. Any line of resection must be so placed as to minimize injury to the blood supply, and many vascular arches and vasa recta as possible must be preserved.

- Hematomas at the anastomotic site will cause ischemia, necrosis, and perforation. Hematomas are most common at the junction of the mesentery with the anastomotic site. Here mesenteric vessels can be occluded, producing local ischemia.
- The fragile pseudocapsule exhibited by some GIST is easily ruptured. Intraoperative procedures must be optimized to minimize the risk of peritoneal dissemination (Demetri).
- The abdominal cavity should be well packed before any enterotomy or enterostomy to prevent contamination and future infection, with resulting intraperitoneal or abdominal wall abscess.
- Leakage at the suture line is the result of poor technique and will be followed by a fistula or general peritonitis. Care in closing the mesentery at the suture line without damage to blood vessels, and prevention of tension on the anastomosis reduces the possibility of leakage.
- An inadequate stoma will result in stasis of intestinal contents and possible obstruction. A slightly oblique line of resection will help enlarge the anastomotic opening and preserve the blood supply to the antimesenteric border.
- Tension and torsion at the anastomosis must be prevented. The surgeon must be sure that any tension or torsion has not been merely transferred to a more distal or proximal site. The resection of an intestinal obstruction does not preclude the presence of another obstruction distal to the anastomosis. This is of great importance in surgery to treat intestinal atresias in infancy.

Organ Injury

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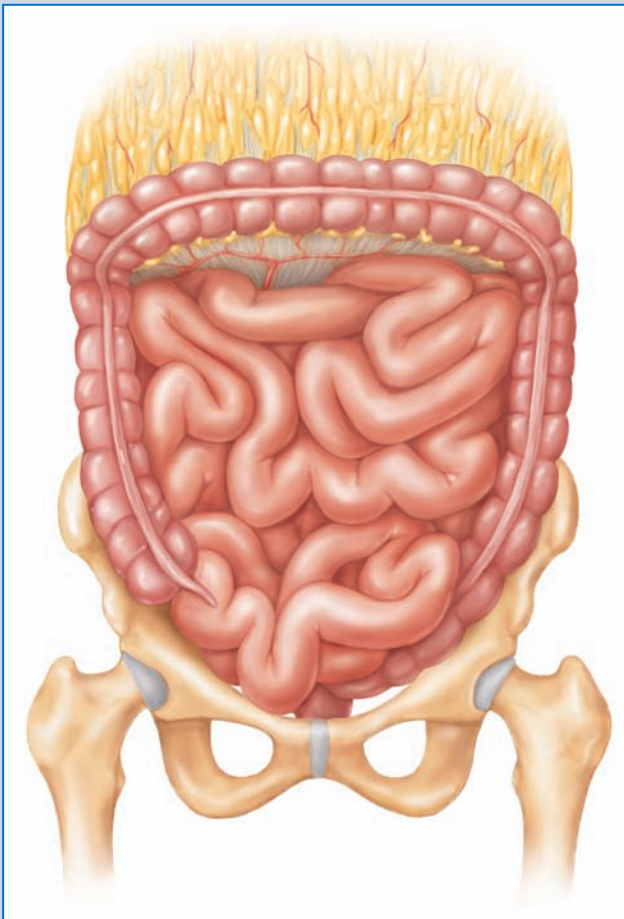
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Colon and Appendix

Edward Lin



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Introduction

Almost 150,000 new cases of colorectal cancer are diagnosed each year in the United States, making them the fourth largest group of new cancer patients. Consequently, colorectal cancer claims 50,000 lives annually. Ninety to ninety-five percent of colon tumors are adenocarcinomas; less frequent types include carcinoids, stromal tumors (formerly leiomyosarcomas), lymphomas, and undetermined lesions. Surgery remains the cornerstone of curative therapy, with the greatest technical advances made in recent years using minimally invasive methods, including laparoscopy and robotics. Indeed, multiple randomized trials have demonstrated equal outcomes for the traditional open approach and the laparoscopic approach to colon cancer surgery.

Regardless of the type of surgical approach to colon cancer, location continues to be the major determinant of the type and extent of colon resection; the degree of resection is based on the arterial, venous, and lymphatic drainage of the affected colon segment. Furthermore, medical societies and healthcare payers are increasingly relying on the adequacy of lymph-node resection, and therefore the number of nodes examined histologically, as a benchmark of satisfactory oncologic therapy.

In this section, the surgical techniques will be outlined, but whenever appropriate, laparoscopic techniques will also be highlighted.

Colon

Surgical Anatomy

Topography

The length of the colon ranges from 120 to 200 cm in length; the luminal diameter is greatest at the cecum (7.5 cm), but gradually diminishes to 2.5 cm in the sigmoid colon. External anatomic characteristics of the colon that distinguish it from the small bowel include the taenia coli, the haustral sacculations of the bowel wall, the appendix epiploicae, and the attachment of the greater omentum to the transverse colon.

Colon surgery and lymph-node harvest are based on the vascular supply of their subsegments. The colon and rectum derive from the embryologic midgut and hindgut, with the blood supplies following the superior mesenteric artery and inferior mesenteric arteries, respectively. Derivatives of the midgut include the cecum and the right-half to two-thirds of the transverse colon. The derivatives of the hindgut are the left one-third to one-half of the transverse colon, the descending colon, the sigmoid colon, the rectum and the superior portion of the anal canal.

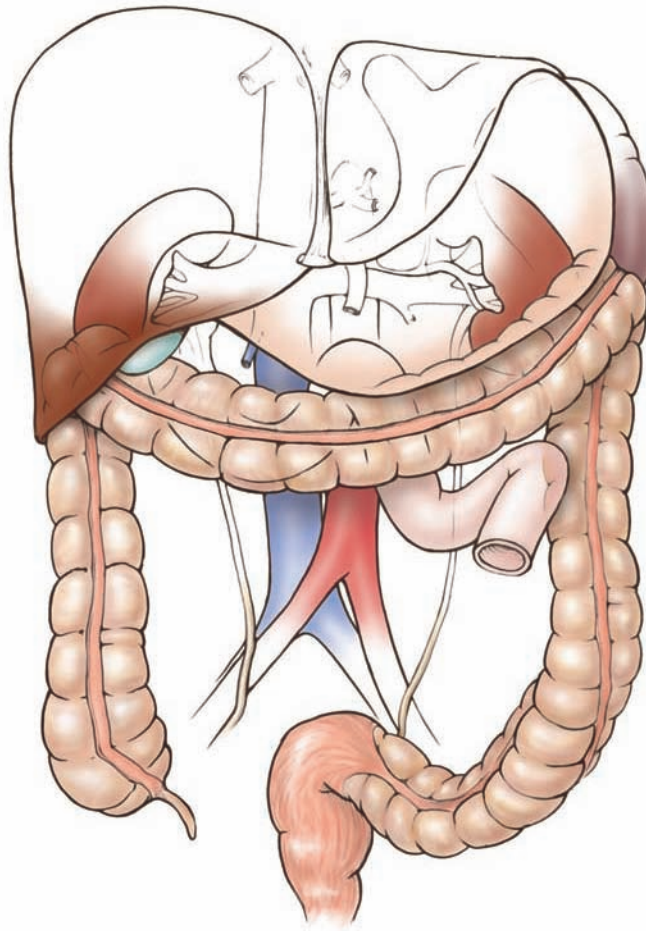


Figure 8.1

Cecum

The cecum is located in the right iliac fossa and is approximately 10 cm long, with the widest transverse diameter of all the colon segments averaging 7.5 cm. It is completely enveloped with the visceral peritoneum and is typically mobile. The gonadal vessels and the right ureter typically course posterior to the medial border of the cecum.

The terminal ileum empties into the cecum from a medial-to-lateral direction through a thickened invagination called the ileocecal valve. The valve prevents retrograde flow from the colon into the small bowel, but in approximately 25–30% of individuals, the ileocecal valve is incompetent. The incompetent valve is most evident during colonoscopies when colonic air readily passes into the small intestines, resulting in marked abdominal distention and patient discomfort. Clinically, patients with distal colonic obstructions and functional ileocecal valves typically have colonic dilatation on radiography that mimics a closed-loop obstruction. While the cecum is quite distensible, a diameter greater than 12 cm can result in ischemic necrosis and perforation.

Ascending Colon

From the cecum, the ascending colon is the 12–20 cm segment that runs upward toward the liver on the right side. With the exception of its posterior surface, which

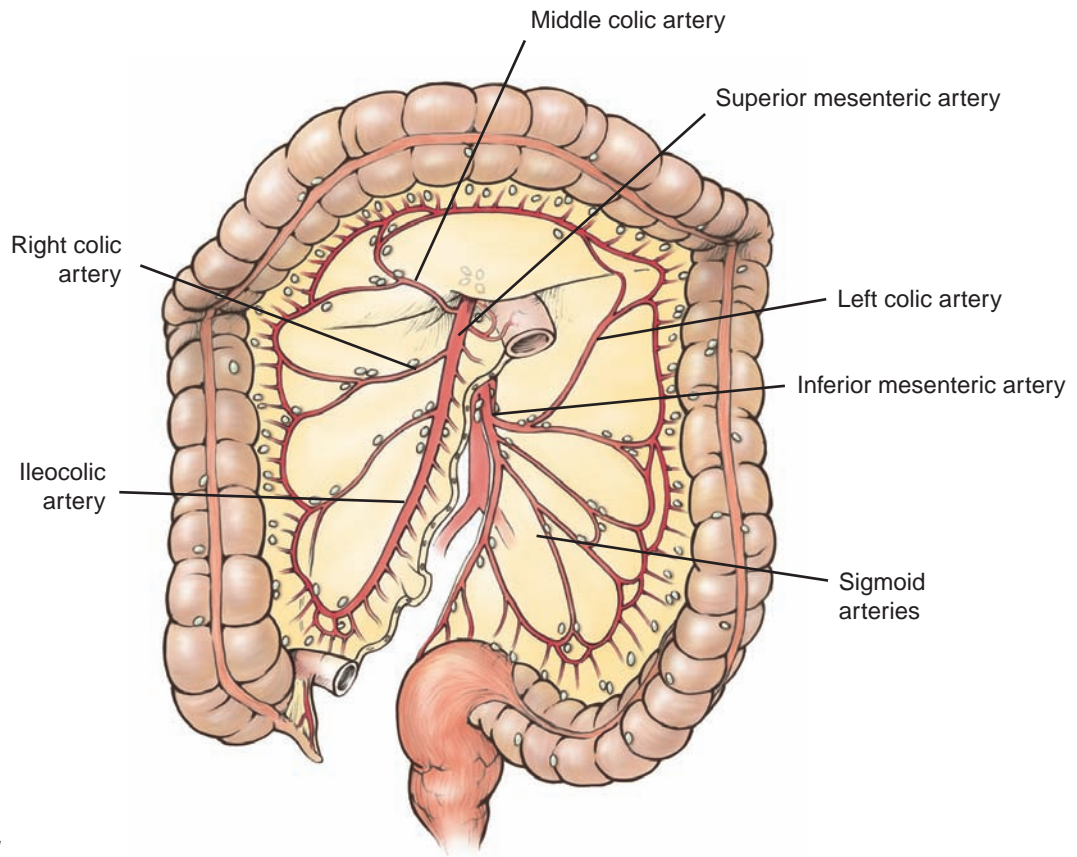


Figure 8.2

is fixed to the retroperitoneum, the ascending colon is covered laterally and anteriorly by the visceral peritoneum. For the surgeon, the psoas muscle, the second portion of the duodenum, the right ureter, and the inferior pole of the right kidney, all have important anatomic relationships to the ascending colon.

The ascending colon is laterally attached to the parietal peritoneum along the white line of Toldt—an area that represents an embryonic fusion plane between the visceral and parietal peritoneum. This subtle anatomic landmark is relatively avascular and serves as the classic landmark for surgical mobilization of the ascending colon away from its retroperitoneal attachments.

The hepatic flexure is the segment of the ascending colon that rests under the right liver lobe and turns medially and anteriorly into the transverse colon. The hepatic flexure can often be identified during colonoscopy by a purplish impression on the superior aspect of the colon wall when the scope reaches the right side.

Transverse Colon

The transverse colon is suspended between the hepatic flexure and the splenic flexure and spans 40–50 cm, sharing important anatomic relationships with the stomach, the tail of the pancreas, the spleen, and the left kidney. It is completely invested with peritoneum and has a long mesentery known as the transverse mesocolon, referred to as the colon's most mobile portion. Indeed, it is not infrequent to find women who have transverse colons that reach into the pelvis. Anatomically, the transverse colon is attached to the greater curvature of the stomach by the gastrocolic ligament or

omentum. The greater omentum descends off the inferior aspect of the transverse colon. Locally advanced tumors of the transverse colon may involve the stomach, pancreas and duodenum posteriorly, and the spleen, as well as the omentum.

Descending Colon

The descending colon extends 25–30 cm from the splenic flexure to the sigmoid colon along the left gutter of the peritoneal cavity, forming important posterior anatomic relationships with the kidney, ureter, and iliac vessels at the pelvic brim. This segment is narrower than the ascending colon, but is similar to it in that it is covered by visceral peritoneum except for its posterior aspect, where it is fixed to the fascia of the quadratus lumborum muscle. The descending colon is also fused laterally to the parietal peritoneum, forming the avascular white line of Toldt.

Sigmoid Colon

At the pelvic brim, the sigmoid colon is located at the lower end of the descending colon and usually extends to the third sacral vertebrae. The entire length is variable but averages 35–40 cm in length. Unlike the descending colon, which is thin-walled and fixed, the sigmoid colon is thicker, mobile, and completely invested in visceral peritoneum. The long floppy mesentery of the sigmoid colon enables the formation of omega loops in the pelvis. More importantly, the mesosigmoid is generally fixed to the left lateral pelvic wall and forms the intersigmoid recess (fossa) which overlies the left ureter as it courses over the iliac vessels. The sigmoid colon ends at the confluence of the teniae coli at the rectosigmoid junction. Endoscopically, because the teniae coli cannot be visualized, the National Cancer Institute defines the rectum to be the last 12 cm above the anal verge as measured by rigid sigmoidoscopy.

Arteries

The right colon and up to two-thirds of the proximal transverse colon are derived from the midgut, a region supplied by the superior mesenteric artery. The distal transverse colon and left colon are derived from the hindgut, supplied by the inferior mesenteric artery. These two arterial systems arborize along the mesenteric border of the colon, forming the marginal artery of Drummond. This marginal system is formed by tributaries from the ileocolic, right colic, middle colic, left colic, and sigmoid arteries, and spans from the ileocecal valve to the rectosigmoid colon. All the terminal vessels that vascularize a limited area of bowel wall are supplied by these arteries. Collateralization is excellent along the marginal arteries, serving as an important source of a segment's blood supply when a major vessel is occluded. The presence of these marginal arteries also allows the sacrifice of major vessels, facilitating the colon's mobilization for distal anastomosis.

The SMA supplies the entire small bowel with 12–18 jejunal and ileal branches to the left and three major colonic branches to the right. The ileocolic vessel is the most constant of these branches and supplies the terminal ileum, appendix, and cecum. The right colic artery is the most variable blood supply of the colon, and may be absent

Blood Supply

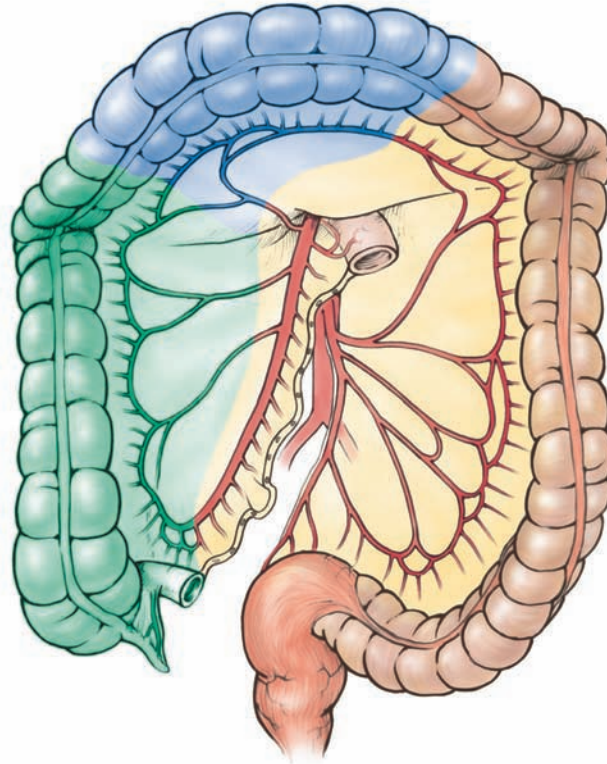


Figure 8.3

in up to 20% of patients. When present, the right colic artery can originate from the SMA, as a branch of the ileocolic artery or middle colic artery. The right colic artery communicates with the middle colic artery through the marginal arteries.

The middle colic artery is a major blood supply to the colon and is an important surgical landmark when planning a colon resection because it is a demarcation point for the clinical definition of a right or left hemicolectomy. This artery arises proximally as the superior mesenteric artery enters the small bowel mesentery at the inferior border of the pancreas. The middle colic artery then ascends into the transverse mesocolon, and typically divides into the right and left colon blood supplies through the marginal artery. The middle colic may also be absent in some patients and the presence of an accessory middle colic artery may be found in 10% of patients.

The left colon receives its blood supply from the inferior mesenteric artery which originates from the L3 level. Like the SMA, the IMA also gives three principle branches: the left colic, sigmoid, and superior rectal arteries. Unlike the SMA, the IMA is more constant in distribution. The first branch of the inferior mesenteric artery is the left colic artery, which divides into ascending and descending branches as it passes upward. The ascending branch anastomoses with the branches of the middle colic artery, a system that supplies the distal transverse colon and splenic flexures. After supplying the left colon, the descending branch joins branches of the sigmoid artery.

Originating from the inferior mesenteric artery, the sigmoid artery divides into ascending and descending collateral branches as it travels through the sigmoid mesocolon. The descending branch supplies the sigmoid colon; the ascending vessels

merge with the marginal artery system. The terminal vessel of the inferior mesenteric artery is the superior rectal (hemorrhoid) artery.

The blood supply to the splenic flexure is most inconsistent, relying on collateral circulation supplied by the left branch of the middle colic and the ascending branch of the left colic arteries. This “watershed” area is vulnerable to ischemia during low splanchnic blood flow. In light of this, bowel anastomoses in the region of the splenic flexure is fraught with risks of leaks and breakdowns.

Veins

The colon’s venous anatomy parallels the arterial supply of the corresponding midgut- or hindgut-derived segments. Drainage of the midgut-derived right colon is achieved by the superior mesenteric venous system, which includes the ileocolic, right colic, and middle colic veins. This configuration forms the superior mesenteric vein and joins the splenic vein to empty into the portal venous system. Drainage of the left colon derived from the hindgut is accomplished by the inferior mesenteric venous system, which differs from the superior mesenteric venous system by joining the splenic vein before entering the portal vein. The course of the inferior mesenteric vein only courses partially with the inferior mesenteric artery, but continues in a cephalad direction to the splenic vein. Due to its proximity to the left renal vessels, the inferior mesenteric vein may be inadvertently ligated during left nephrectomy. In some instances, ligation of the IMV can be performed if additional descending colon length is necessary to reestablish colorectal continuity (i.e., allow the descending colon to reach the pelvis).

The lymphatic drainage starts from the lymphatic follicles with the colonic submucosa, and drains through the muscularis layer into the *epicolic nodes*. From the epicolic nodes, drainage continues to the *paracolic lymph nodes*. The paracolic nodes drain into *intermediate lymph nodes* that course along the major arteries and are clustered at bifurcations. The terminal lymph node basins are the *principle lymph nodes* at the aorta. These principle lymph nodes are the celiac, superior mesenteric, and the inferior mesenteric lymph-node groups, which eventually drain into the cisterna chyli.

Lymphatic Drainage

Most surgical resections for tumors should include the intermediate lymph nodes. The Intergroup 0089 trial for adjuvant chemotherapy in Stages II and III colon cancer treatment showed that the best survival is evident when greater than 20 negative lymph nodes are evaluated for Stage II cancer, and greater than 40 lymph nodes evaluated for Stage III cancer. These findings may suggest more refined staging from adequate lymph-node evaluations, rather than confer causation. For the present, the National Cancer Institute Guidelines 2000 recommends a minimum of 12 lymph nodes in the resected specimen for adequate tumor staging, which also serves as a benchmark for adequate oncologic resection.

Nerve Supply

Just as in the small intestine, the colon contains ganglia in both the submucosa and myenteric plexi. These plexi receive extrinsic innervation from the parasympathetic

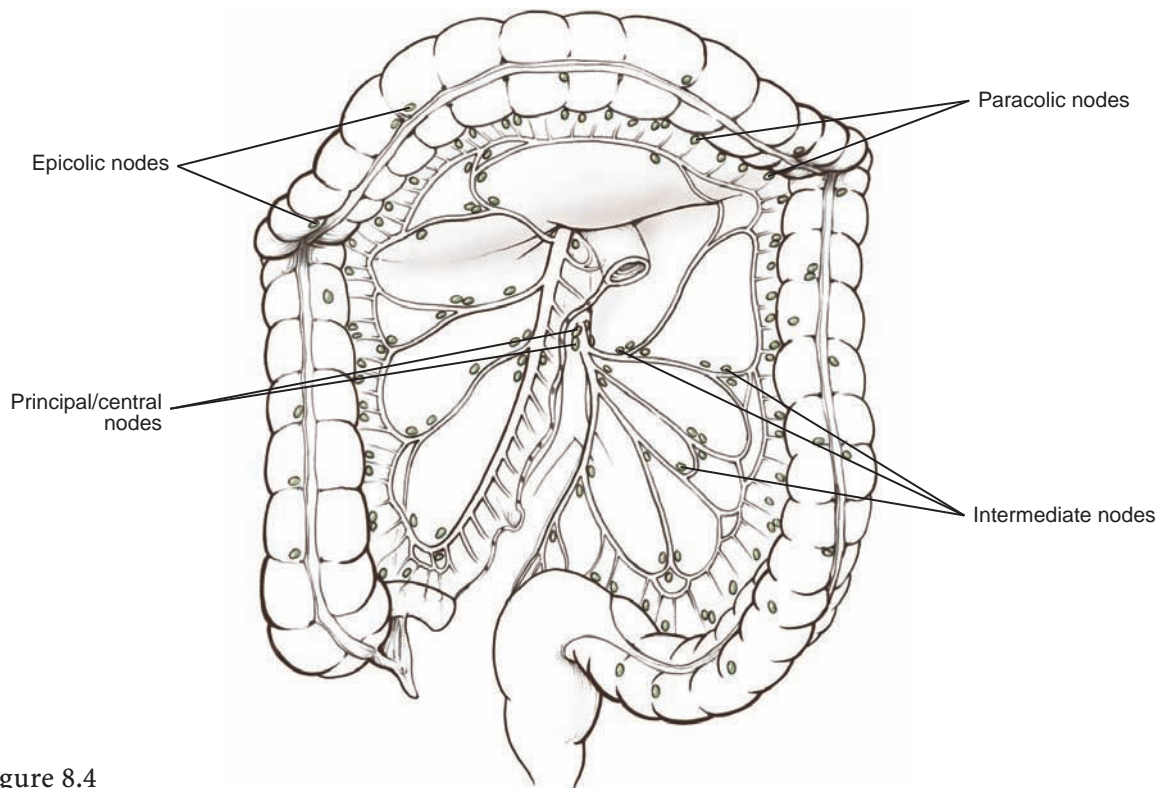


Figure 8.4

and sympathetic divisions of the autonomic nervous system, and the neural supplies are thought to parallel the vascular supply.

The sympathetic nerves consist of afferent and efferent fibers originating from T6 to T12. The postganglionic efferent fibers follow the superior mesenteric artery as it branches to supply the right colon. Left colon and rectum sympathetic fibers originate from L1 to L3 and pass through the preaortic plexus located above the aortic bifurcation, and the postganglionic fibers follow the branches of the IMA, superior rectal artery to the left colon, sigmoid, and rectum.

The right and transverse colon parasympathetic supply comes from the right vagus nerve, and these fibers travel with the branches of the SMA and enter the bowel wall. The origins of the parasympathetic innervation to the left colon are less clear, but are believed to originate from the S2 to S3 spinal segments.

Surgical Applications

Surgical resection continues to be the primary therapeutic method for malignant tumors of the colon. However, screening colonoscopy and possibly CT colonography remain the most effective modalities for the detection of early or premalignant disease. In endoscopically unresectable tumors, the particular tumor's location determines the extent of resection, and the vascular supply and lymphatic drainage to the mesenteric segment define the boundaries of resection.

Most patients undergoing elective colon resection for tumor have had cancer screening to determine distant metastasis or synchronous colonic lesions. Currently, this screening includes biochemical evaluations, positive emission tomography-CT scan, possibly MRI and additional colonoscopic evaluations. Aside from the cecum and rectum, the accuracy of exact tumor location cannot always be ascertained by colonoscopy. Surgical strategy can be anticipated if precise tumor localization can be marked preoperatively by double contrast colonography when feasible or endoscopic ink tattooing or clip marking. Intraoperative colonoscopy to localize the tumor is time-consuming and may unnecessarily induce bowel distention.

An important component of preoperative preparation is mechanical bowel preparation, which classically consists of administration of a polyethylene glycol electrolyte solution, oral nonabsorbable antibiotics, intravenous antibiotics. Alternatives to colon cleansing may be used as long as they can effectively decrease contamination and bacterial load. One should be mindful that left colon tumors are more likely to cause obstruction than right colon tumors due to the smaller lumen size. In order to prepare the obstructed left colon, diverting loop colostomies followed by resection is an option. If a diverting colostomy is to be performed, it is advisable to plan the ostomy at or near the area of planned resection so that the ostomy can be incorporated in the specimen at a later resection. Another option for temporarily relieving the obstruction is to place a colonic stent and allow the bowel to decompress while preparing the patient for elective surgery over the ensuing 2 weeks.

The major surgical procedures for the colon include right hemicolectomy, extended right hemicolectomy, extended left hemicolectomy, left hemicolectomy, rectosigmoid resection. Three main considerations increase anastomotic complications in reestablishing intestinal continuity; lack of demonstrable pulsatile arterial blood flow, tension between the two ends of colon, and perianastomotic hematoma or contamination. Other issues that may increase anastomotic complications include sepsis, circulatory shock, carcinoma at the anastomosis, preoperative radiation.

Standard resections for colon tumors	
Tumor location	Resection
Cecum/appendix	Right hemicolectomy
Ascending colon	Right hemicolectomy
Hepatic flexure	Extended right hemicolectomy
Transverse colon	Extended right hemicolectomy
Splenic flexure	Left colectomy and distal transverse colon (or extended left hemicolectomy)
Descending colon	Left hemicolectomy
Sigmoid colon	Rectosigmoid resection

Tumors located in the appendix, cecum, or ascending colon often require a right hemicolectomy, the anatomic boundaries of which span the cecum to the proximal half of the transverse colon.

An extended right hemicolectomy includes the transverse colon to the splenic flexure that includes the left branch of the middle colic artery. This procedure is

Right Hemicolectomy

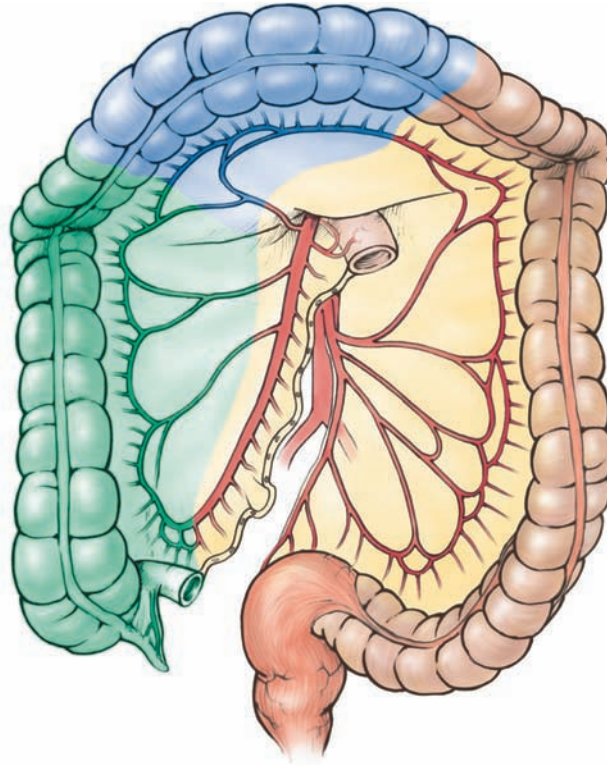


Figure 8.5

appropriate for tumors at the hepatic flexure and the transverse colon. Many surgeons avoid isolated transverse colon resections because a hepatic flexure to splenic flexure anastomosis is a problematic one in terms of tension and uncertain blood supply.

Abdominal incisions used to perform a right hemicolectomy may vary, with choices including a midline, paramedian, transverse supraumbilical, or even a Pfannenstiel incision. The peritoneal cavity is inspected for gross metastasis. A solitary hepatic metastasis may be resected at the same time, but with appropriate presurgical evaluations, this occurrence is generally anticipated rather than unexpected.

The planned resection for right hemicolectomy includes the final 6 cm of the ileum and the proximal transverse colon. Tumors of the cecum should include 10–15 cm of the ileum. The ileocolic, right colic, and right branch of the middle colic vessels are ligated at their origins and the mesentery removed with the colon. For tumors located in the transverse colon, the middle colic vessel should be ligated before the bifurcation at the inferior border of the pancreas. It is probably best to avoid direct manipulation of the tumor during the dissection, but this is more a surgeon preference.

Mobilization of the right colon begins from the cecum toward the hepatic flexure. The colon is retracted medially so that electrocautery can be used to release the lateral peritoneal attachments along the line of Toldt. This can be accomplished by placing the left index finger behind the peritoneal attachments while using electrocautery above the finger.

Mobilization of the right colon is completed when the hepatic flexure is freed from the liver superiorly and from the duodenum posteriorly. The renocolic ligament that anchors the hepatic flexure may be thick and should either be tied with 2–0

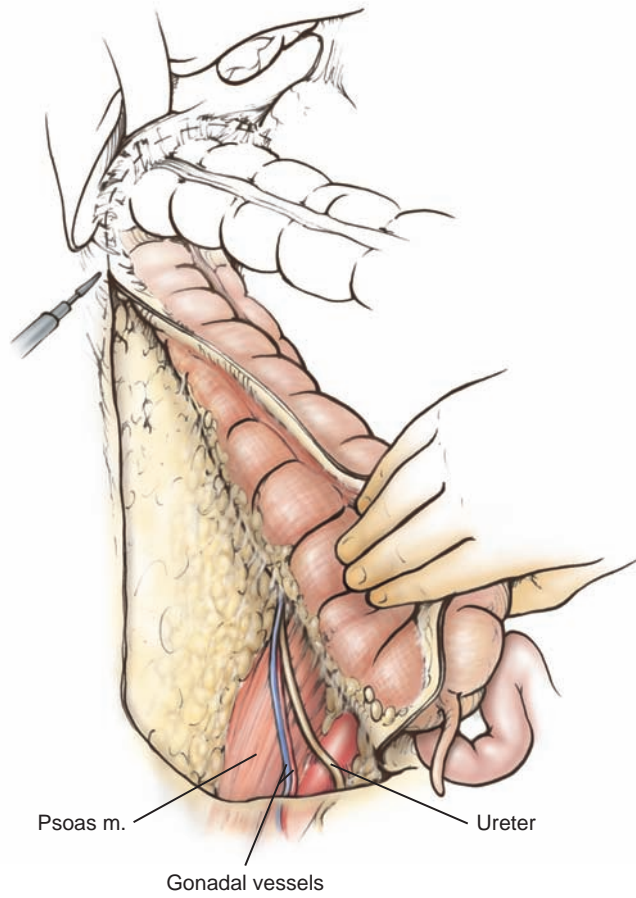


Figure 8.6

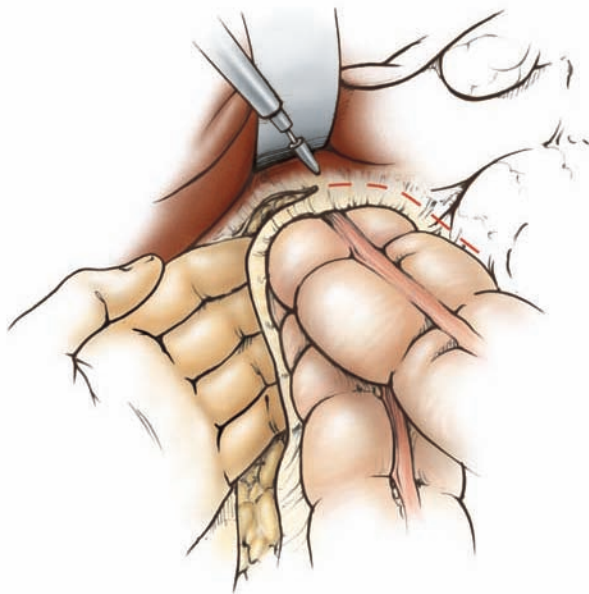


Figure 8.7

suture ligation, divided with ultrasonic shears or electrothermal bipolar device (LigaSure, Covidien, Boulder, CO). The gastrocolic ligament can be divided just below the gastroepiploic arcade of the stomach using the same energy sources. The omentum attached to the resected colon can also be taken with the specimen. There are three areas of caution during cephalad mobilization of the right colon: (1) excessive mobilization deep to the mesentery and entering Gerota's fascia, (2) avulsion of a collateral venous branch between the inferior pancreaticoduodenal and middle colic veins, and (3) injury to the second and third portion of the duodenum.

Caudal mobilization of the right colon includes the cecum and the ileum. The ileum can frequently be attached to the lateral peritoneal wall. The freed peritoneal edge can be divided using cautery, taking care not to raise the ureter and gonadal vessels. The right ureter should be readily visible as it courses from the posterior aspect of the duodenum towards the bifurcation of the iliac vessels.

The transverse colon can be divided with GIA cutting staplers, usually a blue load cartridge. Similarly the appropriate site of the ileum is divided with the same GIA stapler. The result is that the entire right colon is now attached only to its mesentery. The two major lymphovascular pedicles are the ileocolic and the middle colic vessels. The mesenteric peritoneum can be outlined by electrocautery from the cut end of the transverse colon to the ileum, much like a wedge. The apex of this wedge is the

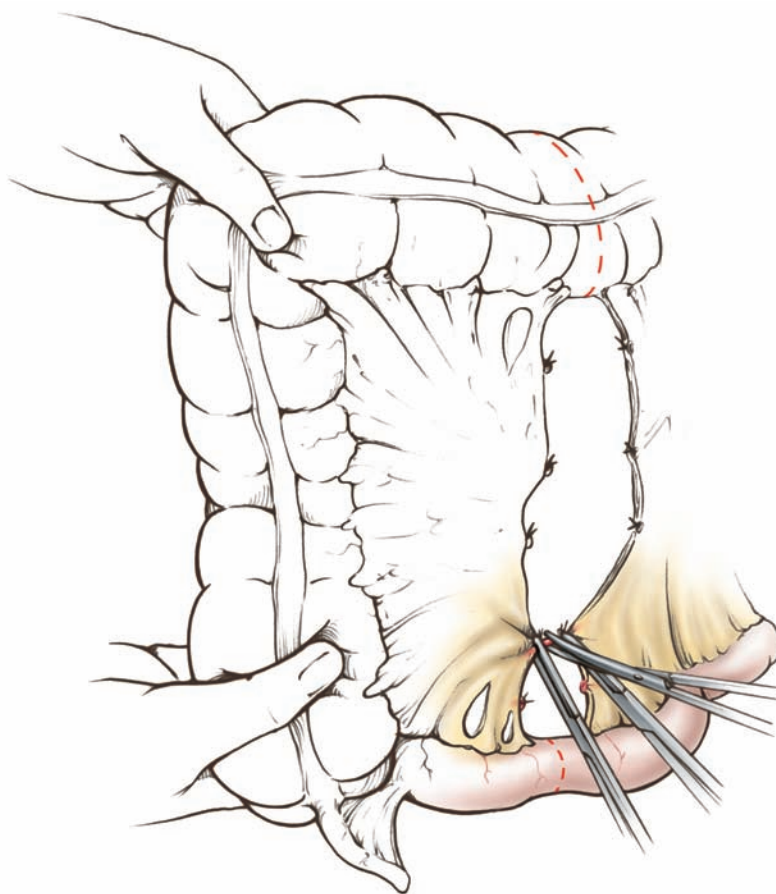


Figure 8.8

base of the ileocolic pedicle, which can be doubly ligated with 2-0 ties. The branch of the middle colic is also divided using similar technique. Once the vascular pedicles are divided, the remaining mesentery is divided by a series of double clamping and mesentery ligation using 2-0 or 3-0 ties. An alternative, but very efficient, method of dividing the mesentery is to ligate the lymphovascular pedicles and then divide the mesentery along the previous cautery outline using the LigaSure device. The LigaSure device is effective for sealing and dividing vessels that are up to 7 mm in diameter.

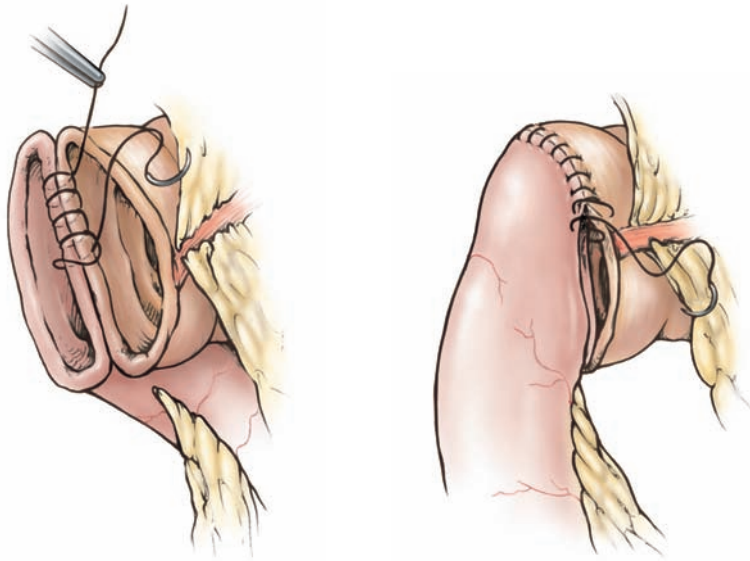


Figure 8.9

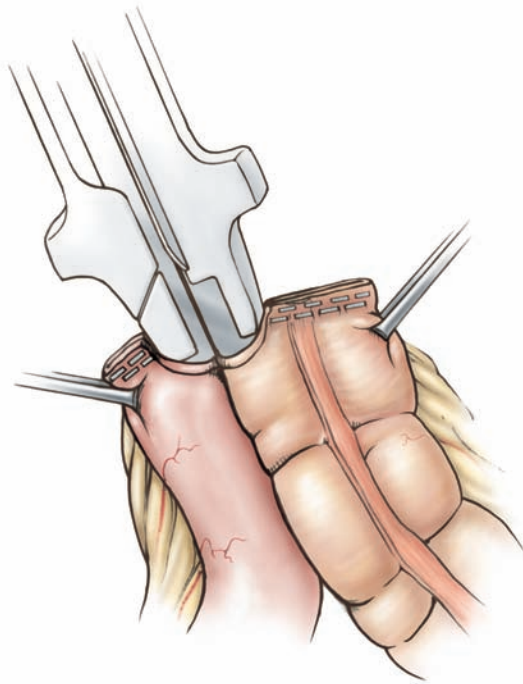


Figure 8.10

Intestinal continuity can be restored by hand-sewn (one- or two-layer) or stapled technique with equivalent functional results, but the stapled technique does save some time.

The stapled anastomosis begins by aligning the two ends of the bowel along the end of the antimesenteric borders. For the most part, spillage of bowel content is minimal during this procedure and therefore, it is not often necessary to place bowel clamps proximal and distal to the anastomosis. The antimesenteric corner of the staple line is excised on both bowel ends, and the forks of the blue-cartridge GIA instrument are inserted into the ileum and colon. On firing the instrument the internal staple line is checked for bleeding, and the resultant ileocolostomy edges are aligned using Allis clamps or anchored with stay sutures.

The opening of the ileocolostomy can be closed with a TA-55 stapler or simply with another blue-cartridge linear GIA. It is also acceptable to close the common opening using interrupted 2-0 or 3-0 sutures. The merits of closing the mesenteric defect are unknown, but a running 2-0 suture should suffice.

Laparoscopic Approach to Right Hemicolectomy

There are several variations to performing a laparoscopic right hemicolectomy. The peritoneal cavity is entered most commonly through the umbilicus, and the video scope placed through the umbilical port. A 10-mm port is placed in the mid-epigastrium and a 5-mm port is placed midway between the umbilicus and the pubic symphysis. Essentially, there are three trocars placed along the midline, or paramedian. The patient is supine, but the table is turned in the right-side-up position. The surgeons stand on the left side of the patient. One of the most certain methods to assure adequate lymphovascular isolation is to divide these pedicles first – a method commonly referred to as medial-to-lateral approach.

To identify the ileocolic pedicle, the right colon is retracted away from the midline and the ileocolic pedicle becomes visible as a pulsatile ridge. The mesenteric window at the vascular base is opened to either side of the pedicle and a white vascular

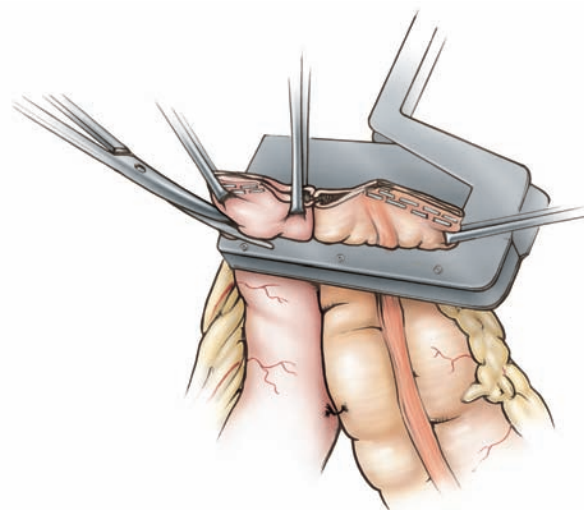


Figure 8.11

endoscopic GIA stapler is used to divide the pedicle. Once divided, the ileocolic pedicle is lifted anteriorly like a handle, and blunt dissection along the avascular retroperitoneal plane is achieved by lifting the mesentery, while simultaneously sweeping the retroperitoneum posteriorly. This can be accomplished without any energy source. The ultimate landmark of the cephalad dissection is to identify the duodenum and remain anterior to the duodenum. By heeding this landmark, the duodenum and the ureter posterior to it remain safe. The right branch of the middle colic or the root of the middle colic can be divided at this juncture using vascular staplers. Again, if the vessels are less than 7 mm, the LigaSure device may be used. The transverse colon can be divided by an endoscopic GIA stapler. The caudal dissection is performed by the same technique towards the ileum, staying in the avascular plane. By using the lymphovascular pedicle as a handle and sweeping the retroperitoneum down and posterior, the ureter and gonadal vessels remain in the retroperitoneum. The remainder of the mesentery can be divided using the LigaSure device from the middle colic pedicle down to the ileum. The ileum is divided using an endoscopic GIA stapler. The remaining attachments of the colon are the gastrocolic ligaments and the lateral peritoneal attachments. It is advantageous to leave these attachments until the final stages because they hold the colon in position while focus is on the lymphovascular pedicles. (NOTE: If the laparoscopic approach began by mobilizing the lateral attachments, it becomes difficult to identify the base of the vascular pedicles as the colon collapses over its mesentery.)

The resected colon can be removed at any time through the umbilical port, which is extended to approximately 3 cm and a wound protector is placed within it. To create the ileocolic anastomosis, it is possible to bring both barrels of the bowel out through the protected umbilical port and perform the anastomosis as in the traditional open technique. However, an intracorporeal anastomosis results in the least manipulation and especially when the transverse colon or the descending colon (in the case of an extended right hemicolectomy) cannot be exteriorized.

For an intracorporeal anastomosis, the terminal ileum is placed side-by-side in isoperistaltic fashion. A stay suture can be used to align the two barrels of the bowel. Small enterotomies are made with electrocautery in the ileum and the adjacent colon to accommodate the white-cartridge endoscopic GIA that forms the common ileocolostomy. It is advisable to use a 45-mm or 60-mm long endoscopic stapler for maximum stomal diameter. The opening of the ileocolostomy may be closed by another endoscopic GIA either in transverse fashion or longitudinal fashion. Alternatively, the opening can be closed with single-layer interrupted or double-layer running sutures.

For extended right hemicolectomy, we prefer to bring the ileum directly to the proximal descending colon and not to the splenic flexure to avoid the risk of involving the watershed area.

Whether to close the mesenteric defect or not remains a topic of debate, but should be managed the same way as one would for open surgery.

Tumors of the distal transverse colon, splenic flexure, descending colon require a left hemicolectomy. The left hemicolectomy specimen includes the distal transverse

**Left
Hemicolectomy**

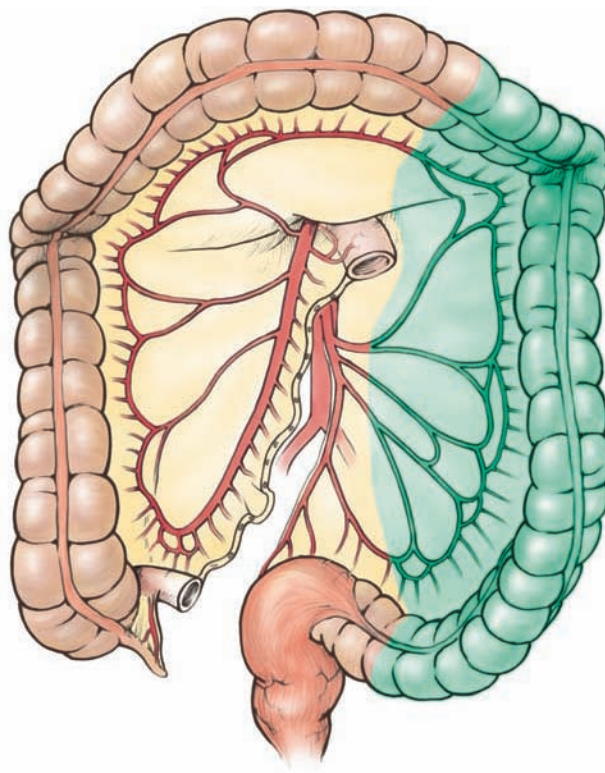


Figure 8.12

colon and the descending colon down to 2–3 cm above the sacral promontory. No presacral elevation of the rectal stump is necessary and the anastomosis is intraperitoneal. The standard vertical midline incision from the epigastrium is most commonly used, which also facilitates splenic flexure mobilization.

A mechanical retractor such as the Thompson or Bookwalter greatly enhances exposure, particularly for splenic flexure mobilization. The small intestines are exteriorized and wrapped in moist laparotomy pads. The left colon is reflected medially, exposing the white line of Toldt. This lateral peritoneal fold is sharply incised using an electrocautery or scissors, and the opening is extended from the sigmoid colon to the splenic flexure. At the splenic flexure, mobilization should follow the edge of the colon and its curve to avoid injury to the spleen. For all practical purposes, the renocolic, splenocolic, and pancreaticocolic attachments are bundled into one avascular structure that makes up the anchor of the splenic flexure. Blunt dissection of the renocolic ligament often avulses the veins on the surface of Gerota's fascia. The left colon is distracted inferiomedially and any attachment divided using cautery or scissors. Free the omentum from the distal 8–12 cm of the transverse colon.

If the tumor is at the splenic flexure or the distal transverse colon, the omentum can be incorporated in the specimen. Once the splenic flexure is mobilized from the direction of the paracolic gutter, the gastric colic ligament is divided toward the splenic flexure to free the distal transverse colon. The final aspect of freeing the splenic flexure from the posterior attachments is most easily accomplished with one surgeon placing the splenic flexure of the colon between the left thumb and index finger and thinning out the tissues while the assistant uses cautery to divide the attachments.

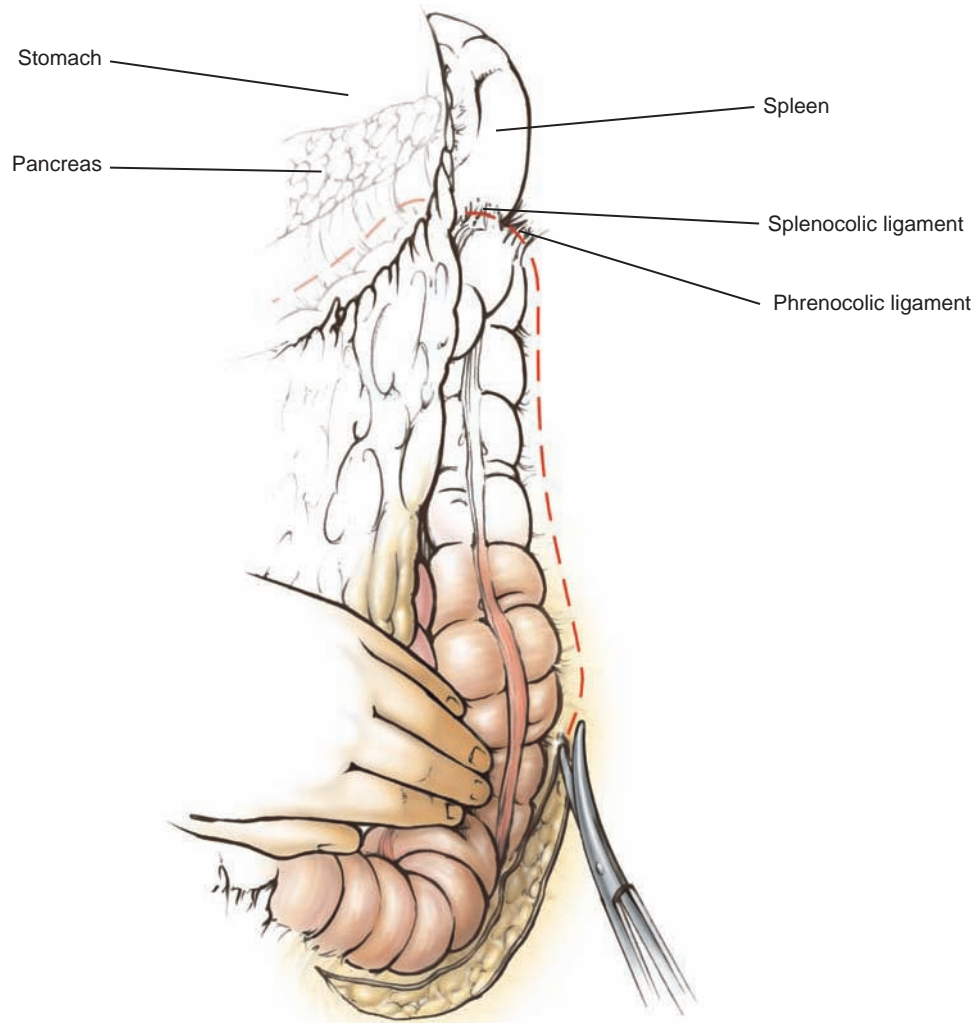


Figure 8.13

Once the splenic flexure is mobilized, the retroperitoneal attachments from the sigmoid colon to the transverse colon can be swept posteriorly, giving view of the ureter and gonadal vessels.

The medial aspect of the mesocolon is marked by cautery from the level of the duodenum down to the sacral promontory. The inferior mesenteric artery is skeletonized and ligated with 2-0 ties and divided, leaving a stump off the aorta of approximately 1.5–2.0 cm to avoid injury to autonomic nerve fibers. The inferior mesenteric vein is ligated near the ligament of Treitz. The transverse colon and descending colon are divided using blue-cartridge GIA cutting staplers. The mesentery between the two cut ends of colon are divided to include the marginal arteries using standard clamp-and-tie techniques, having constant awareness of the course of the ureter. The LigaSure device can be used to divide the mesentery in place of the clamp-and-tie technique.

An anastomosis between the transverse and sigmoid colons can be stapled or hand-sewn. At the outset of stapling, the two ends of the bowel lumens are aligned along the antimesenteric border using stay sutures. The antimesenteric corners of the

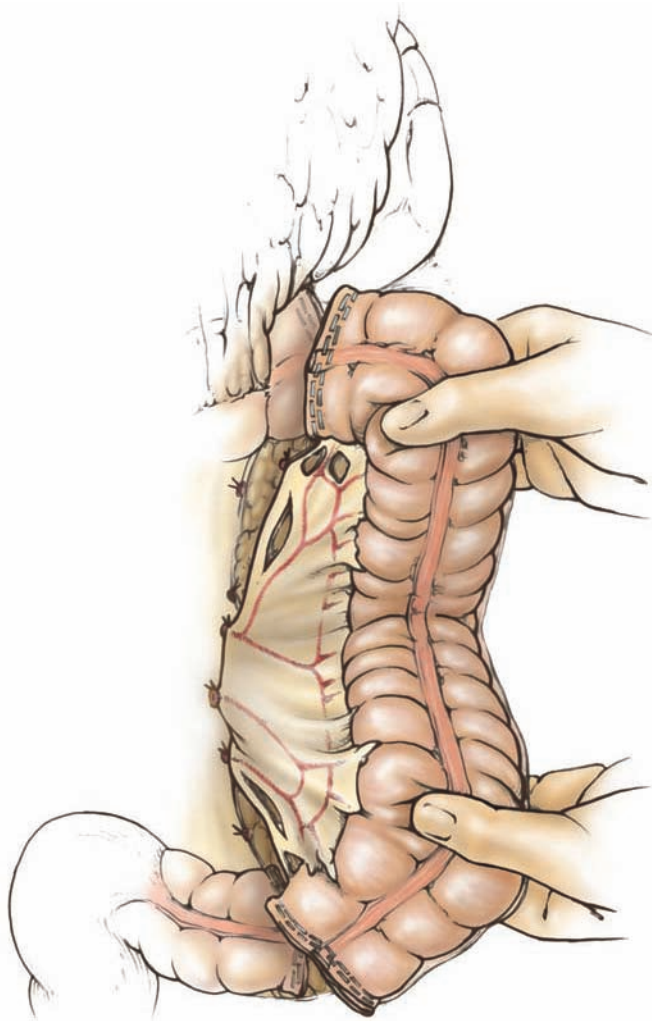


Figure 8.14

GIA staple lines are removed with scissors, and the forks of the GIA are inserted into the bowel lumen and the instrument fired. After inspection of the anastomosis the ostomy is closed with another GIA cutting stapler.

Alternatives to stapling can include a single-layer interrupted end-to-end or side-to-end (Baker's) anastomosis using 3–0 sutures. A two-layer anastomosis is sometimes used.

Rectosigmoid Colectomy

While left colon resections usually encompass portions of the sigmoid colon, lesions amenable to sigmoid resection, which extend from the lower portion of the descending colon to the level of the sacral promontory, are located at the proximal two-thirds of the sigmoid colon. When a sigmoid tumor crosses the pelvic brim, additional challenges can arise involving the bladder, ovaries, uterus, or distal ureter. Typically, lesions of the proximal sigmoid would require an anastomosis between the descending colon and the distal sigmoid. Lesions of the distal sigmoid would require an anastomosis between the proximal sigmoid and the upper rectum. Lesions of the middle sigmoid would depend on the redundancy of the colon.

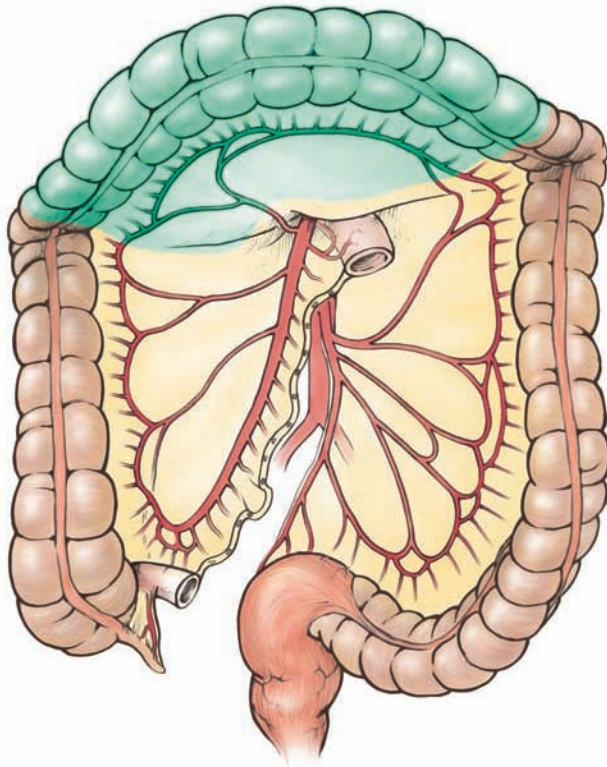


Figure 8.15

Sigmoid colon tumors can be approached through a standard midline incision, being ready to mobilize the splenic flexure if necessary. Whenever it is anticipated that the anastomosis will approach the pelvic brim, it is advisable to place the patient

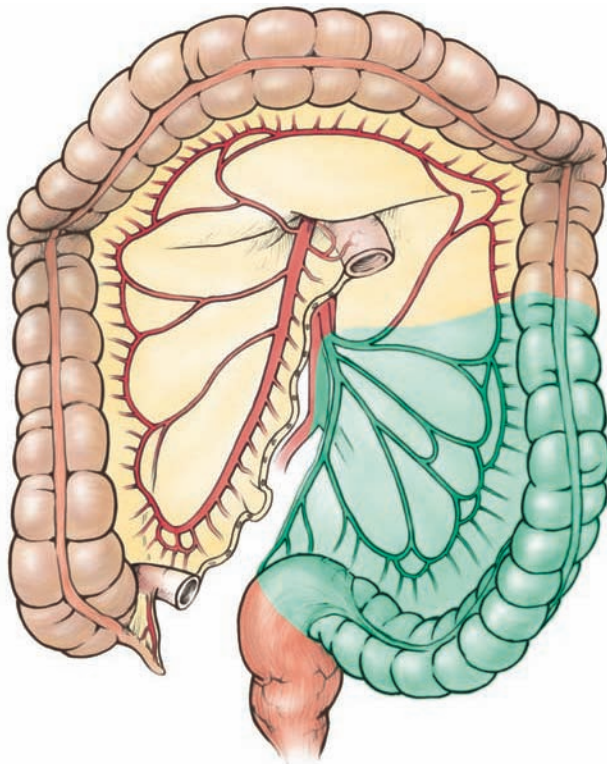


Figure 8.16

in the supine modified lithotomy position with Allen stirrups so that the anal canal is accessible for possible circular stapled anastomosis or proctosigmoidoscopy.

Mobilization of the left colon and splenic flexure from the lateral peritoneal wall is accomplished by medial retraction of the colon and a combination of blunt finger dissection and sharp dissection with an electrocautery or scissors. The sigmoid colon is retracted medially and mobilized from its lateral attachments down to the rectosigmoid junction. The ureter is identified as it courses over the iliac vessels along the pelvic wall.

The lymphovascular pedicles that are divided as part of a rectosigmoid colectomy depend on the portion of the sigmoid colon involved. Lesions at the proximal sigmoid colon may require ligation at the root of the inferior mesenteric artery. Middle or distal sigmoid lesions may be treated by ligating the inferior mesenteric artery distal to the left colic artery. Obviously, ligation of the main trunk of the inferior mesenteric artery would make splenic mobilization necessary and absolute confirmation of pulsatile blood supply of the descending colon prior to anastomosis.

Restoration of bowel continuity is undertaken with an end-to-end or side-to-end anastomosis using either a hand-sewn or stapled technique. The hand-sewn technique involves either one or two layers. If there is adequate redundancy, a side-to-side stapled anastomosis can be performed as described for left hemicolectomy.

In cases where the anastomosis is being formed with the rectum, a circular stapled technique with a 29-mm or 31 mm EEA may be appropriate. However, when the rectal stump is long and the presacral space is still undisturbed, it is difficult to pass the EEA stapler to the level of anastomosis. In such instances, primary hand-sewn anastomosis or intra-abdominal stapling techniques are more appropriate.

The mesocolic defect may be closed with running sutures, but this may not be an easy task. In several hundred cases of left and sigmoid colectomy without mesocolic closure, we have not encountered any bowel obstructions from internal hernias.

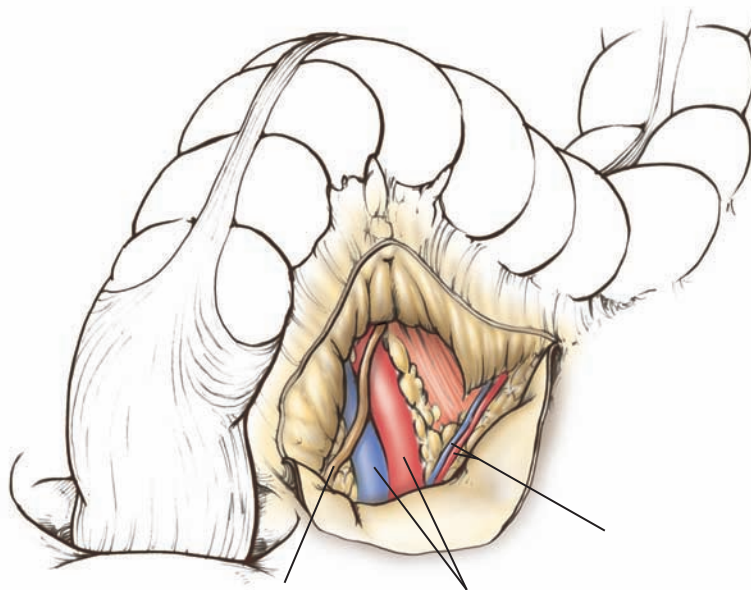


Figure 8.17

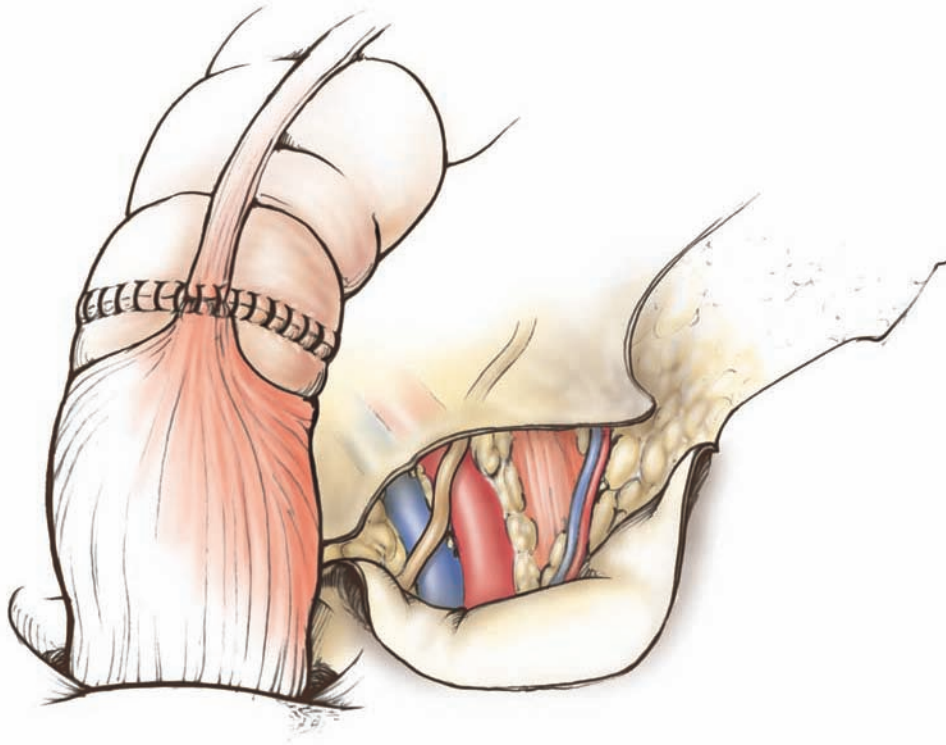


Figure 8.18

Technical pitfalls that are more relevant to left and sigmoid colectomy include splenic capsule avulsion, ureteral injury and anastomotic failure secondary to tension or poor blood supply.

Laparoscopic Left and Sigmoid Colectomy

There are variations to laparoscopic left and sigmoid colectomy, but the setup is similar. The techniques for distal descending and sigmoid tumors are the same. A commonly used approach is the hand-assisted technique with a hand-assist port placed through a midline periumbilical incision. The patient is in the modified lithotomy position with Allen stirrups. The other laparoscopic approach performs the entire dissection, resection, and anastomosis intra-abdominally with the video-scope placed through the umbilicus and operating ports placed to each side of the patient's abdomen. An angled videoscope is used. A mechanical arm is of value in holding the videoscope. The left side of the table is turned up. When the dissection is in the pelvis, the patient is in the steep Trendelenberg position, but reversed when the dissection is toward the splenic flexure.

As with right hemicolectomies, one technique to assure adequate lymphovascular pedicle ligation is to perform a medial-to-lateral ligation of the inferior mesenteric artery branches. The divided pedicle is lifted up away from the retroperitoneum and another dissecting instrument is used to sweep the retroperitoneal structures away. This dissection occurs in an avascular plane toward the pelvis. The ureter and the gonadal vessels will come into view. For tumors of the sigmoid colon, the retroperitoneal dissection is performed toward the pelvis once the inferior mesenteric artery

is ligated distal to the left colic artery with a vascular load endoscopic stapler. The proximal portion of the rectum is mobilized and the distal colon is transected at that level with blue-load endoscopic GIA staplers. The proximal aspect of the sigmoid colon is divided with endoscopic GIA staplers at the descending colon. The lateral attachments of the sigmoid colon are avascular and divided using cautery scissors. Virtually all sigmoid colectomies require mobilization of the descending colon, but not all will require splenic flexure mobilization.

If the tumor is in the proximal descending colon or splenic flexure, the left colic vessel is divided first with hemoclips, bipolar electrocautery or a vascular stapler. The pedicle is lifted up away from the retroperitoneum and a blunt dissecting instrument sweeps the retroperitoneal attachments posteriorly in a cephalad direction. This maneuver will lead directly to the distal half of the transverse colon, to the left of the duodenojejunal junction. A window is made in the transverse mesocolon and blue-load endoscopic GIA staplers are used to divide the distal transverse colon. The distal descending colon can be divided with the same stapler. The base of the mesentery and the inferior mesenteric vein can easily be divided using the LigaSure device. The lateral attachments of the bowel and the splenic flexure are mobilized using cautery scissors and the LigaSure device in a manner very similar to the open technique. Awareness of the course of the ureter and gonadal vessels are important.

Common pitfalls that increase the complexity of a laparoscopic operation include undermobilizing the lateral and splenic flexure attachments resulting in anastomotic tension or inadequate oncologic margins, and entering a deeper retroperitoneal plane and encountering bleeding from retroperitoneal veins and lumbar vessels. (NOTE: This approach for oncologic laparoscopic left colon and sigmoid colectomy is very different from the approach for benign diseases such as diverticulitis.)

Colon continuity is typically restored using either a side-to-side intracorporeal anastomosis or by circular EEA staplers. The side-to-side anastomosis is suitable for transverse or descending colon to sigmoid anastomosis. To augment the length of the colon, the gastrocolic ligaments will need to be divided. Stay sutures are used to bring the two barrels of the bowel in antemesenteric alignment. Cautery is used to make small colotomies in each barrel of the bowel so that blue-load endoscopic cutting GIA staplers can be used to form the common channel. The ostomy is closed using running sutures or another GIA stapler.

For descending colon to rectum anastomosis, the umbilical port is enlarged to 3 cm and the descending colon exteriorized through a wound protector. The transected edge of the distal colon is opened and the anvil of the EEA stapler is inserted into the opening. A purse-string suture using 3-0 PDS is used to close the colotomy around the spike of the anvil in preparation for an end-to-end stapled anastomosis. The colon with the anvil is returned to the abdominal cavity. The resected bowel specimen can also be brought out of the abdominal cavity at this time. The stapler is introduced in the rectum by the assistant and the spike introduced through the rectal stump. The anvil and the stapler are engaged, closed and fired. The anastomosis is tested by insufflation and direct inspection with a proctosigmoidoscope. Drains are not necessary when the presacral space remains undisturbed.

The extended umbilical fascial incision is closed with heavy absorbable sutures such as running Number-1 PDS.

A subtotal colectomy for cancer consists of removal of the entire intraperitoneal colon, and is often required for multiple polyps that are not amenable to endoscopic resection or the presence of synchronous tumors. A standard midline incision initiates the subtotal colectomy. The operation commences usually with mobilization of the lateral attachments beginning at the cecum. The lateral peritoneal attachments of the right colon are mobilized. The colon itself is mobilized from the duodenum at the level of the hepatic flexure, and the hepatocolic ligament is sharply divided. The omentum is usually taken with the specimen by dividing the gastrocolic ligaments along the length of the transverse colon. The mobilization continues around the splenic flexure and along the lateral peritoneal reflections of the descending colon and is completed at the rectosigmoid junction. However, in order to use the circular EEA stapler for anastomosis, the proximal rectum needs to be mobilized off the presacral space.

The margins for bowel transection are determined after complete mobilization. A GIA cutting stapler is used to divide the terminal ileum 4 cm proximal to the ileocecal valve; the distal point of transection is usually at the proximal rectum with a TA-55 stapler. To assure adequate lymph-node harvest, the named segmental arteries are ligated at their origins. Mesenteric ligation is best accomplished with an assistant holding the bowel segment anteriorly while the surgeon divides the mesenteric

Subtotal Colectomy

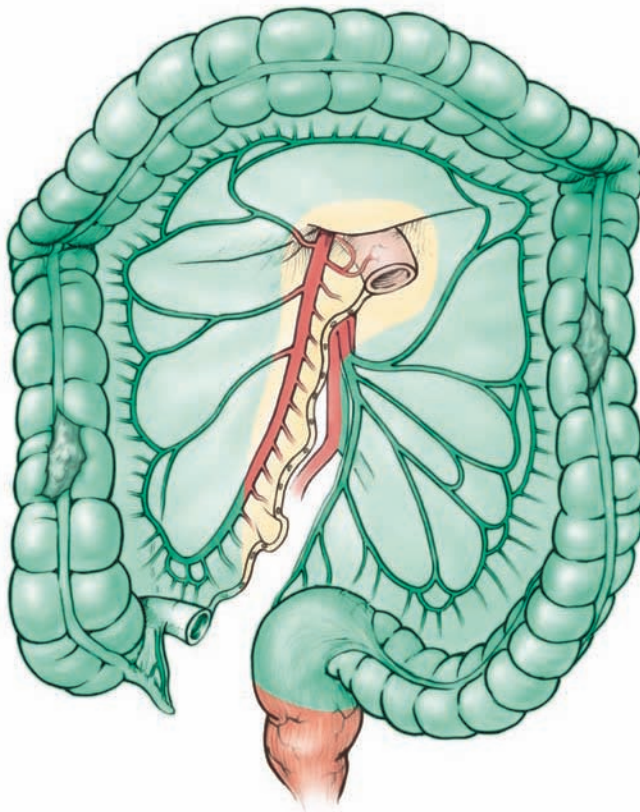


Figure 8.19

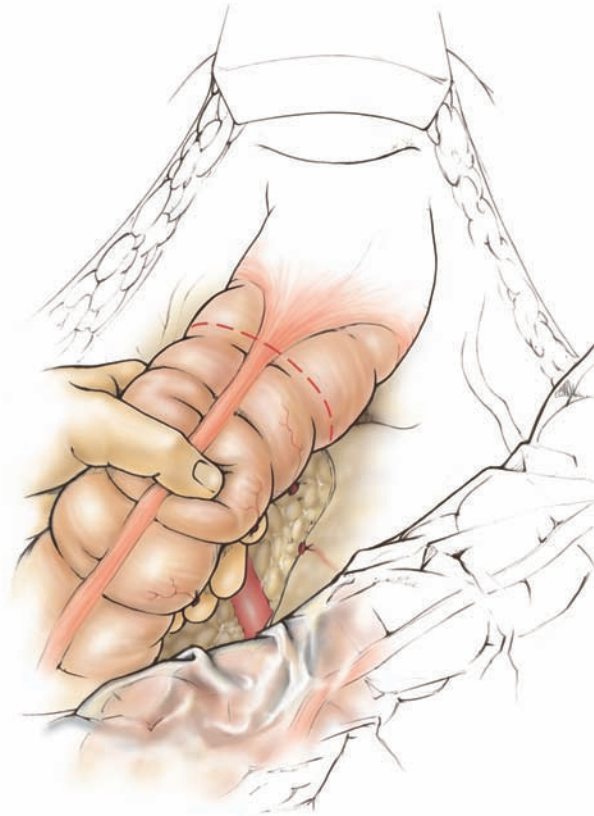


Figure 8.20

vessels with suture ligation, or with the LigaSure. The same technical pitfalls for right and left colectomy described previously apply.

Restoration of gastrointestinal continuity requires an anastomosis between the ileum and the rectum, completed with a hand-sewn technique in single layer using interrupted 3-0 or 4-0 sutures. However, a side-to-end anastomosis using the circular EEA stapler is an excellent method of creating an anastomosis. A side-to-end anastomosis is preferable to compensate for the lumen disparity between the ileum and the rectum.

Laparoscopic-Assisted Subtotal Colectomy

Laparoscopic subtotal colectomy for oncologic therapy can be cumbersome given the multiple quadrants that the colon resides. It is probably more practical and time-saving to use a hand-assist port. In patients without extensive intra-abdominal fat, it is more feasible to laparoscopically divide the three main vascular pedicles; ileocolic, middle colic, and inferior mesenteric arteries followed by dividing the ileum and rectosigmoid junction, LigaSure applied to the base of the mesentery and finally, divide the lateral attachments. In patients with significant intra-abdominal fat, we have used laparoscopic methods to mobilize the splenic flexure, transverse colon, and hepatic flexure followed by extending the midline incision to complete the remainder of the procedure with a smaller abdominal incision.

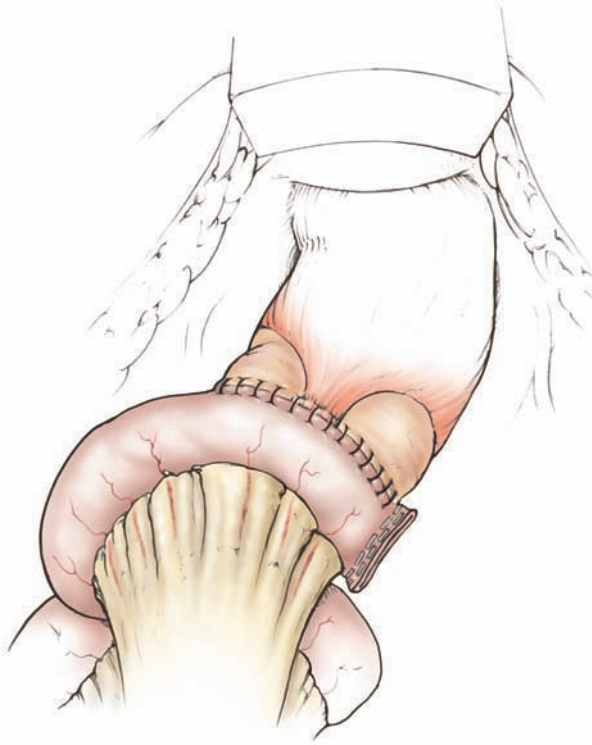


Figure 8.21

To restore intestinal continuity, we prefer the side-to-end anastomosis between the ileum and the rectum.

Appendix

Surgical Anatomy

The appendix extends from the base of the cecum as a long tube with varying length, but averages about 9–10 cm. While the base of the appendix emerges at the convergence of the teniae coli, the tip of the appendix can be found in various positions. The retrocecal location is the most commonly encountered position of the appendix. The appendix is typically located inferior and posterior to the fold of Treves, a triangularly shaped antimesenteric epiploic appendage that marks the junction of the ileum and the cecum. The fold of Treves is useful in identifying the appendix when using small-incisions, and can frequently be used to locate the appendix on computer tomography.

Topography

The appendiceal artery is a branch of the ileocolic artery that runs through the mesoappendix.

Blood Supply

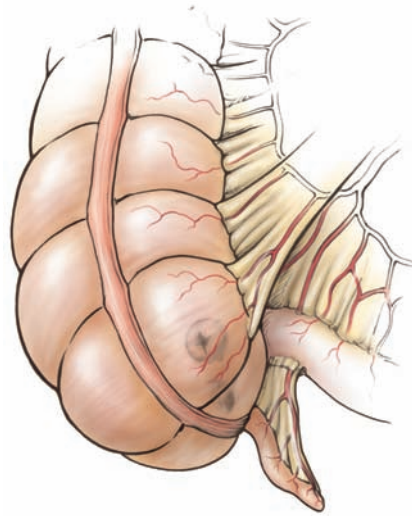


Figure 8.22

Nerve Supply The appendix is innervated by both the parasympathetic and sympathetic divisions of the autonomic nervous system, duplicating the innervation of the cecum.

Lymphatic Drainage Lymphatic drainage from the appendix is encompassed in the right colon distribution.

Surgical Applications

Malignant tumors arising from the appendix are rare. Carcinoids are the most common appendiceal neoplasm, and are often found incidentally during appendectomy for acute appendicitis. When carcinoids exceed 2 cm in size, malignancy risk increases and a formal right hemicolectomy is indicated. In carcinoid tumors smaller than 2 cm and localized, only a simple appendectomy is needed.

Adenocarcinomas are more inclined to produce symptoms than carcinoids are. The common histologic variants of adenocarcinoma are well-differentiated or mucin-producing tumors (malignant mucocoele) or poorly differentiated adenocarcinomas. Both of these lesions can metastasize to regional nodes and distant sites. Adequate treatment requires a mesenteric resection encompassing the primary nodal drainage system. If the diagnosis of an adenocarcinoma is made incidentally, as in an appendectomy specimen, subsequent right hemicolectomy offers the greatest curative potential.

In summary, right hemicolectomy is indicated if the appendiceal tumor is an adenocarcinoma, mucin-producing tumors, has lymphatic invasion or direct invasion of the serosa or mesoappendix.

Incision for Appendectomy The terms Rockey-Davis and McBurney's incisions are probably of historical interest, with most surgeons describing their technique as some variation of a right lower quadrant incision (e.g., curvilinear, transverse, oblique). Classically, a transverse incision of approximately 6 cm is made at one-third the distance from the anterior

superior iliac spine to the umbilicus. Obviously, in very obese patients, this landmark is not feasible and for such patients, a laparoscopic appendectomy may be desirable. The dissection is carried down through the subcutaneous fat until the external oblique aponeurosis is identified and an incision is made along the grain of its fibers. The underlying muscle layers are split (without cutting) using two Kelly clamps alternatingly opened in perpendicular directions until the peritoneum is visible. The peritoneum is incised with Metzenbaum scissors to enter the abdominal cavity.

In cases where malignancy or perforation is suspected, a wound protector may be advantageous to reduce surgical site infections, and the theoretical possibility of tumor implants within the incision.

After the peritoneum is opened, the appendix is identified by following the cecal taenia distally, and the cecum and appendix are delivered into the wound by gentle traction. Occasionally the lateral peritoneal reflection of the cecum is divided to improve exposure. These maneuvers should bring the cecum and appendix to the anterior abdominal wall, facilitating removal without vigorous retraction. Freed from any attachments, the mesoappendix can be identified, divided between clamps, and ligated to control the appendicular artery.

In perforated appendicitis, when the wound is contaminated, it is still best to leave a portion of the skin wound open for secondary closure. Most appendectomies do not require postsurgical drainage.

Once the appendix is delivered out of the abdominal cavity, the base of the mesoappendix can be ligated using a clamp and dividing between 2-0 or 3-0 silk or absorbable ties. It is also possible to ligate the mesoappendix using bipolar energy sources such as the LigaSure device (Covidien, Boulder, CO). Once the appendiceal mesentery and artery are ligated, the appendix can be divided.

Appendectomy

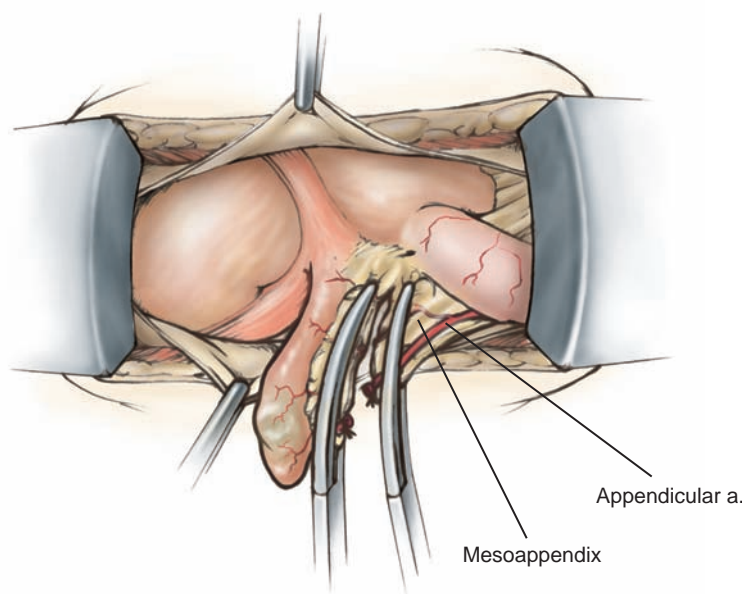


Figure 8.23

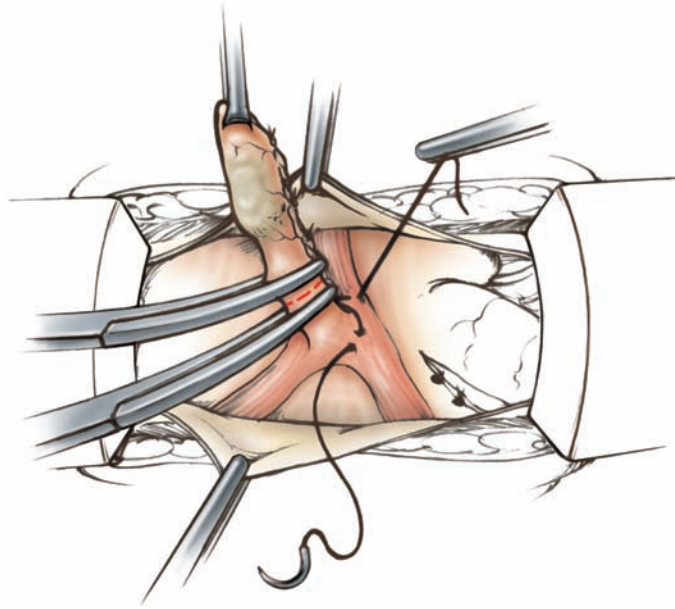


Figure 8.24

To divide the appendix, a straight hemostat can be applied to its base 5–10 mm from the cecum. The appendix can be transected with a blade above the hemostat, and 2–0 silk or absorbable ties applied below the hemostat. We prefer a double tie in case one tie slips. Some surgeons advocate applying cautery to the appendiceal stump mucosa to mitigate risks of mucocoele formation.

If the surgeon wishes to invert the appendiceal stump, a Z-stitch is then placed as a Lemberg suture in the cecum, around the base of the appendix. Prior to tying the suture, the appendix is inverted into the cecum with a clamp or forcep, and the suture is tied down, leaving the stump inverted. An alternative to the Z-stitch is to perform a purse-string suturing around the base of the stump.

There is no proven advantage or disadvantage to stump inversion or cauterizing the mucosa, and the divided appendix can simply be left alone. Pitfalls and dangers to appendectomy are the finding of inflamed cecum, possibility of cecal Crohn's disease, and poor vascular control in edematous mesoappendix. In cases where the bleeding vessel is not visible, it is advisable to perform suture ligation.

Laparoscopic Appendectomy

Laparoscopic appendectomy can be performed by multiple trocars or through a single incision in the umbilicus. The patient is positioned supine, with the operating table oriented partially in Trendelenberg and right-side up. At least one trocar should be a 10-mm trocar. The base of the appendix is identified and a window is made at the base of the mesoappendix adjacent to the appendix using dissecting forceps. The window should be large enough to accommodate a blue endoscopic cutting stapler to divide the appendix at its base. The mesoappendix can be divided with a vascular-load endoscopic cutting stapler, the Ligasure bipolar cautery, or a

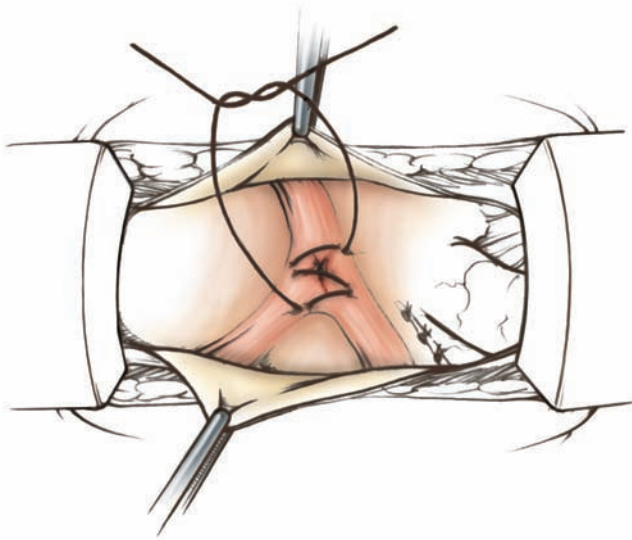


Figure 8.25

preformed tie. The specimen can be retrieved lengthwise out of the 10-mm trocar or with a specimen retrieval bag.

A pitfall of laparoscopic appendectomy, especially when a retrocecal appendix is encountered, is leaving a residual appendical stump that is too long, or encountering inflammation close to the base of the appendix. With the use of endoscopic cutting staplers, it is appropriate in the latter circumstance to divide a cuff of healthy cecum along with the appendix specimen.

Anatomic Basis of Complications

- Right colectomy
 - Injury or inadvertent ligation of superior mesenteric vessels.
 - Injury to the retroperitoneal duodenum, for both laparoscopic and open approaches.
 - Injury to the right ureter if dissection of the mesentery is deeper than the avascular plain.
 - Avulsion of venous branch between inferior pancreaticoduodenal and middle colic veins, particularly in aggressive medial retraction during open colectomy.
 - Lateral colon mobilization enters retroperitoneal fat and the kidney.
- Left colectomy
 - Excessive traction on the descending colon before dividing the lineocolic ligaments can cause splenic capsule laceration.

- Inadequate mobilization of colon length creates tension at an anastomosis and increases the risk of leakage.
- Injury to the left ureter if dissection is carried deeper than the avascular plain.
- Laparoscopic dissection deep into lumbar vessels.
- Rectosigmoid colectomy
 - Presacral hemorrhage
 - Injury to ureters as they cross over the ileac vessels.
 - Anastomotic tension from failure to mobilize splenic flexure.

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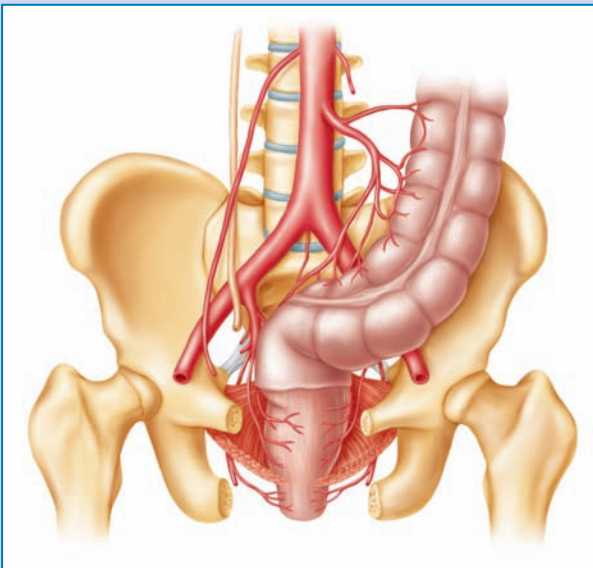
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Rectum

Charles A. Staley

William C. Wood



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Introduction

Rectal tumors account for a significant part of a surgeon's practice, and gaining exposure to the distal rectum, especially in the narrow male pelvis, poses a formidable challenge. Forty-one thousand new rectal tumors are diagnosed in the United States annually. These are more common in males than females, with a ratio of 1:0.73. The risk of adenocarcinoma of the rectum increases with each year of age. Other tumors can also develop in and about the rectum. These tumors raise both patient and surgeon concerns about tumor control and cure, and anxiety regarding the morbidity of rectal surgery. Fear of colostomy is mingled with fear of fecal or urinary incontinence and, for male patients, impotence as well. In addition to the adenocarcinoma of the rectum, squamous cell carcinoma of the anus, basaloid tumors, melanomas, and sarcomas of the supporting structures also require detailed knowledge of the anatomy of the region, and the possible routes of local and regional spread.

The goals of treatment of a patient with rectal cancer are controlling the local disease, preventing distant spread, restoring bowel continuity and maintaining normal anal continence, preserving sexual and bladder function and minimizing treatment related morbidity and mortality. Choice of treatment depends on clinical staging, closeness to the anal verge, imaging studies that may include endorectal ultrasonography (EUS), CT, MRI, and PET scanning, histopathology of the lesion, technical considerations, and the patient's operative risks and comorbidities. A clear understanding of the tumor biology along with the precise anatomy significantly influences the results of surgical procedures in the rectum. Improved surgical techniques and multidisciplinary treatment of rectal cancer have steadily improved patient survival and quality of life through sphincter preservation.

Surgical Anatomy

The anorectum is commonly visualized in terms of the "rule of four." The first 4 cm from the anal verge comprise the anal canal; the next three 4 cm sections make up the lower, middle, and upper thirds of the rectum. These dimensions are approximately correct when the rectum is either stretched from above or lifted with a rigid proctoscope. If the rectum is collapsed into the sacral hollow, however, these lengths are exaggerated, and 3 cm each would be a better estimate of the lower, middle, and upper thirds. These distances also correspond to the transverse folds of the rectum (valves of Houston): the left superior, right middle, and left inferior.

Three histologic patterns define the anal canal. The cutaneous zone of the perianal skin up to the anal verge (anocutaneous line) is covered by pigmented skin with

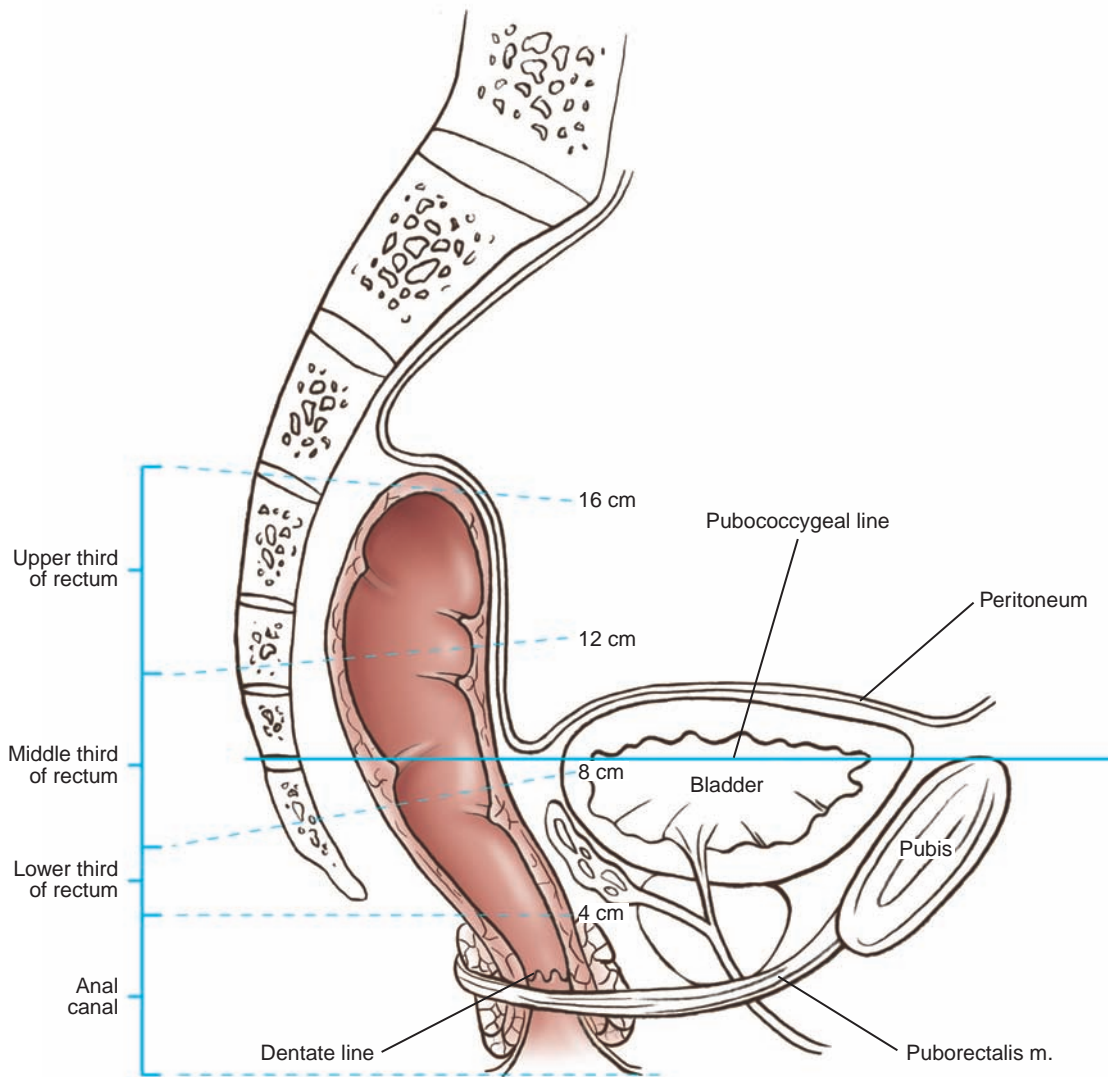


Figure 9.1

hair follicles and sebaceous glands. Above the anal verge is the transitional zone, with modified skin containing sebaceous glands, but no hair follicles. This lining extends to the pectinate line defined by the anal valves. Above that line begins the true mucosa of the anal canal. The pectinate line is a topographic feature formed by small mucosal pockets between the vertical folds of mucosa known as the anal columns of Morgagni. These extend upward from the pectinate line to the upper end of the surgical anal canal at the puborectalis sling. Their appearance derives from vertical bundles of the muscularis mucosae. The actual junction of the stratified squamous and columnar epithelia is just above the pectinate line, and this is the true mucocutaneous junction. The pectinate line marks the transition from the visceral tissues above and the somatic tissues beneath.

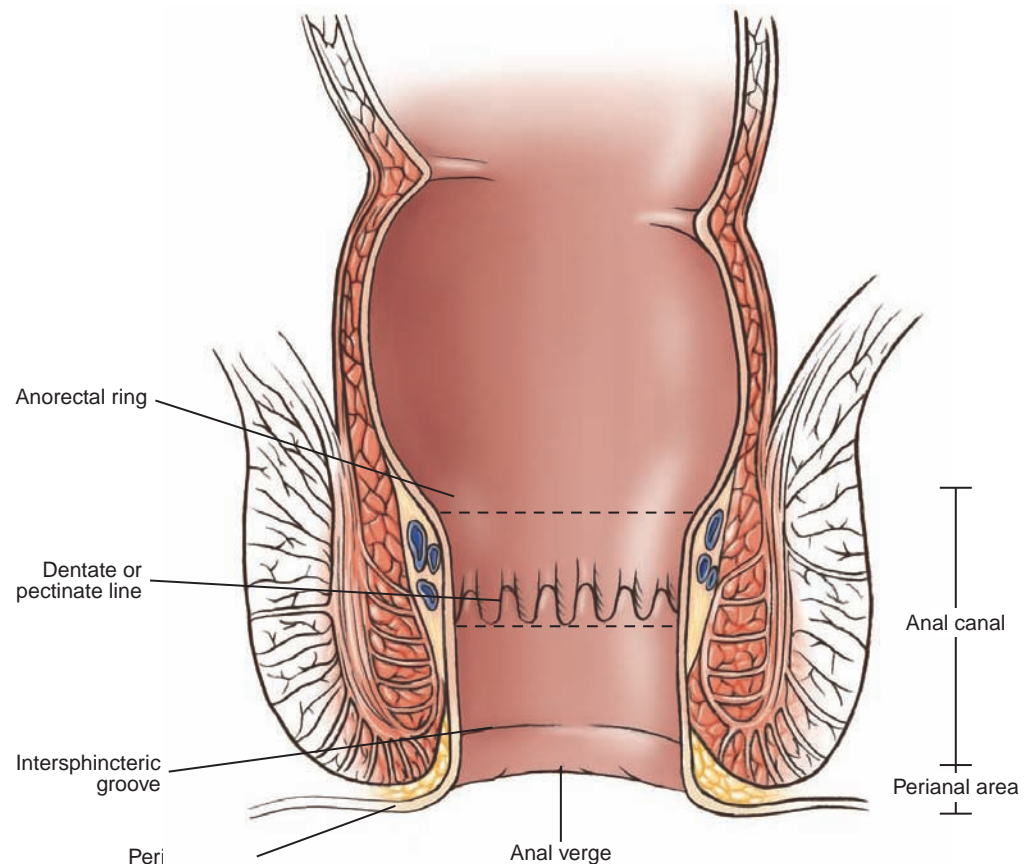


Figure 9.2

Blood Supply

Arterial supply, but more significantly the venous and lymphatic drainage vessels and nerve supply, all change at the level of the pectinate line. The blood supply to the anorectum is derived from the superior rectal artery, the lowest extension of the inferior mesenteric artery. The middle and the lower portions of the anorectum are supplied by branches of the hypogastric artery, specifically the middle rectal and inferior rectal arteries, which branch off the internal pudendal artery. The middle rectal artery is occasionally absent, and it has also been found to arise from the inferior vesicle or internal pudendal artery. This usually poses no problem to the surgeon.

The inferior rectal artery, which arises from the internal pudendal artery, may be confused because of varying origins of that vessel. It may arise in common with the obturator or the umbilical artery. The inferior rectal artery is not a dominant single trunk but a series of small unnamed branches that supply the lower part of the levator ani, the sphincter muscles, and the lower anorectum. These vessels and their relationship to the pudendal nerves and inferior rectal nerves are demonstrated in the female and the male perineum.

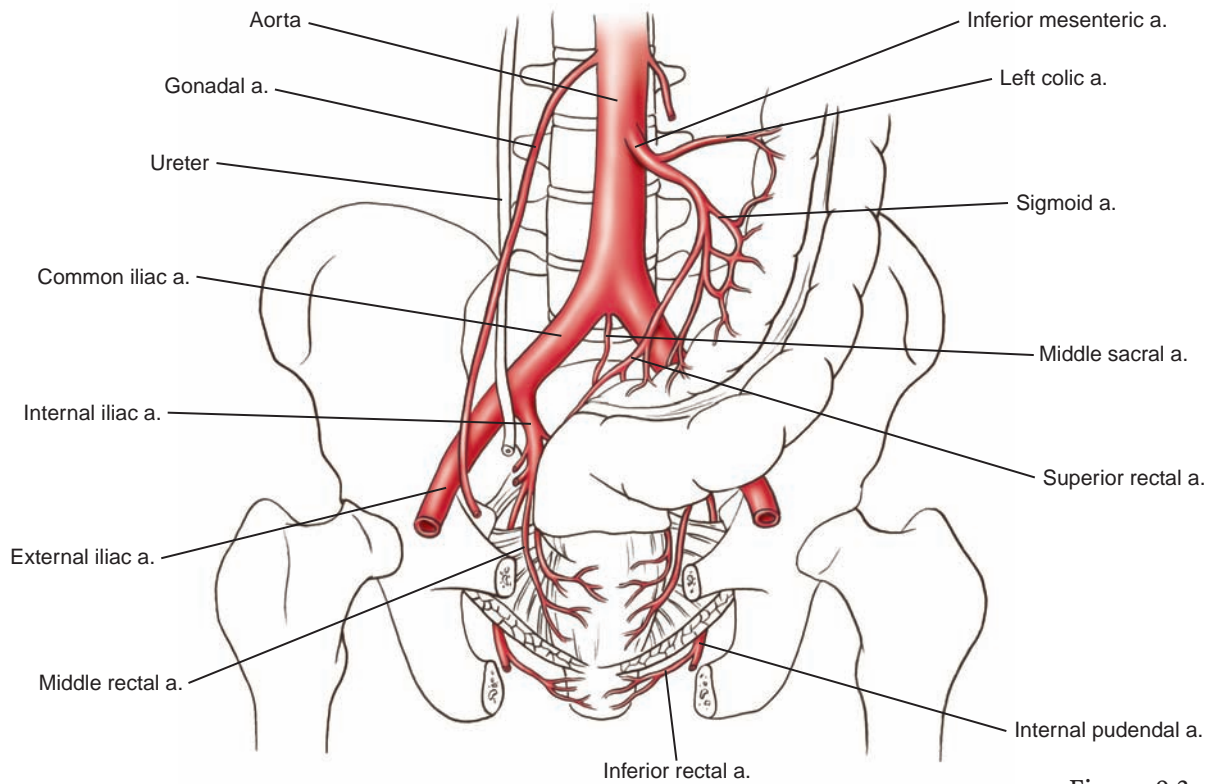


Figure 9.3

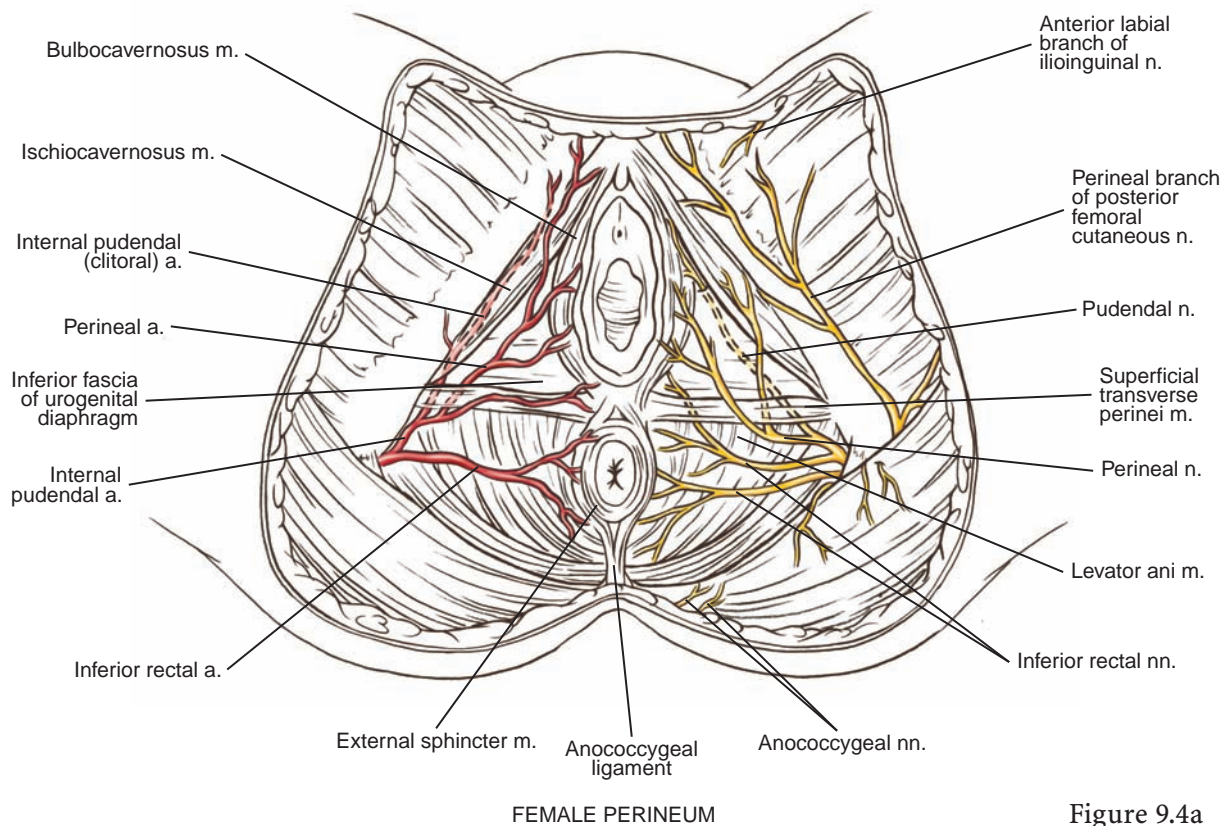


Figure 9.4a

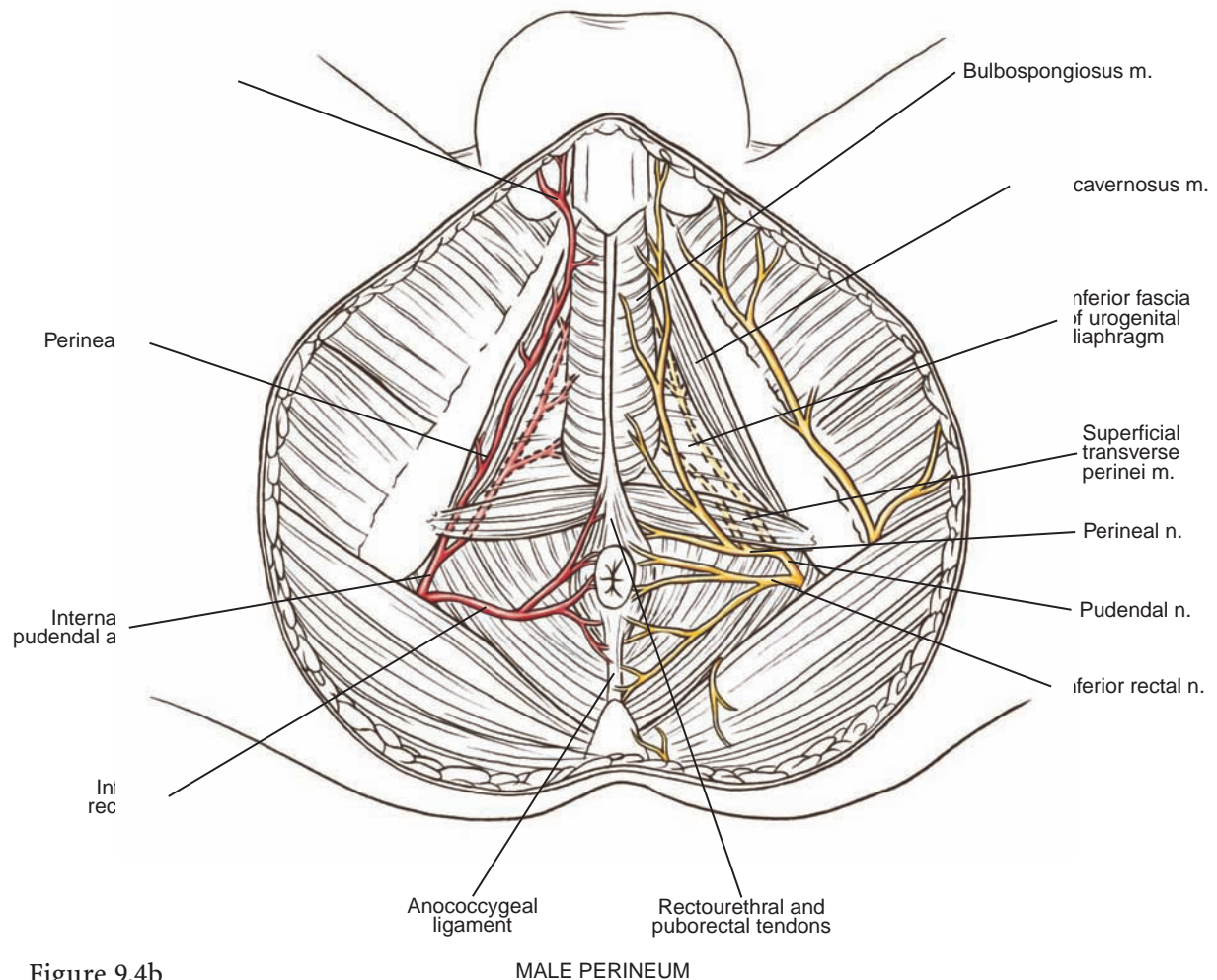


Figure 9.4b

The inferior rectal (hemorrhoidal) veins beneath the pectinate line and the levator sling drain into the internal pudendal veins and from there to the internal iliac vein. Just above the levators, the middle rectal veins follow the same drainage pattern.

Lymphatic Drainage

Lymphatic drainage parallels the venous drainage of the anorectum. This leads the lymphatic vessels from this region out along the levator sling to the pelvic sidewall. At the level of the superior rectal arteries, the venous and lymphatic drainage is portal and flows up to the inferior mesenteric vein. Below the pectinate line, the lymphatic plexus drains into the inguinal nodes. Consequently, the “watershed” of the extramural anorectal lymphatic vessels is at the pectinate line. The watershed for the intramural lymphatic vessels is higher, at the level of the middle valve. There are venous and lymphatic anastomoses between the lower branches draining with the systemic veins and the higher branches draining into the portal system.

Nerve Supply

Motor innervation of the internal rectal sphincter is sympathetic, causing contraction with parasympathetic fibers also supplied that inhibit contraction of this sphincter.

Parasympathetic afferent nerves carry sensations of rectal distention through the sacral plexus. The external rectal sphincter is supplied by an inferior rectal branch

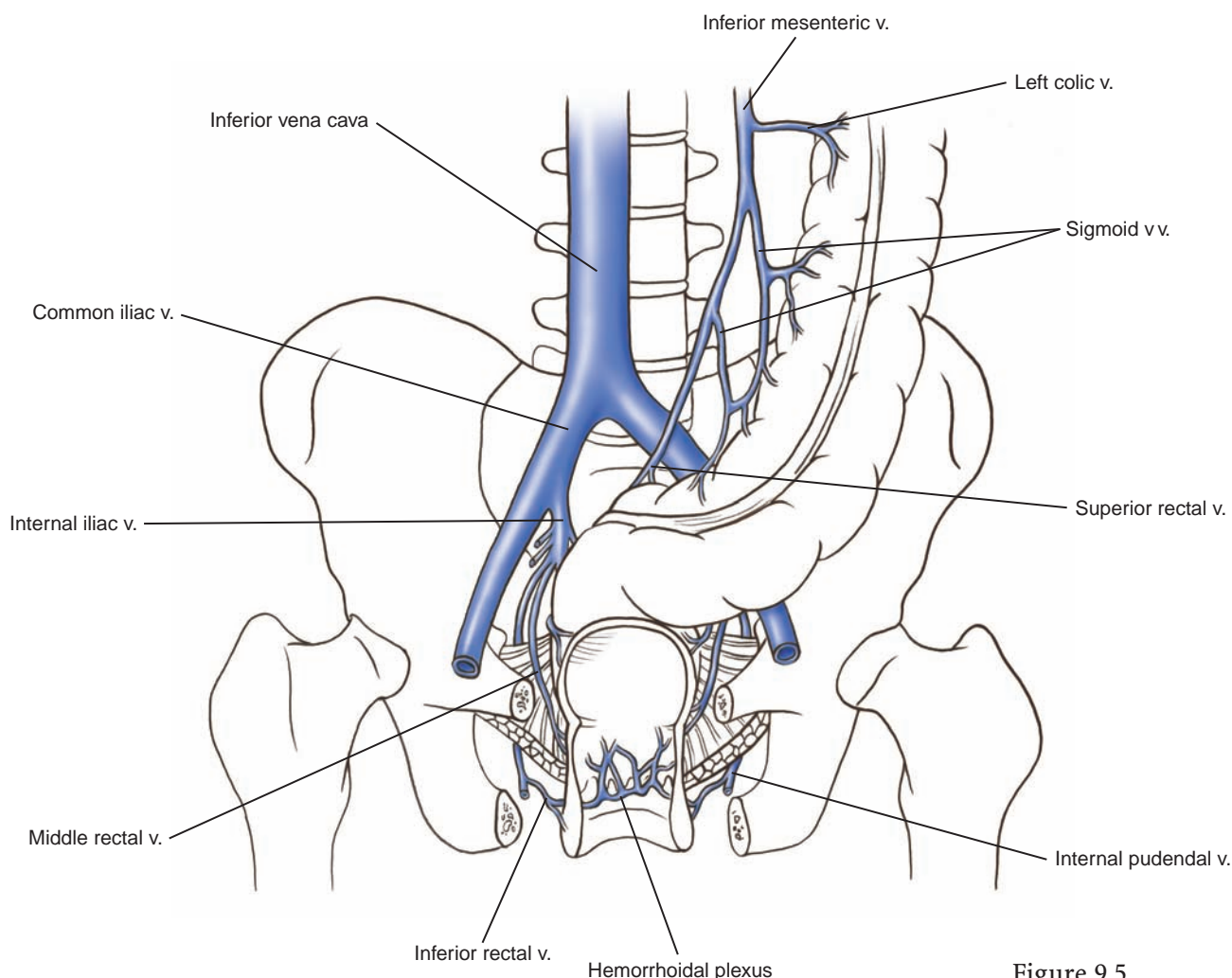


Figure 9.5

of the internal pudendal nerve and by a branch of the fourth sacral nerve. The parasympathetic pelvic splanchnic nerves and the sympathetic hypogastric nerves supply the wall of the lower rectum and together form the rectal plexus. The levator ani muscles are controlled by the third and fourth sacral nerves. Rectal continence is maintained by the pudendal and pelvic splanchnic nerves. The nerves that pass through the splanchnic nerves also supply the seminal vesicles and prostate gland in the male, and the bladder. These are all at risk for injury during rectal dissection, which could affect the bladder and sexual function (see low anterior resection, p. 425, and abdominoperineal resection, p. 433).

The relation of the sphincteric muscles of the anus and the muscular pelvic floor, and their separate innervations has remained a contentious area of surgical anatomy. A variety of schematic illustrations are used to define the functional aspects of muscular support and sphincter function. The inability to identify each of these structures in individual persons suggests that the external sphincter is one muscle mass and is not necessarily divided into layers and laminae, as may be found in some individuals. This external sphincter muscle mass retains skeletal attachment by the anococcygeal ligament to the coccyx. The perineal body is the anatomic location in

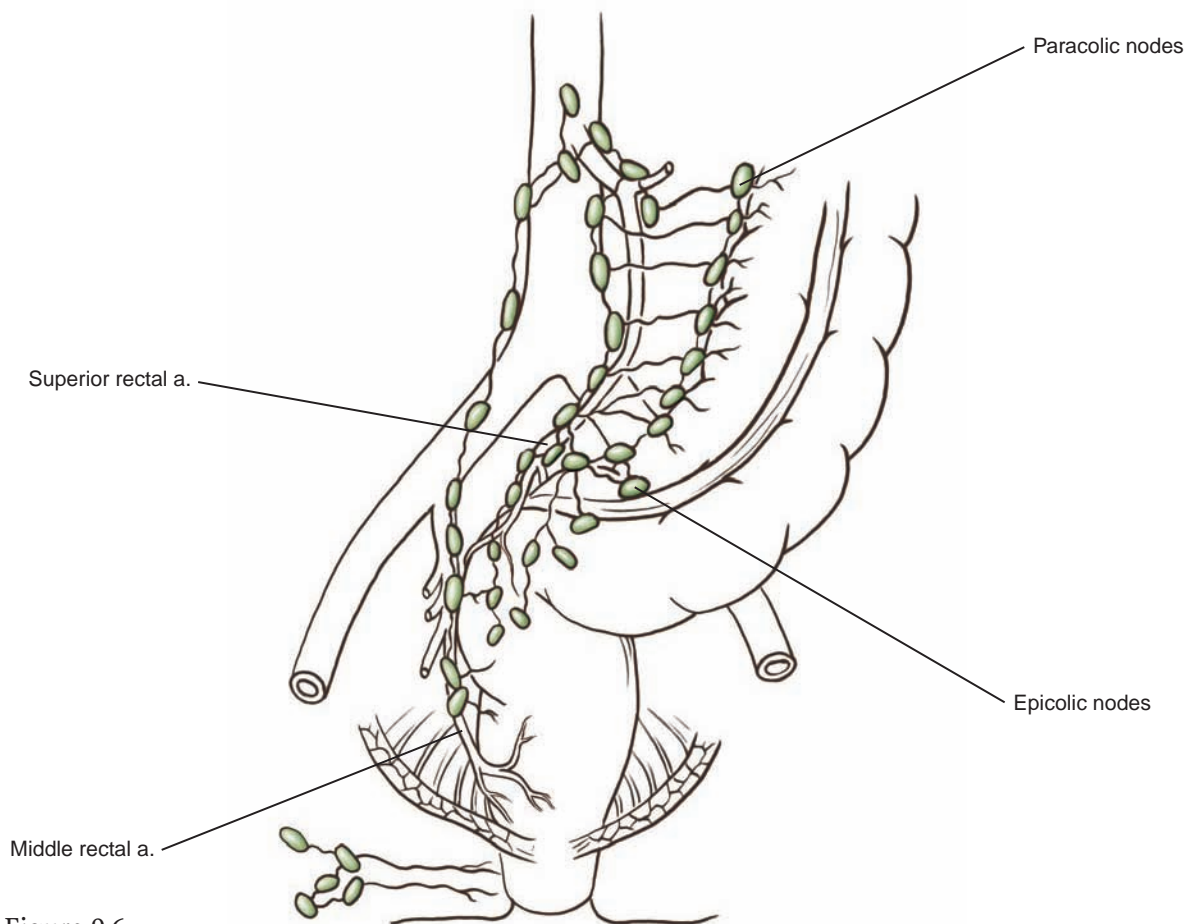


Figure 9.6

the central perineum where there is a meeting of the anterior pelvic muscles (bulbospongiosus and superficial and deep transverse perineal muscles) and the external sphincter posteriorly. The superficial perineal muscle separates the anus from the vagina in the female and gives support to the perineum. The external sphincter muscle is supplied by the inferior rectal nerve and the perineal branch of the fourth sacral nerve. The internal sphincter muscle is merely a downward continuation of the circular smooth muscles of the inner muscular layer of the rectum that becomes thickened and rounded. The conjoint longitudinal muscle is the longitudinal muscle layer of the rectum, which is a continuation of the teniae coli above the peritoneal reflection that forms a coat descending between the internal and external sphincters and inserts into the perianal skin. It has been suggested that the role of the conjoint longitudinal muscle is to evert the anus during defecation. The levator ani muscle is a broad, thin muscle that forms the greater part of the pelvic floor and is supplied by the fourth sacral nerve. It is made up of the iliococcygeus, pubococcygeus, and puborectalis muscles. The significance of each of these elements in contributing to the support of the pelvic floor is contentious. The pudendal nerve supplies the latter two muscles, but there may also be a perineal nerve supply.

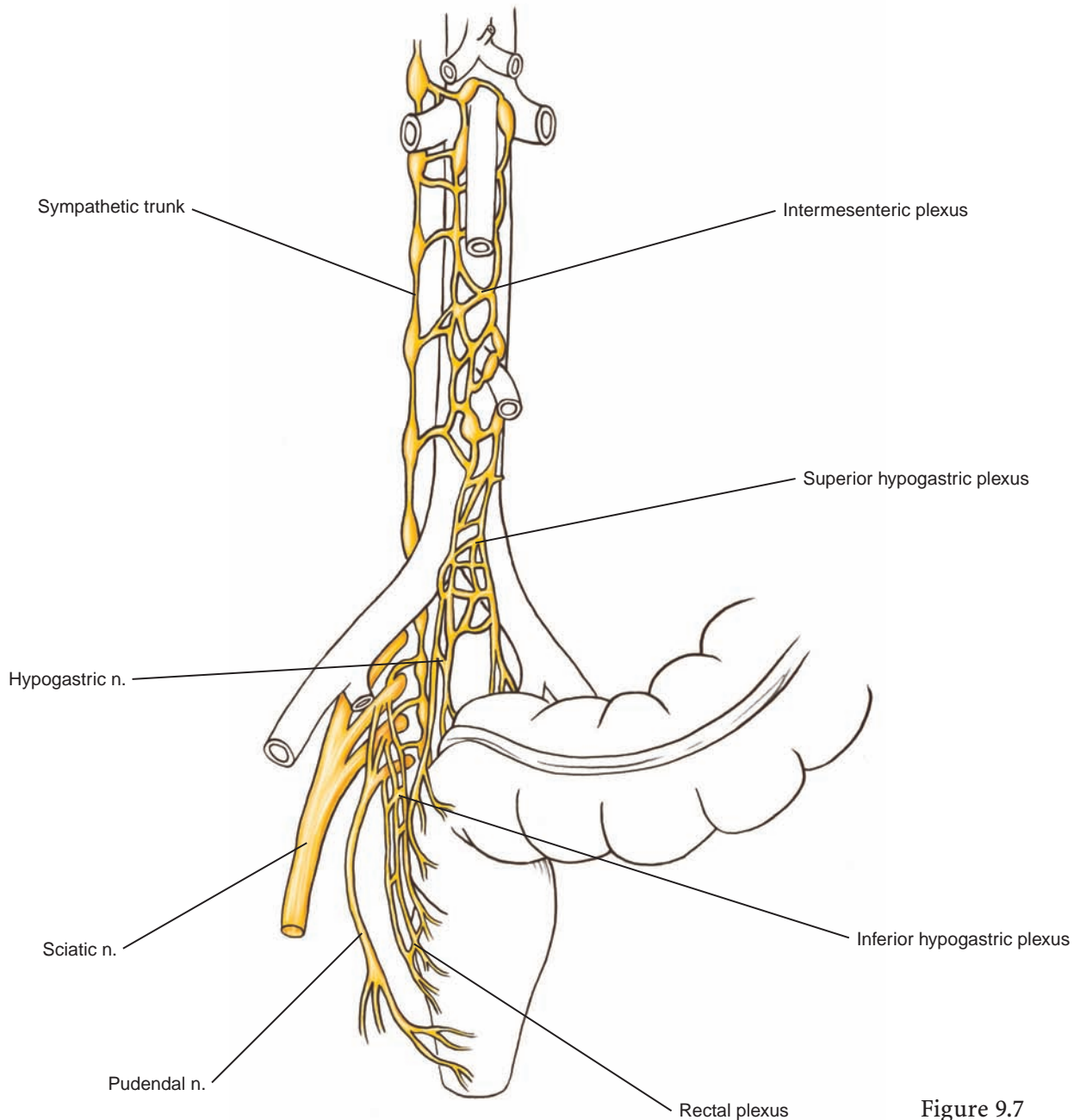


Figure 9.7

In addition to the muscular floor of the pelvis, the anorectum is supported by fascial reflections. They are the anterior and posterior peritoneal reflections, and a rectosacral fascia, from about the S4 level of the sacrum, that is a distinct supportive band of surgical importance. On the side of the rectum below the peritoneum is a condensation of fascia, known as the lateral ligaments or lateral stalks, that connect the rectum to the parietal pelvic fascia. The sacrum and coccyx are covered by the strong parietal pelvic fascia. In the presacral area, the parietal fascia covers the middle sacral vessels. The rectosacral fascia is also known as Waldeyer's fascia. Anteriorly, the rectum below the peritoneal reflection is covered with a visceral fascia

Fascial Support

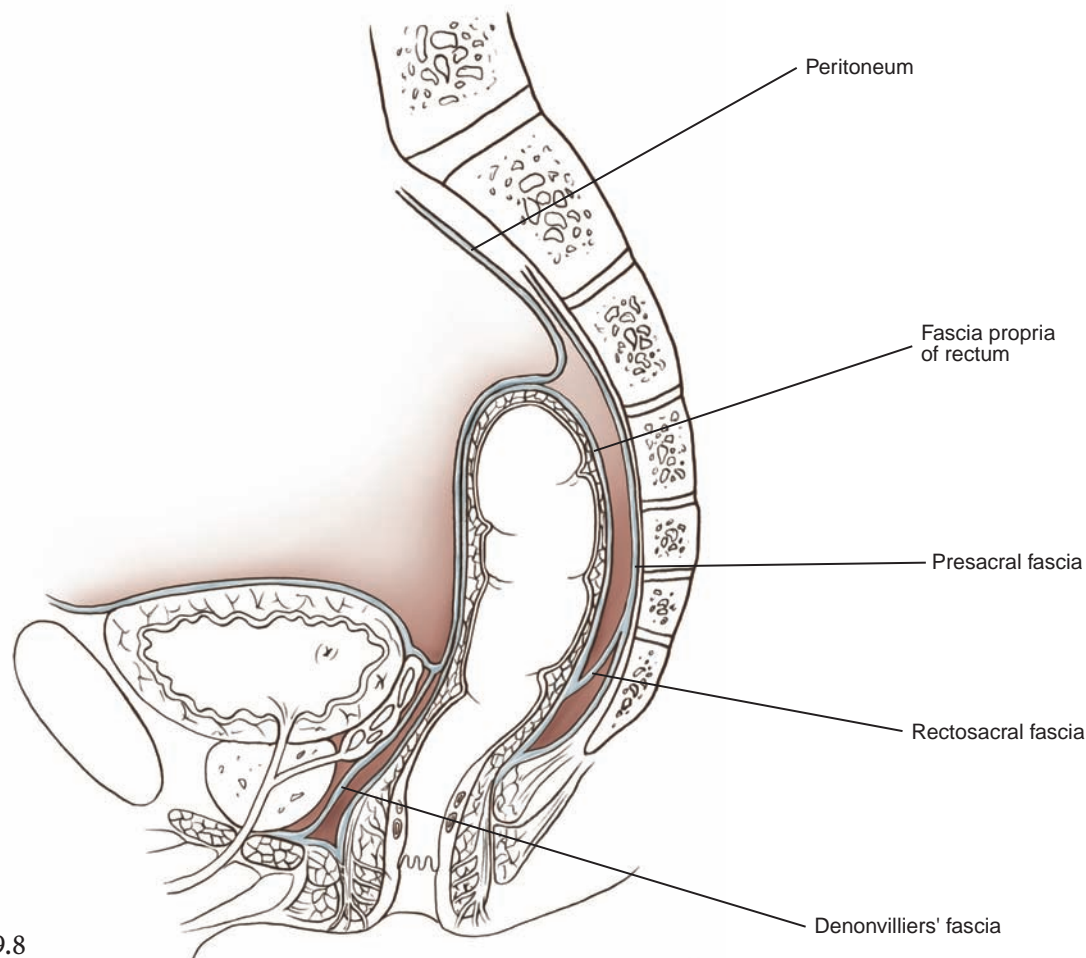


Figure 9.8

that is relatively delicate, known as Denonvilliers' fascia. It separates the rectum from the vagina in the female, and from the seminal vesicles and prostate gland in the male. These fascia are significant in resections of the rectum.

Surgical Applications

For many years, an operation proposed by Miles combined a radical abdominal and perineal approach for the surgical resection of rectal carcinoma. The abdomino-perineal resection (APR) with a permanent colostomy was the gold standard for rectal tumors from the anal verge to 15 cm above the anal verge. However, the morbidity of this radical operation is significant and includes loss of anal continence and possible sexual and urinary dysfunction. A significant improvement in the quality of life for rectal cancer patients was obtained by the introduction of circular mechanical stapling devices allowing a technically lower anastomosis. At the same time, the

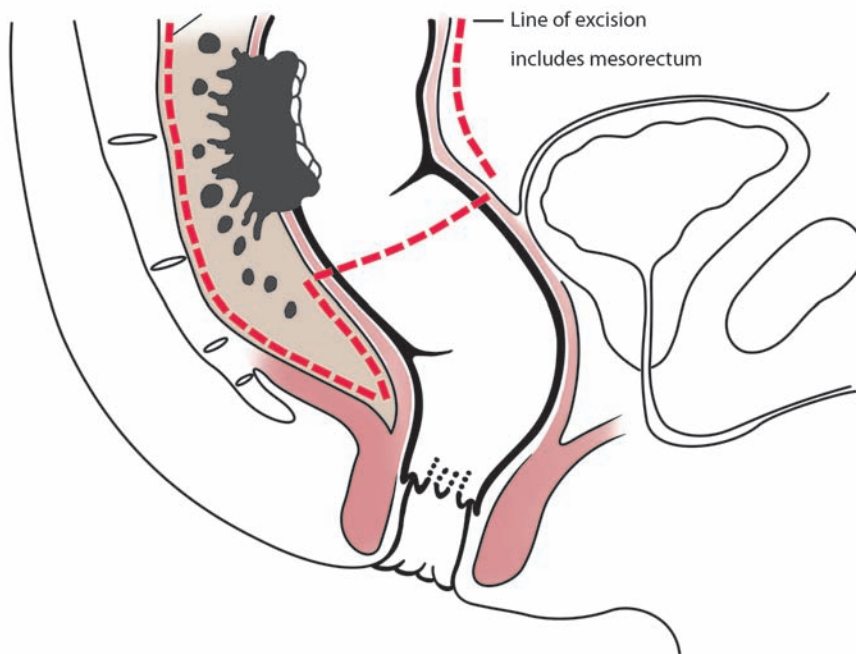
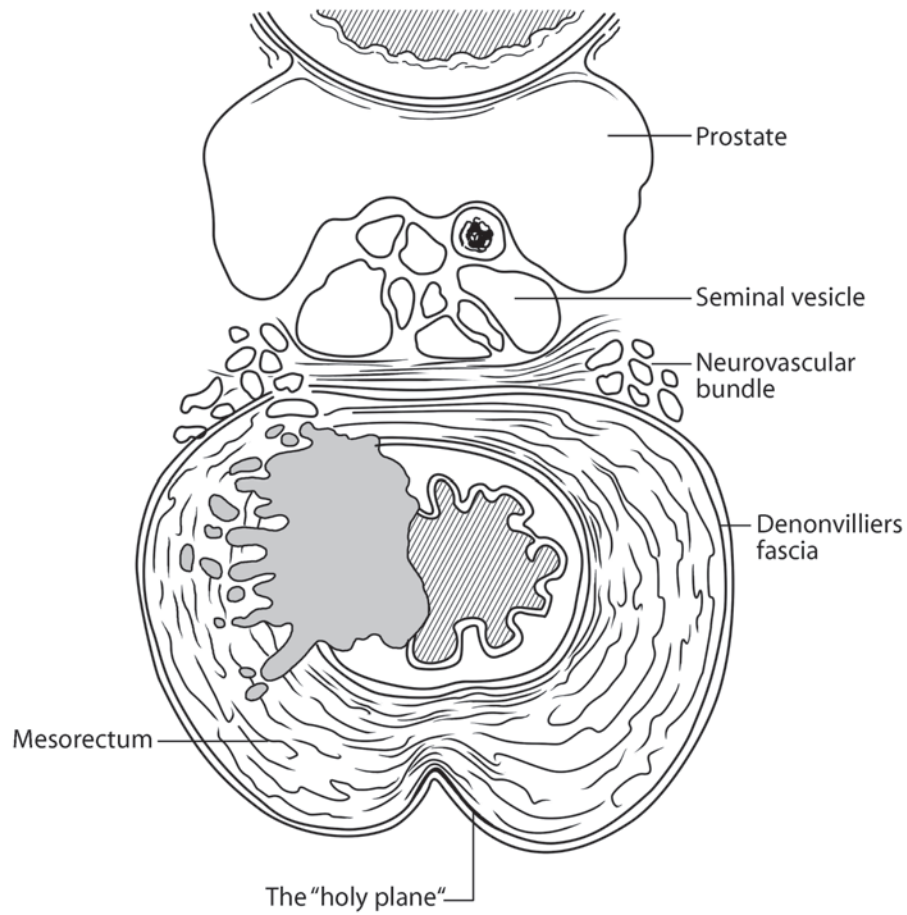


Figure 9.9

observation that a smaller distal margin of 2 cm was safe began to usher in an era of sphincter preservation. Improved surgical techniques in the treatment of rectal cancer resulted in safe lower rectal resections with sphincter preservation instead of the much more mutilating APR with an implicit colostomy. New approaches, including total proctectomy with a coloanal anastomosis, have extended possible sphincter preserving surgery for patients with extremely low rectal carcinomas.

Despite improvements in sphincter preservation, a unique problem in the treatment of rectal cancer has been the inability to optimize local tumor control. Blunt dissection of the pelvis, often resulted in incomplete removal of the mesorectal lymphatic tissue, leading to unacceptably high local recurrence rates. The concept of total mesorectal excision was introduced by Heald in 1979. Heald proposed a sharp dissection technique of the total mesorectum which also allowed for preservation of the pelvic autonomic nerves reducing sexual and urinary dysfunction. Figure 1 shows the axial and coronal boundaries encompassed by the mesorectal excision. The first series by Heald reported 112 curative lower anterior resections with total mesorectal excision that had an impressive local recurrence rate at 5 years of 2.7%. These results were the best reported in rectal cancer treatment up to that time.

Well designed large randomized trials done by the Gastrointestinal Tumor Study Group (GITSG) and the North Central Cancer Treatment Group (NCCTG), demonstrated that the combination of postoperative radiation therapy and chemotherapy reduced the local recurrence of rectal cancer by approximately 50%, when compared to surgery alone. Based on these results, the National Institute of Health Consensus Conference in 1990 recommended postoperative chemotherapy and radiation therapy for Stage II and Stage III rectal cancers. Neither of these studies showed any effect on overall survival.

However, many surgeons were of the opinion that chemoradiation was somehow compensating for the inadequate resection of the mesorectum. In 1996, a large prospective, randomized trial was conducted by the Dutch Colorectal Cancer Group to determine if preoperative radiotherapy was beneficial to patients treated with TME when compared to TME alone. Standardization of quality control in surgery, radiotherapy and pathology were accomplished. A total of 1861 patients were randomized to either preoperative radiotherapy and surgery with total mesorectal excision or surgery with total mesorectal excision alone. The results showed a 2-year local recurrence rate of 8.2% in the TME alone group and 2.4% in the radiotherapy and TME group, which was statistically significant. The main conclusion of this study was that, even in the setting of standard TME, preoperative radiotherapy was still beneficial in decreasing the risk of local recurrence but had no effect on survival.

With the acceptance of postoperative chemoradiation for Stage II and Stage III rectal cancer came the appreciation of the associated toxicity of radiation enteritis and functional changes in a patient's bowel function. Compared to postoperative chemoradiation, preoperative chemoradiation has less acute radiation toxicity, smaller radiation fields, and improved sphincter preservation. The most significant disadvantage of preoperative therapy is that a small percentage of patients will be treated unnecessarily due to the inherent inaccuracy of preoperative clinical staging. However, the widespread use of endorectal ultrasound has minimized the number of inappropriately radiated patients. A biologic advantage of a neoadjuvant approach is

that it is potentially more effective in well oxygenated tissue and responders to neo-adjuvant therapy have a documented improved overall prognosis. These potential benefits of preoperative chemoradiation led to the initiation of two large randomized trials in the United States, comparing preoperative chemoradiation vs. postoperative chemoradiation. Unfortunately, both the studies were terminated early because of poor patient accrual. At that time, many surgeons, medical oncologists, and radiation oncologists had become proponents of either preoperative or postoperative therapy and were unwilling to randomize their patients. However, in 2004, the German Rectal Cancer Study Group published their randomized trial of 421 patients who had been randomly assigned to receive preoperative chemoradiation compared to 401 patients who had received postoperative chemoradiotherapy for rectal carcinoma. All the patients underwent total mesorectal excision according to a standardized technique. The incidence of local recurrence was significantly less in the preoperative chemoradiation group, 6% vs. 13%. Preoperative therapy was also associated with a significant reduction in both acute and long term toxicity. Among patients with very distal tumors, sphincter preserving surgery was increased two fold in patients who had undergone preoperative chemoradiation therapy. There was no statistically significant difference in 5 year overall survival rates between the two treatment groups. This is an important trial that demonstrated the benefits of preoperative chemoradiation which included significant decrease in local recurrence, a significant increase in sphincter preservation and a significant improvement in toxicity which is now the standard treatment for stage II and III rectal cancer.

For tumors of the anorectum, the tension lies between widely ablative procedures with generous margins and the removal of broad areas of lymphatic drainage, and the disability produced by such wide ablations. For lesions of the lower rectum, APR, particularly at its most radical, achieves widespread resection but at a considerable cost. The loss of anal continence and the production of an abdominal colostomy are well managed by patients, particularly those who are taught by skilled enterostomal therapists. Nonetheless, the ability to treat tumors of the anorectum with equivalent benefit and with preservation of anorectal continence, sexual function, and urinary continence is ideal. The principals of surgical care of rectal cancer patients include: (1) the control and resection of the primary tumor, and (2) preservation of function and continence. These are not seen as competing goals; however, control of the tumor must never be compromised by any attempt to preserve function. A margin negative resection that includes a negative circumferential, proximal, and distal margin along with a total mesorectal excision and sphincter preservation is the optimal surgical treatment of rectal cancer.

The procedures discussed in this chapter include:

1. Low anterior resection
2. Coloanal resection
3. Abdominoperineal resection
4. Total pelvic exenteration
5. Per anal excision (or transanal excision)
6. Posterior approaches

for tumors of the anorectum, the choice among these procedures is predicated on the basis of the knowledge of tumor size, histology, distance from the anal sphincters and staging information. It must be understood that a finding of severe dysplasia in a villous adenoma of the low rectum is common when other areas of the villous adenoma exhibit frank adenocarcinoma. A combination of a CT of the abdomen/pelvis and chest X-ray or a CT/PET can adequately rule out distant metastatic disease. A full colonoscopy should be done to document the size, location, and histology of the primary tumor and to exclude other synchronous colorectal polyps or cancers in the colon. Transrectal ultrasonography provides the best and the most accurate primary Tumor (T) and nodal (N) staging of the rectal cancer. Careful digital palpation will further define the relationship of the tumor to the anal sphincters and also determine if the tumor is fixed to the side wall. It is only after accomplishing all of these that the optimal procedure can be selected. For adenocarcinomas of the anorectum that are tethered or fixed, neoadjuvant chemoradiation therapy should precede surgery. Tumors of the rectosigmoid greater than 15 cm above the anal verge or any stage 1 (T1-2, N0) rectal cancer are well managed with low anterior resection alone. For EUS staged T3-4, N0 or any N1 disease, preoperative chemoradiation therapy produces dramatic disease regression and complete regression in about 15% of the patients. Following preoperative therapy each rectal tumor is restaged to determine if sphincter preservation can be accomplished. The optimal time for surgery is 6–8 weeks after the completion of chemoradiation. For patients with bulky rectal tumors or a remote history of pelvic radiation, preoperative cystostomy with the placement of ureteral stents should be considered. For residual rectal cancers above the anal sphincters that undergo a margin negative proctectomy, a low anterior resection with a stapled anastomosis or coloanal anastomosis, either stapled or handsewn to the anal sphincters, can be performed. Local recurrence and survival are not compromised in patients with distal third rectal cancer when treated by sphincter-saving resection, provided the oncologic principles are not violated. A protective diverting ileostomy is normally done for low lying radiated tumors that have sphincter preservation. The only true indication of an APR is the inability to achieve a negative distal margin or a tumor involving the anal sphincters.

For exophytic (T1), smaller (<3 cm), low-grade lesions of the low rectum (within 6–8 cm of the anal verge), transanal excision afford control equivalent to that of APR. Transsphincteric and posterior approaches have strong advocates, but have never received the same degree of acceptance by the broad community of surgeons dealing with rectal tumors, as have the other procedures relative to the complications associated with these procedures. The fact that a few individuals have been their champions suggests that when frequently performed, the complications and morbidity of these procedures may be lessened. Total pelvic exenteration is an appropriate procedure for well-staged, centrally based primary tumors or local recurrences that invade the bladder and/or prostate and vagina but have no evidence of disease outside the pelvis. The status of the ureters should be assessed with computed tomography (CT) with contrast medium as part of the preoperative staging of rectal tumors, and a decision made on the necessity of ureteral stents, perioperatively. In female patients, if the

anterior fixation is only to the uterus and vagina, posterior exenteration, sparing the bladder, may be performed. If the anterior fixation is also accompanied by lateral fixation to the pelvic sidewalls or posterior fixation to the sacrum above S3, no advantage can be shown to pelvic exenteration.

Rectal cancer with synchronous liver metastases offers a particular challenge to clinicians. In general the most life threatening area of cancer will direct the therapy. In patients with diffuse bilobar high volume liver metastases, initial systemic chemotherapy should be considered. Rectal stents can be used if the patient has obstructing symptoms. For those with low volume resectable liver metastases, chemoradiation with oxaloplatin based therapy can be done followed by simultaneous or staged rectal and liver resections.

If the lower margin of the tumor cannot be elevated with a rigid proctoscope at least 3 cm above the most cephalad portion of the palpable anal sphincteric mechanism, low anterior resection is not an appropriate procedure. An indwelling urinary catheter should be placed in patients undergoing any anorectal surgery. For low anterior resection, the ideal position is the patient supine with legs in Allen or Lloyd-Davies stirrups with the knees at the level of the trunk or lower. Pneumatic sequential compression leggings are used to minimize the risk for deep venous thrombosis. A foam pad is used to elevate the sacrum and buttocks to provide easy access to the anus. When anything other than a very straightforward dissection is expected (e.g., in patients with prior pelvic surgery, pelvic radiation therapy, or recurrent tumors),

Low Anterior Resection

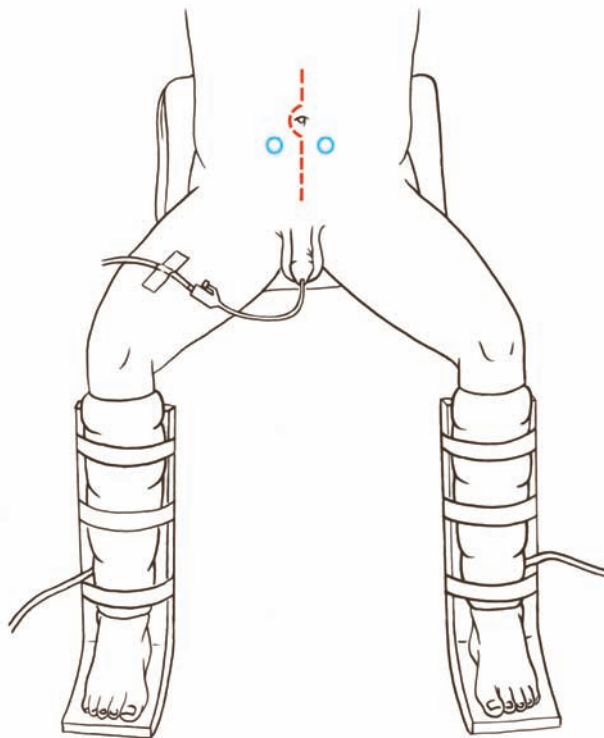


Figure 9.10

ureteral stents minimize the risk for ureteral injury and facilitate pelvic dissection. After preparing and draping the abdomen and perineum, a midline incision is made from just above the umbilicus to the pubis.

After careful exploration of the abdomen, the left colon is mobilized by dividing the peritoneal reflection (white line of Toldt). The ureters and gonadal vessels are identified and spared. Some surgeons have advocated early ligation of the mesenteric and lymphatic vessels to prevent proximal dissemination of tumor during manipulation of the rectum. There is no evidence that this is effective, and evidence suggests that it makes no difference whether the vessels are ligated. Nonetheless, this is an appropriate time to divide the superior rectal vessels just beneath the takeoff of the left colic vessels. Again, no advantage has been shown for taking the inferior mesenteric vessels at their origin. An appropriate area for proximal colonic transection is identified and the colon is divided with a linear stapler. The mesentery is scored with the electrocautery unit down both sides of the sacral promontory.

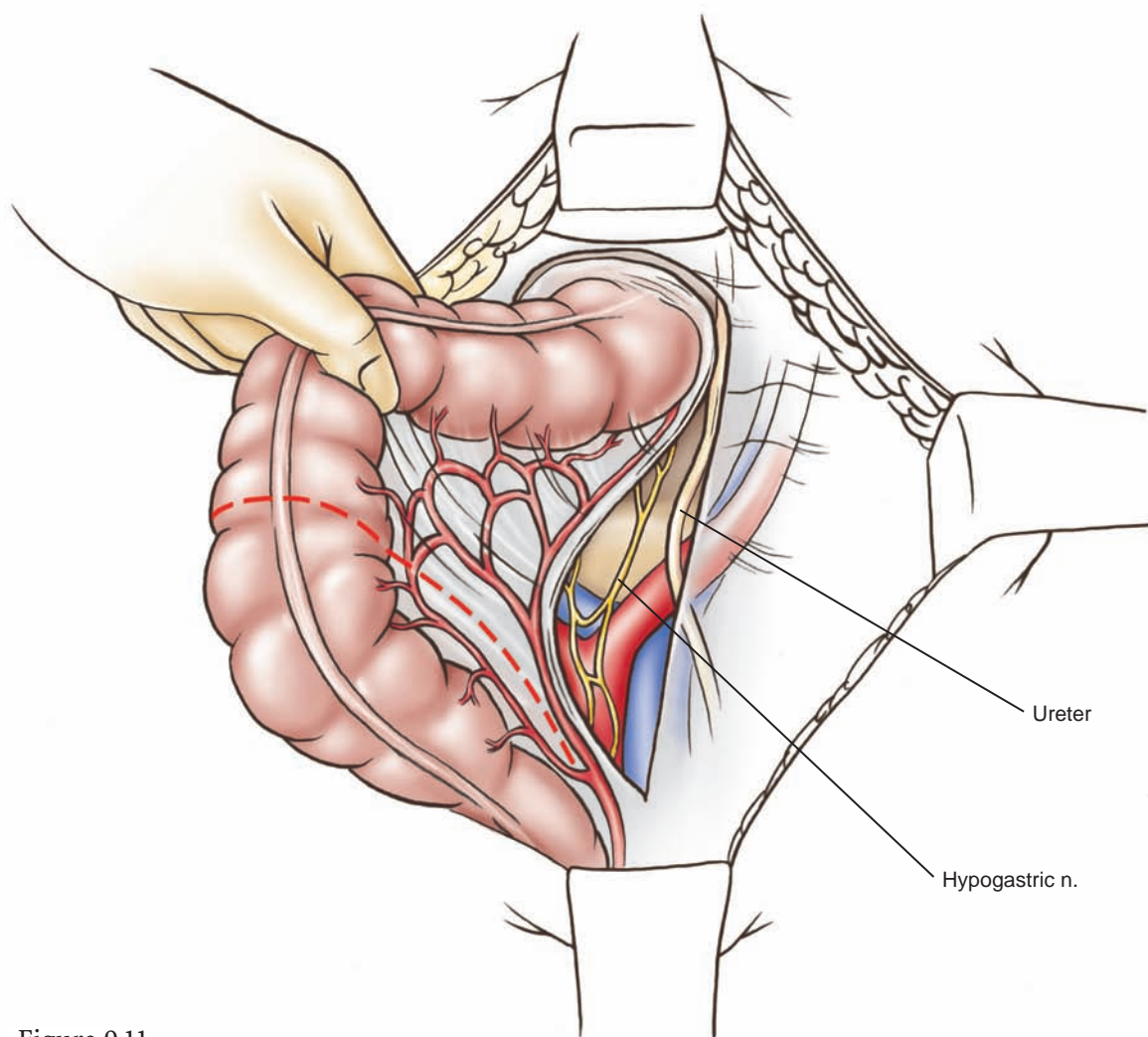


Figure 9.11

The hypogastric nerve plexus should be identified and carefully spared unless there is evidence of fixation or tethering of tumor that would require its resection. It is essential that the left ureter is identified and protected from division with the inferior mesenteric vessels. By drawing the rectum anterosuperiorly, a plane of areolar tissue appears anterior to the sacral promontory. With scissors dissection the retrorectal space can be entered with minimal bleeding. This plane anterior to the presacral nerves is pursued. The nerves bifurcate just below the sacral promontory. This plane is then developed by both blunt and sharp dissection until the rectosacral fascia is encountered. This must be sharply divided; bleeding from the presacral venous plexus is usually caused by attempts to break through this ligament bluntly. After the rectosacral fascia has been incised, the dissection can easily proceed to the coccyx. If bleeding occurs from the presacral veins or the basivertebral veins through the sacral foramina, direct pressure with or without electrocoagulation will usually suffice to restore hemostasis. A titanium thumbtack can be placed directly into the sacrum if required. In patients with a bleeding disorder or who fail to respond to other measures to control bleeding from the presacral tissues, prolonged packing can be used and removed in 2–3 days.

The anterior surface of the rectum is now cleared. In the male, the rectovesical fold is entered, and with traction on the rectum superoposteriorly and on the bladder anteriorly, sharp dissection is continued in the plane between the seminal vesicles anteriorly and Denonvilliers' thin fascia posteriorly. The dissection continues to the base of the seminal vesicles and then over the surface of the prostate gland. Electrocoagulation is helpful to control small bleeding vessels.

In women, the rectovaginal fold is incised and the posterior wall of the vagina cleared to the level at which the pubic bone can be palpated. If there is tethering or

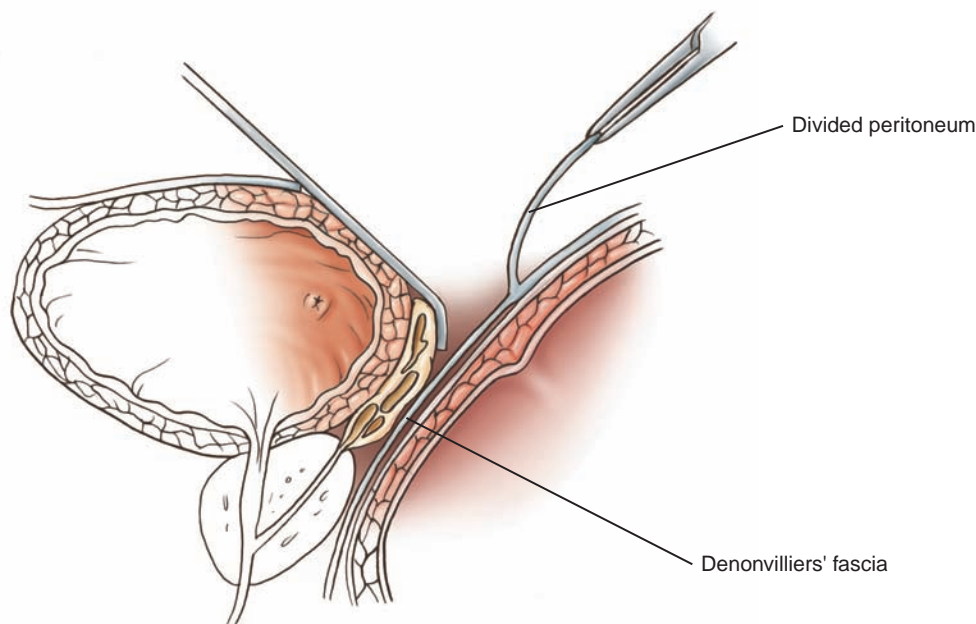


Figure 9.12

fixation, the posterior wall of the vagina can be resected and closed primarily by absorbable suture.

At this point, the hypogastric nerves have been spared and the lateral ligaments are to be taken. At this juncture, the anatomy is significant in detail. Heald and Enker both advocate a total mesorectal excision (TME) that involves sufficient lateral dissection to clear the mesorectal tissues. Their data suggest that local failure is markedly diminished by such careful wide dissections of the mesorectum. Although attention has been paid to the longitudinal margin on the bowel wall, fairly recent emphasis has been placed on adequate sharp dissection of the lateral or circumferential margins. The temptation, if clamps and fingers are used laterally, is to cone down through the mesorectum to the distal rectal wall, leaving the distal mesorectal tissues laterally. With the rectum pulled sharply to the left, the ligaments can be divided with an electrocautery or between clamps. A strong, deep pelvic retractor, such as the St. Mark's pelvic retractor, placed anterior to the rectum and lifted forcefully upward, makes it possible to take the lateral stalks under direct vision. On completion of the anterior dissection, a Foley catheter in the trigonal area of the bladder, just anterosuperior to the prostate, and between the seminal vesicles is a useful palpable landmark.

A conceptually ideal operation would include Denonvilliers' fascia with the rectum anteriorly, with the plane of dissection on the outer surface of the fascia, finally

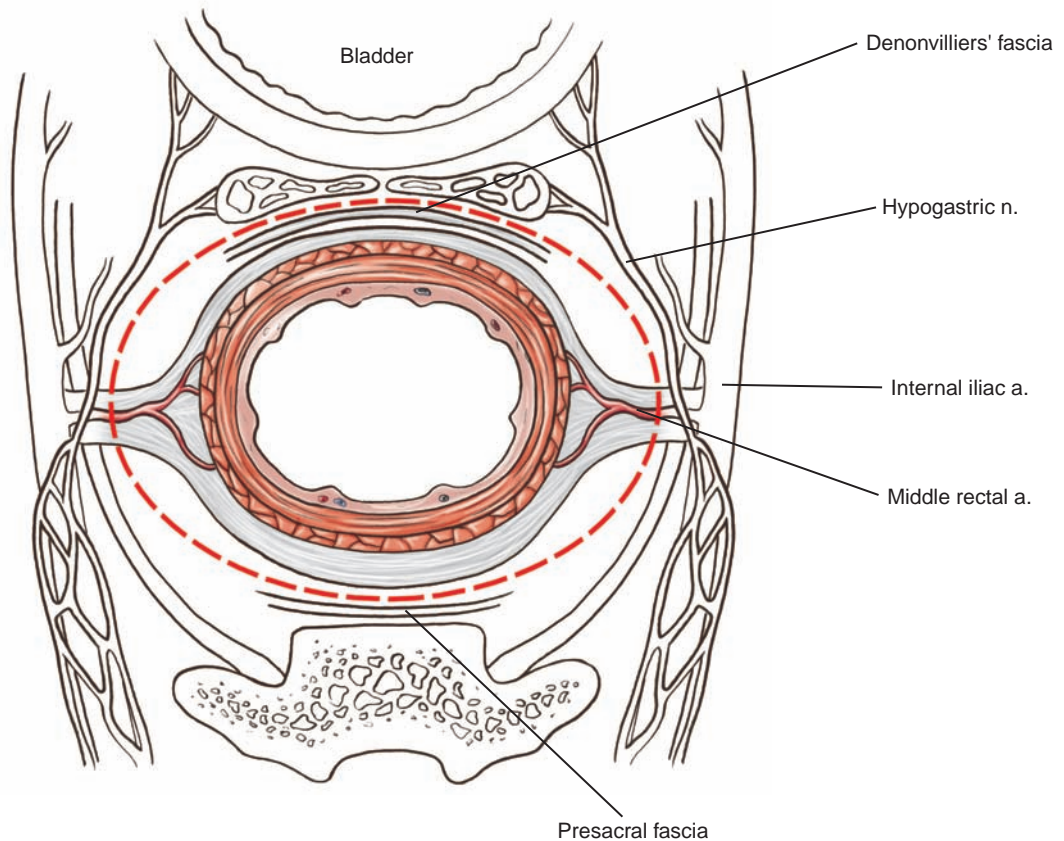


Figure 9.13

dividing distally at the prostate. Within the lateral stalks lie the middle rectal vessels, which must be taken along with their associated lymphatics. Also within them lie a condensation of parasympathetic nerve fibers supplying the rectum that must, of necessity, be divided. In addition, there are nerve fibers running longitudinally in the lateral edge of the lateral stalks adjacent to the pelvic sidewall. These may easily be drawn into the dissection and divided, leading to impairment. These partially make up the hypogastric nerves and parasympathetic nerves. The sympathetic or hypogastric nerves, which were followed down from the aortic bifurcation above to the point anterior to the lateral ligaments, can often be visualized and avoided. They course 1–2 cm medial to the ureters. If one takes the time to manage the individual vessels in the lateral ligaments, as one would in the superior pole of a thyroid gland, the ligament may be taken between small clips, or with ties, or even with a

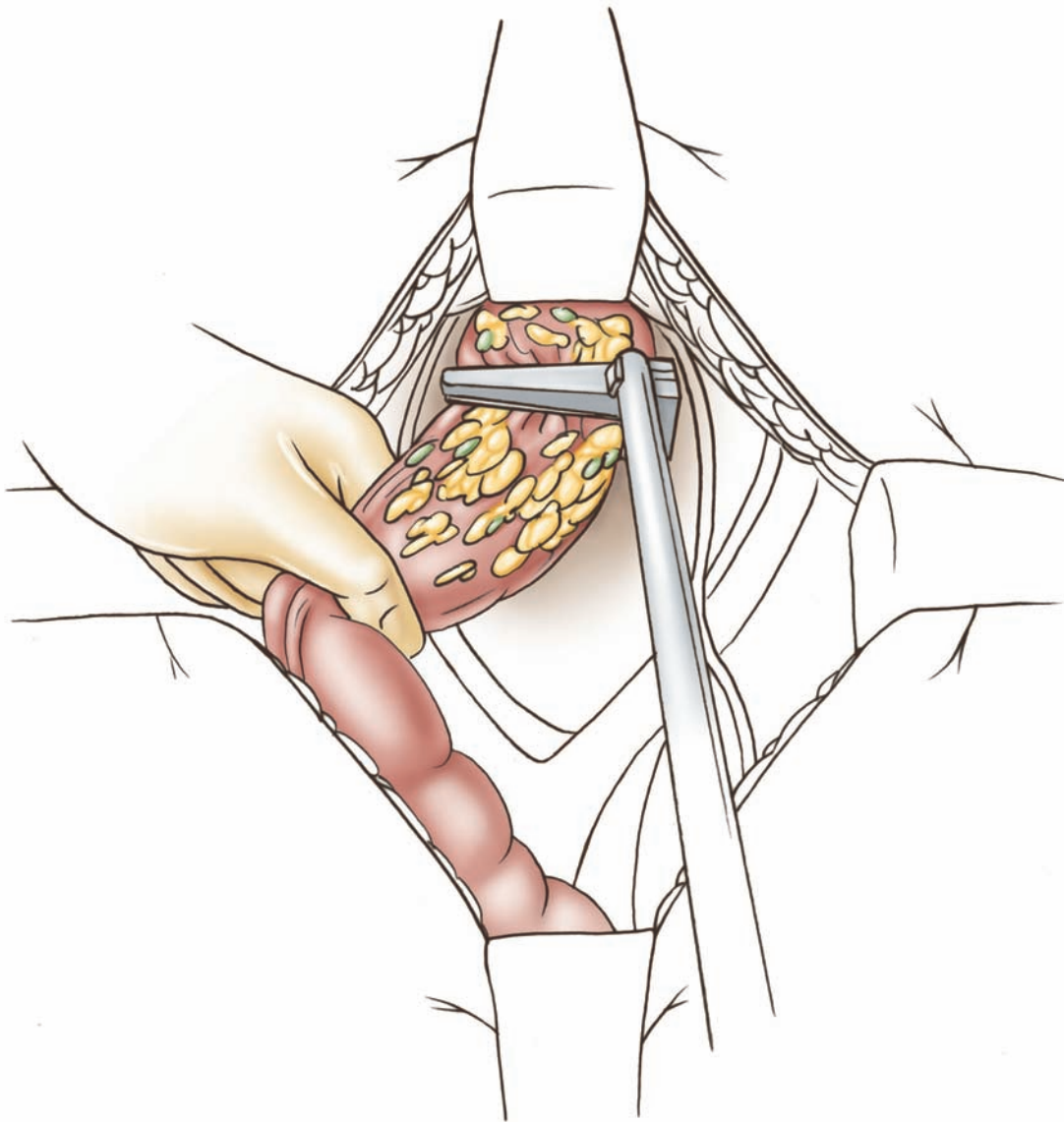


Figure 9.14

cautery, minimizing the risk of damage to the truncal parasympathetic nerves and sacral structures, preserving any that are coursing in a direction other than toward and into the bowel wall. There is no evidence that significant innervation lies anteriorly between the rectum and the seminal vesicles or prostate. Consequently, the surgeon need not be concerned that dissection in this region will contribute to sexual dysfunction. The twin goals in a meticulous dissection of the lateral ligament are preservation of both sympathetic and parasympathetic nerves and the clearance of lymphatics out to those anterior-posterior, and cephalad-caudad running, longitudinal small nerve trunks. This achieves local clearance superior to that achieved with broad clamping and contributes to preservation of function, as demonstrated by the work of both Heald and Enker.

When dissection has progressed to at least 2 cm beneath the inferior margin of the tumor, the distal rectal is divided with a stapler. The 30 mm size will usually fit deeper in the pelvis for a transection as low as possible. If the proximal colon will not fit into the pelvis without tension, the splenic flexure will need to be mobilized. Many a time,

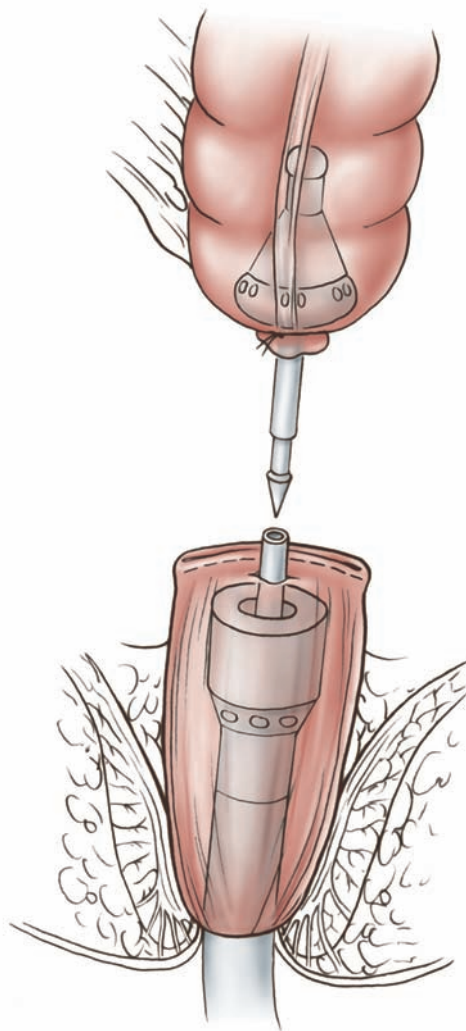


Figure 9.15

the colon mesentery is the point of tension and requires dividing the more proximal left colic artery to gain length on the mesentery. Either stapled or open anastomosis may now be performed. Modern circular staple devices allow very low anastomoses with great safety and have virtually eliminated the need for an abdominosacral approach to low tumors. A purse-stringing device or manual purse string suture of a 2-0 monofilament is placed in the cut end of the proximal colon with bites about 6 mm apart. Appropriate sizers are then used to size the proximal colon. The anvil of the stapler is placed into the proximal colon and the purse string is tied securely.

The stapler is then introduced through the anus and the spike is brought out near the rectal staple line. The anvil is connected to the stapler, closed and then inspected to make sure of the correct mesentery orientation, and to make sure that no additional tissue was incorporated into the anastomosis. The stapler is fired and then removed. The two rectal doughnuts are inspected for continuity. The anastomosis is visually inspected and air insufflated while a bowel clamp is applied to the more proximal left colon and water is placed in the pelvis. Any bubbling of air indicates a possible leak. Many a time, a visible leak can be sealed with individual sutures. If there is any sign of a leak or nonintact rectal doughnuts, a diverting ileostomy should be done. The incision is then closed in the usual fashion.

Coloanal resection is performed after chemoradiation therapy for lesions in the low rectum that regress sufficiently enough for a margin to be obtained above the dentate line. The procedure differs from APR in that the sphincteric structures, the levator sling, and the lymphatic and blood vessels below the levator muscles are all spared. These must be sterilized with chemoradiation therapy, or the surgery will not be successful in controlling tumors at the level of the low rectum. The abdominal dissection is the same as in the low anterior resection however the dissection continues down around the rectum to the level of the levator muscles.

From inside, the mucosa is taken from the pectinate line up to the superior margins of the sphincter (submucosal infiltration with epinephrine in saline solution facilitates this dissection); then the entire rectum is circumscribed and excised. A finger placed through the wall of the submucosal rectum guides this division. The

Coloanal Resection

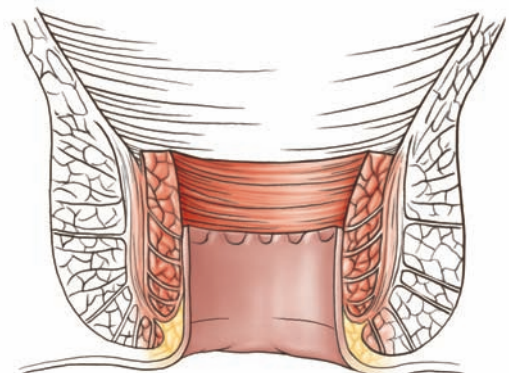
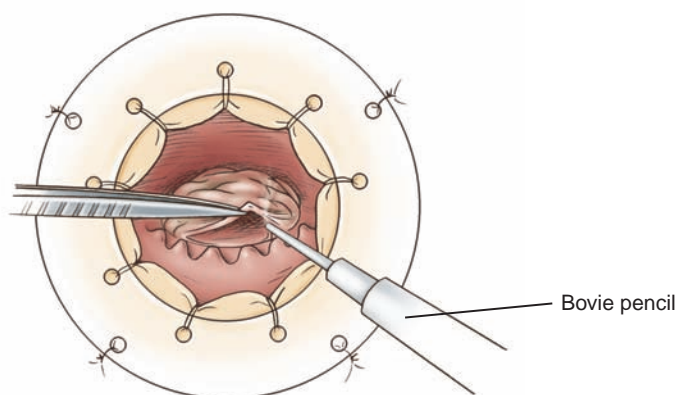


Figure 9.16

splenic flexure must be freed to allow sufficient colonic length into the pelvis, and the left colon must be divided above the level of irradiation so that the unirradiated bowel is brought down into the pelvis.

An end-to-end coloanal anastomosis may be made or a J pouch created by stapling the antimesenteric borders together. The pouch has been associated with less stool frequency in the early months after the procedure and appears to engender greater patient satisfaction. A diverting ileostomy is usually done to allow the coloanal anastomosis to heal. Any clinical leak will lead to significant sphincter fibrosis and subsequent anal incontinence.

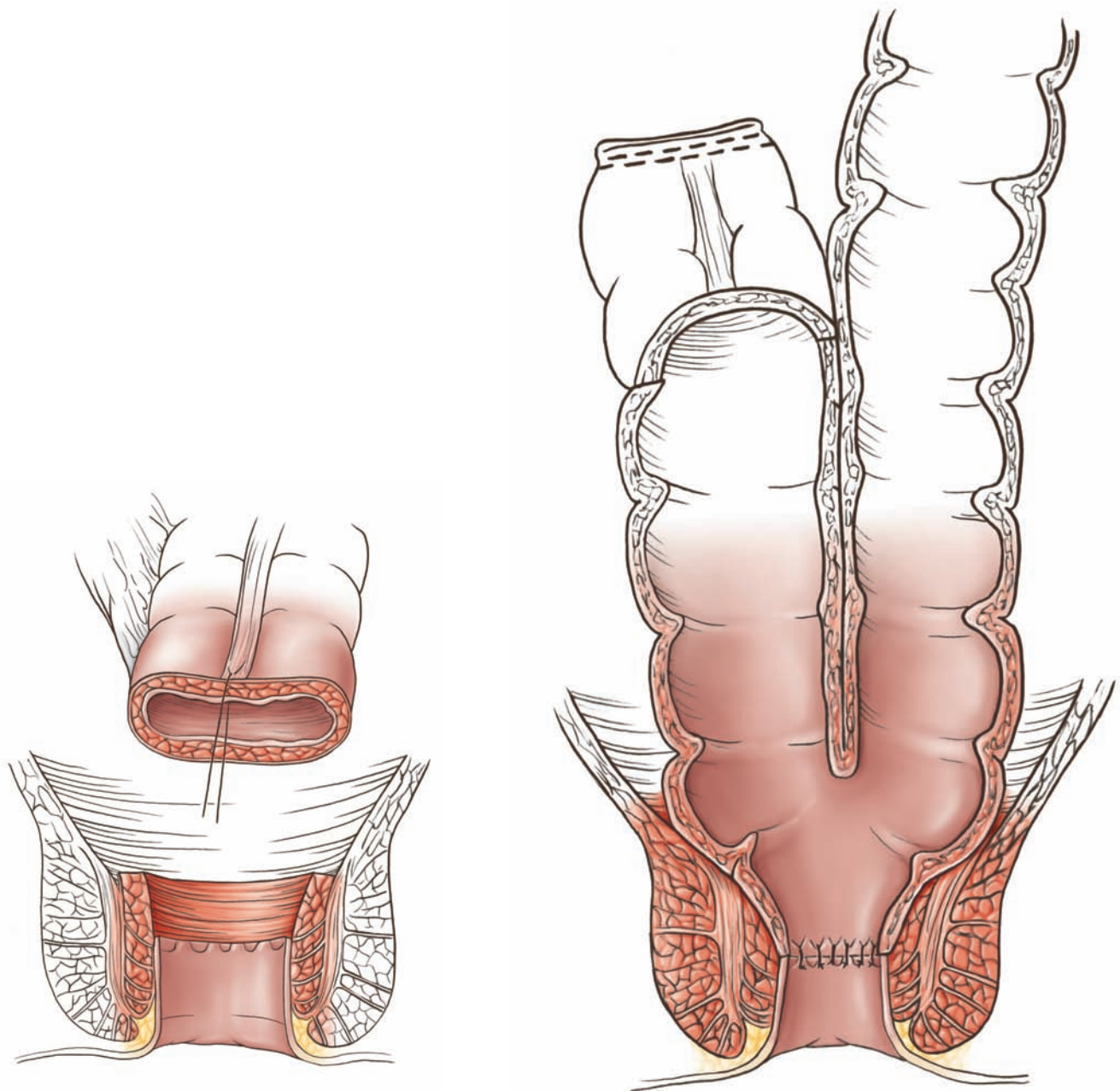


Figure 9.17

Abdominoperineal Resection

The patient is positioned with the legs in Allen or Lloyd-Davies stirrups, and an indwelling Foley catheter is placed. A site for a stoma should be chosen and identified prior to making the skin incision. The best plan is to bring the stoma through the rectus muscle on the left side to minimize the size of the peristomal hernia and place it in an area where there is sufficient flat abdominal wall (i.e., several centimeters from the umbilicus and anterior superior iliac spine) that a stoma disk can lie flat. It must remain in position when the patient is seated and, ideally, not be directly on the beltline but below it. After careful exploration of the abdomen, the rectosigmoid colon is mobilized. Early division of the sigmoid colon facilitates the pelvic dissection. The procedure progresses as described for a low anterior resection. The dissection continues circumferentially down around the rectum to the levator muscles.

To facilitate the perineal dissection, the anus is closed with two purse-string sutures of 2-0 silk. In male patients an elliptical incision about the anus is made to remove the pigmented perianal skin. In female patients the posterior vaginal wall may be included in the excision if the tumor lies in the anterior rectal wall. After posterior vaginectomy, the fourchette is reconstituted, and the posterior vaginal wall may be closed or allowed to heal by second intention.

The fatty subcutaneous tissue is taken with an electrocautery. Vascular bundles representing the inferior rectal (hemorrhoidal) vessels are identified both superiorly and inferiorly on the sides in the ischiorectal fat. The dissection is continued posteriorly to the upper part of the coccyx. With a scissors or electrocautery, it is possible to divide the rectococcygeus ligament right at the tip of the coccyx. With a finger placed into the retrorectal space and swept laterally, the levator sling is divided with

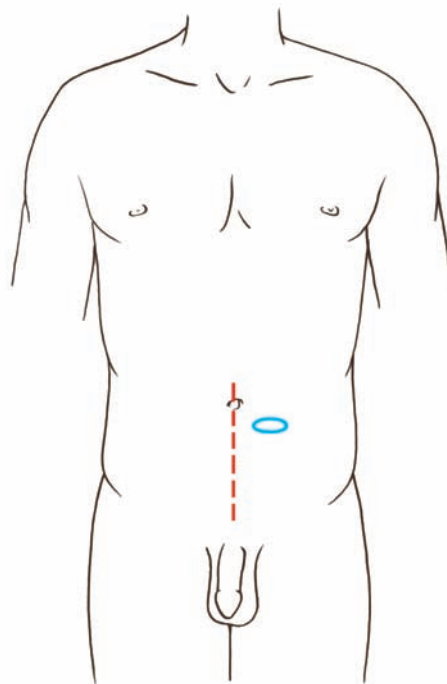


Figure 9.18

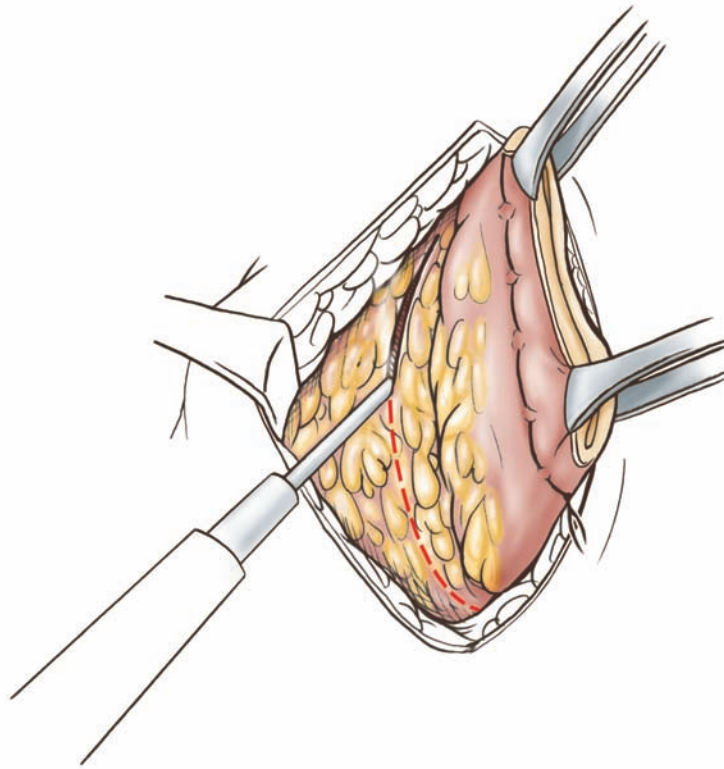


Figure 9.19

the electrocautery. This dissection is carried out on both sides, leaving only the area from 11:00 o'clock to 1:00 o'clock intact anteriorly. The rectum should then be passed through from above so that it is only tethered by the puborectalis and rectourethralis muscles anteriorly. These are defined sharply by stripping away the overlying fat with scissors or bluntly with a sponge-covered finger.

Division of these muscles and the tissue immediately behind them is the most difficult step in the operation. The proper plane is just posterior to the prostate gland and is defined by palpation of the rectum and prostate in the surgeon's noncutting hand. This 2 cm area of division frees the specimen and completes the dissection. Hemostasis is now secured from both above and below. The fatty subcutaneous tissue of the perineum is approximated with at least two, and preferably three, layers of absorbable sutures, followed by skin closure. Suction drains are placed to prevent a pelvic collection. These drains may be brought out through the perineum, but patients are more comfortable when the drains are brought out from above in the lower quadrants of the abdomen.

The omentum is released from the right and proximal transverse colon, and rotated down the left gutter into the pelvis, to fill the empty space. This omental flap has been shown to significantly decrease postoperative abscess formation.

To form the stoma, a skin ellipse of appropriate diameter is excised, and the anterior fascia of the rectus muscle is exposed. Either a cruciate incision may be made or a circle excised to allow easy passage of two finger breadths. The rectus muscle is spread in the direction of its fibers and the peritoneum is incised. When two fingers

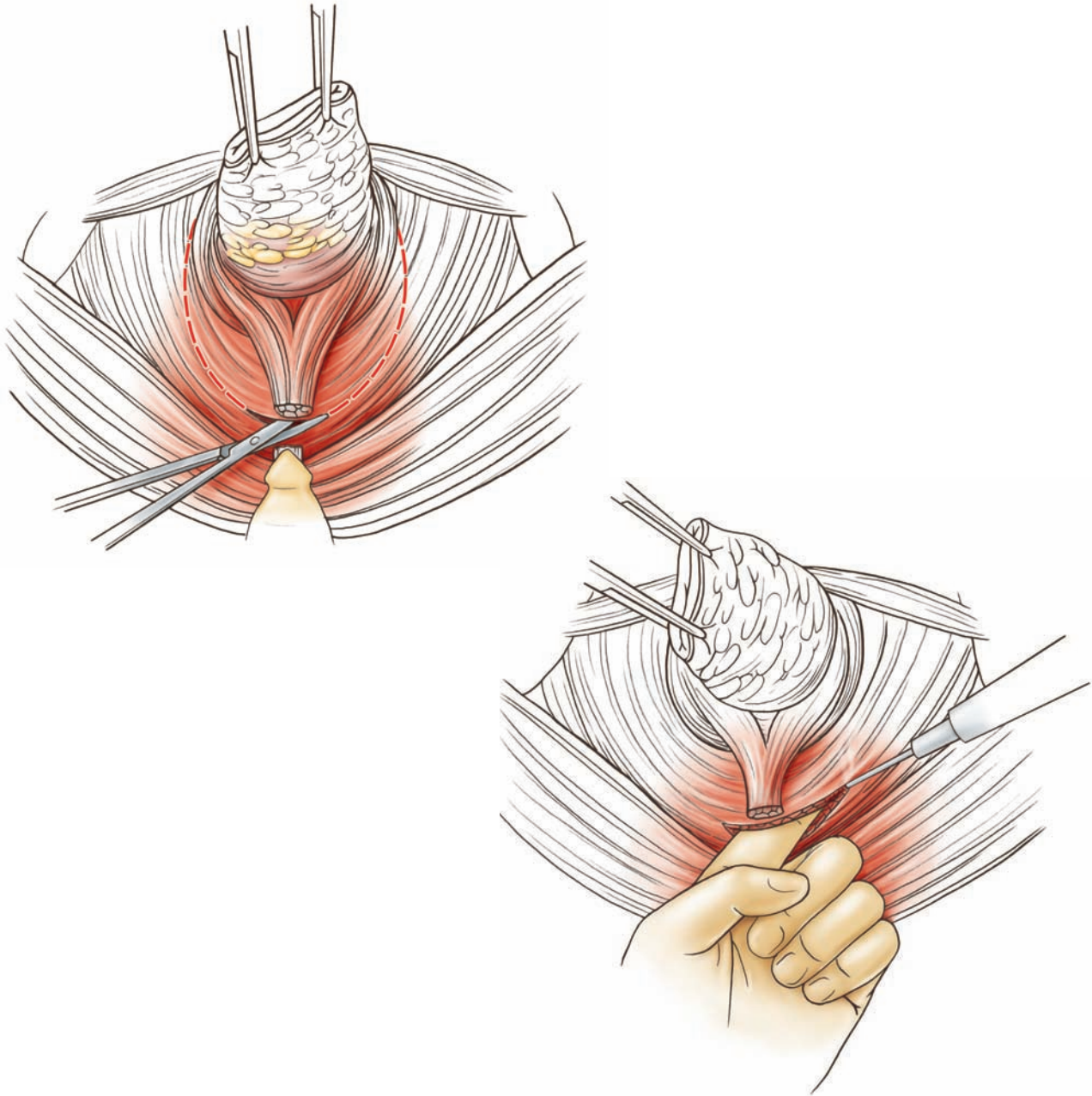


Figure 9.20

can pass through very easily, the sigmoid colon is brought out with care to allow it to lie untwisted and without tension. It may be brought out lateral to the peritoneum in a retroperitoneal manner to avoid later herniation, or it may be tacked to the lateral peritoneal wall to avoid this site for internal herniation. There are no convincing data that either of these maneuvers is of any value, but both are widely practiced. It is matured by suturing a single layer of interrupted sutures through the full layer of the bowel wall and full thickness of the skin, once the abdominal incision has been closed.

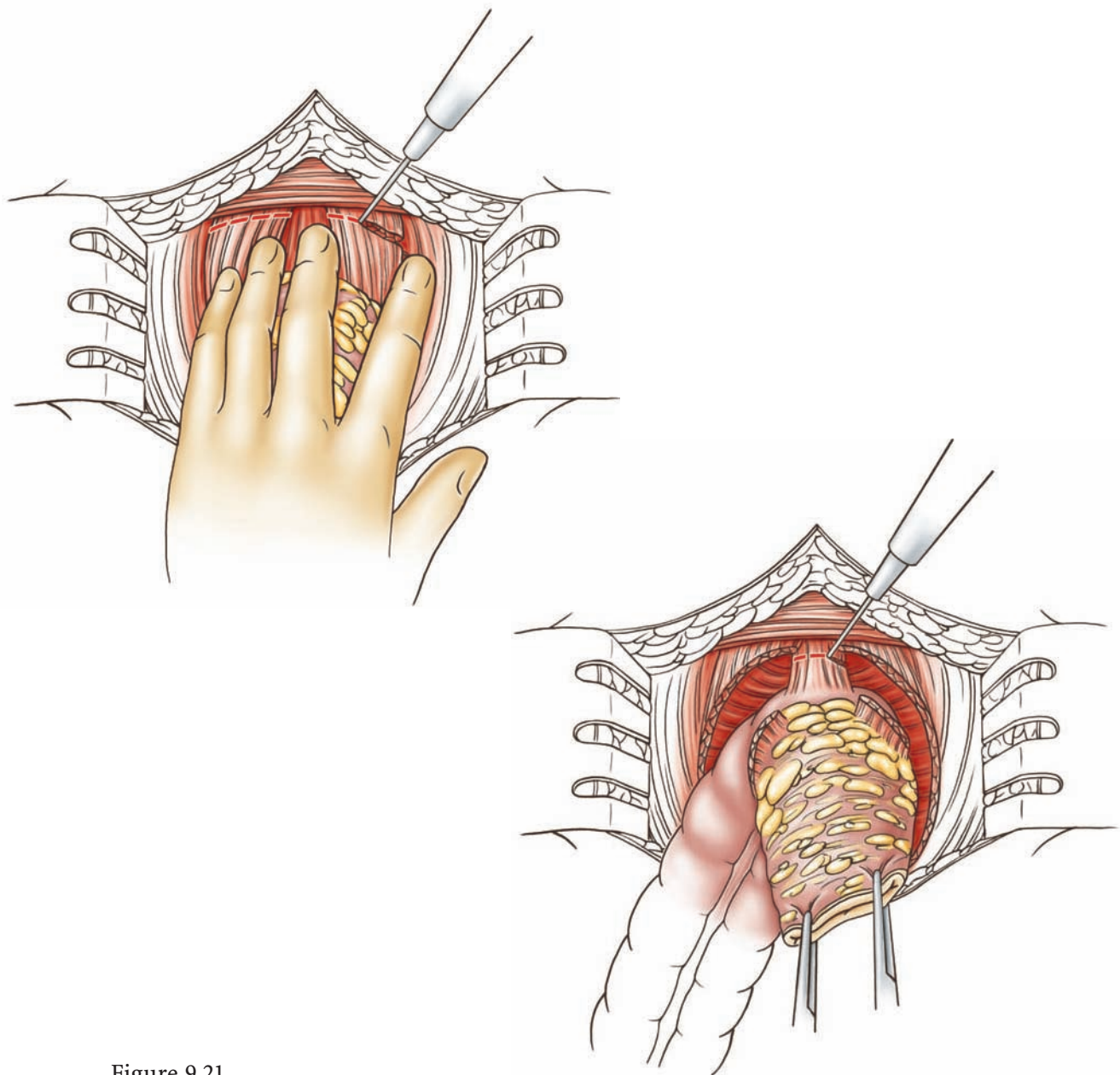


Figure 9.21

Total Pelvic Exenteration

Rectal cancers invading centrally and free of the pelvic sidewall and major vessels may be appropriate for a pelvic exenteration. This procedure combines en bloc APR with cystectomy in male patients and hysterectomy and vaginectomy in female patients if the tumor extends beyond the posterior vagina or uterus. The appropriate chapters should be consulted for more detailed descriptions of the anatomic details that influence these procedures. From below, the ellipse of skin excised includes the vagina and the urethra in female patients.

Abdominally from the aortoiliac bifurcation into the sacral hollow and the pelvic sidewalls, all soft tissues are resected. The sacral plexus is spared, but all anterior tissues are cleared. The ureters are divided and anastomosed to an ileal conduit.

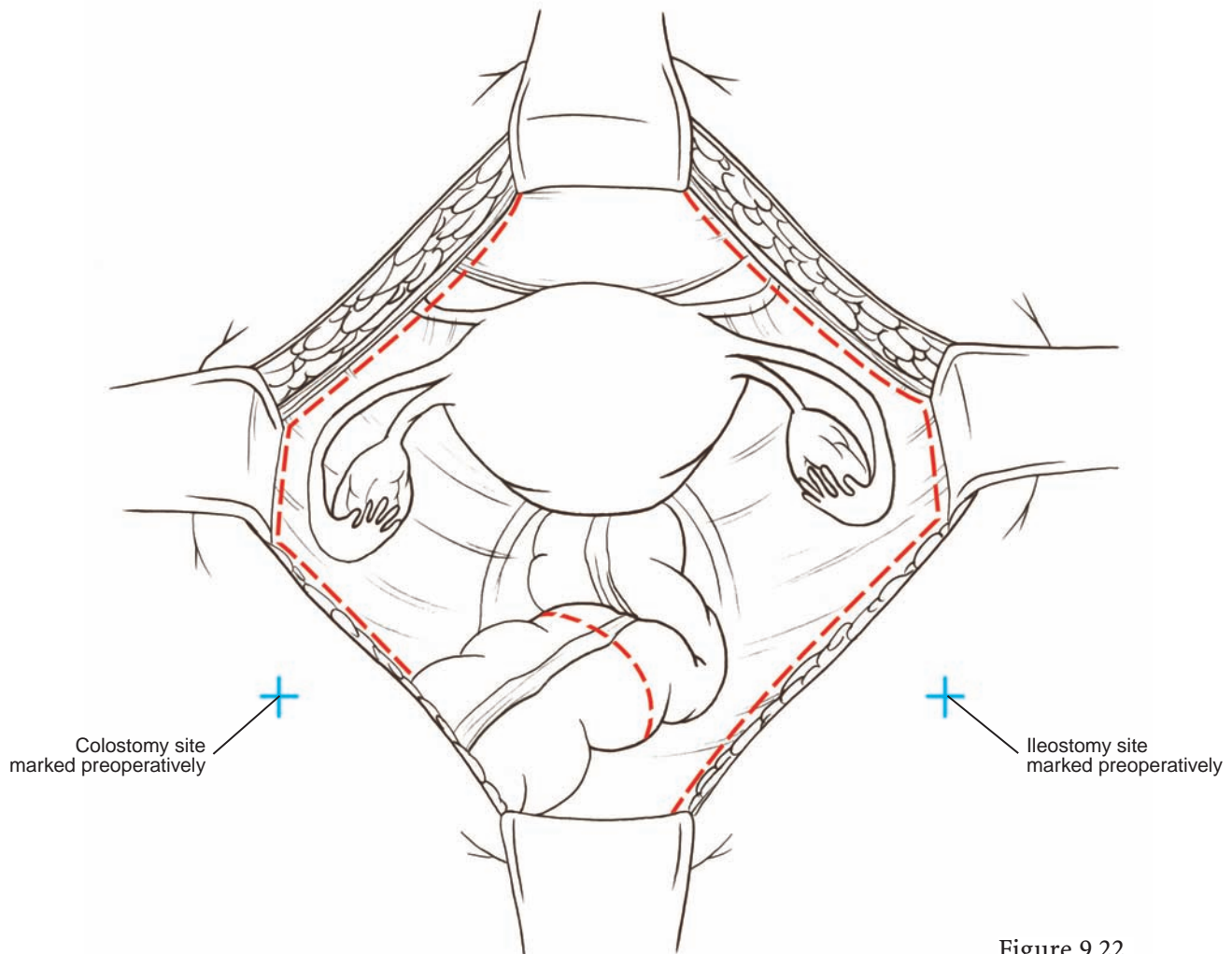
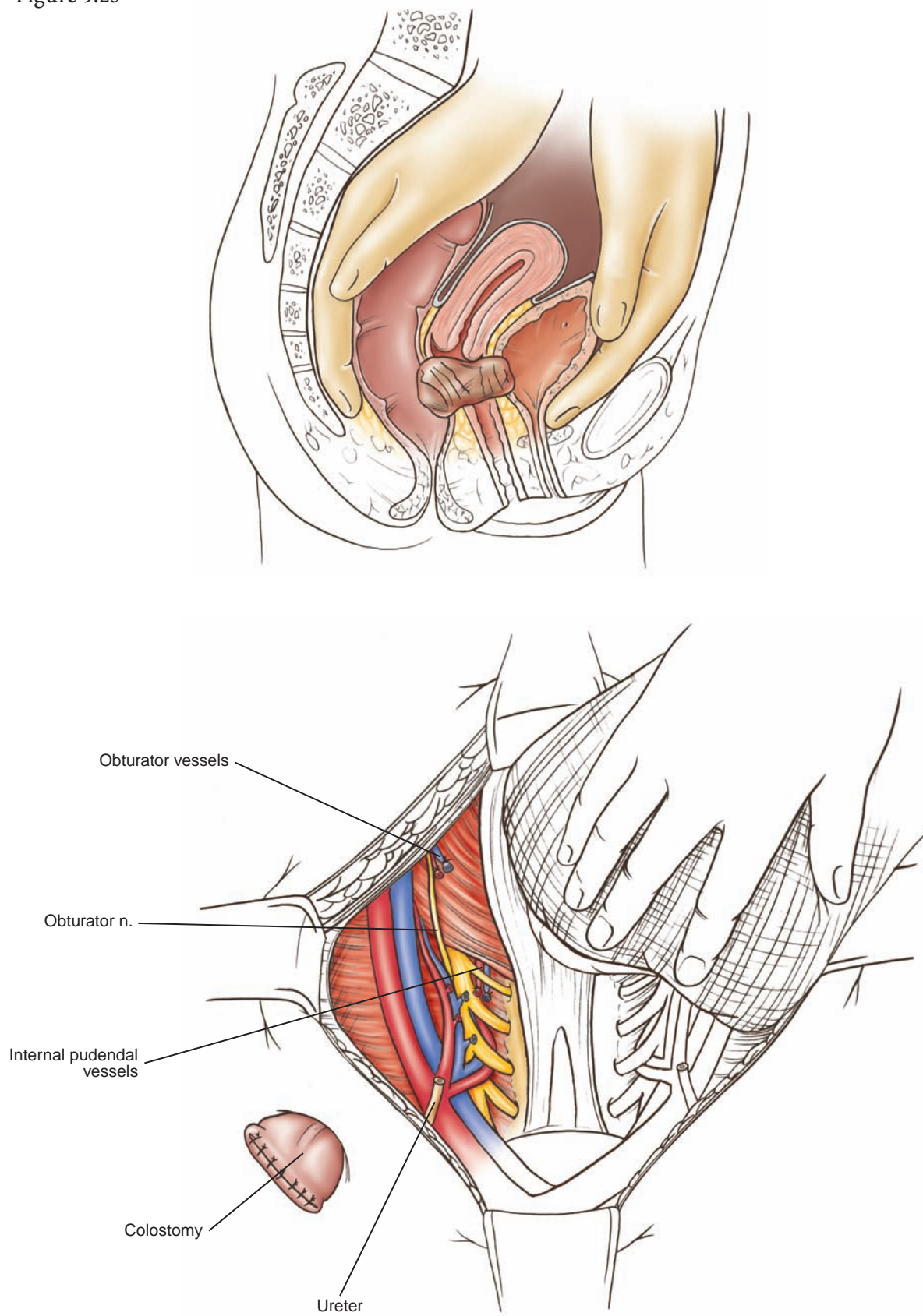


Figure 9.22

Although a majority of patients with rectal cancer will require a radical resection, a small subset of carefully selected early tumors may be managed by local procedures. The advantages of the local approach include avoidance of a colostomy, improved quality of life and avoidance of the morbidity and mortality associated with radical rectal surgery, particularly urinary and sexual dysfunction. Local excision has always been an accepted alternative for patients unfit for a radical operation due to advanced age or multiple comorbidities. The optimal treatment of rectal cancer through a transanal approach requires consideration of the tumor size, location, depth of invasion, nodal status, and histology, as well as patient-related factors. A digital rectal exam can confirm location, size and whether or not the lesion is fixed. Rectal endoscopic ultrasound (EUS) is the most accurate preoperative method of determining the depth of invasion and presence of lymph nodes. An analysis by Solomon and McCleod showed that the accuracy of determining that a tumor was not penetrating outside of the rectal wall was 97%. Favorable lesions for transanal approach by endoscopic rectal ultrasound (EUS) include lesions in the last distal 6–8 cm from the anal verge,

Transanal Excision

Figure 9.23



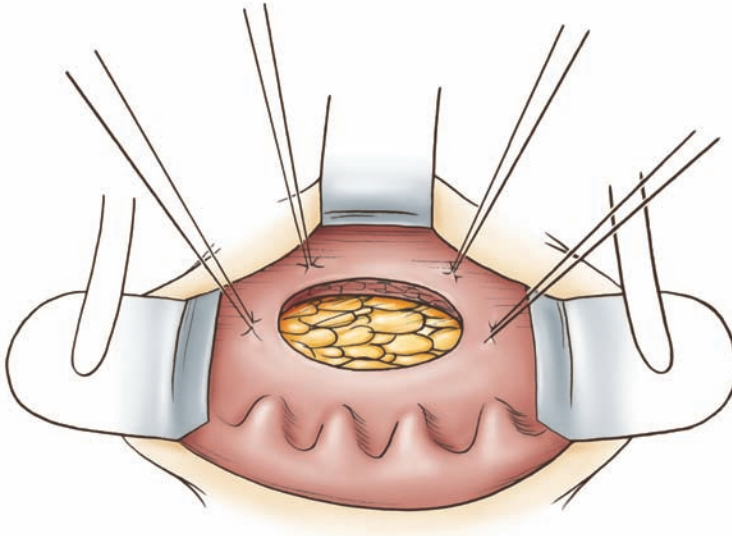


Figure 9.24

tumors less than 3 cm in size, and tumors that are limited to the bowel wall and have no lymph node involvement. The depth of invasion is particularly important given the fact that the incidence of lymph node metastasis increases with tumor penetration into the different layers of the rectal wall. The incidence of lymph node metastasis ranges from 6 to 12% for T1 tumors, 20 to 26% for T2 tumors, and 51 to 66% for T3 tumors. Histopathologic features provide further information and are associated with the risk of lymph node metastasis. Tumors that have poor differentiation or are undifferentiated, lymphovascular invasion, or mucinous histological features are associated with a high risk of lymph node metastasis and are poor candidates for transanal excision.

To perform a transanal excision, the patient undergoes either a full mechanical bowel preparation and/or enemas. The patient is positioned in either a lithotomy or a prone position, depending on the location of the rectal tumor. For posterior lesions, the patient is placed in lithotomy and for anterior lesions, the patient is placed prone. The key to a successful transanal excision is adequate exposure. The combination of self-retracting anal retractors and/or a speculum can be used to adequately expose the tumor. Stay sutures are routinely placed around the lesion to be excised. The lesion is then circumferentially excised with a 1-cm margin as a full thickness excisional biopsy all the way through to the periorectal fat. The specimen is then taken to pathology for orientation.

If there are any close margins, additional tissue is obtained as a new margin. After achieving hemostasis, the rectal wall is reapproximated, either obliquely or transversally to prevent stricturing of the rectum. The transanal excision is usually a well tolerated procedure requiring at most an overnight admission. Potential but rare

complications include bleeding, urinary retention, fecal incontinence, rectovaginal fistula, and rectal stricture.

The results of local excision for rectal cancer are difficult to interpret in the literature due to small retrospective studies and widely varied indications for the procedure. Given these limitations, the majority of studies indicate adequate local control and survival rates for T1 tumors compared to radical resection. However, local excisions for T2 tumors have unacceptably high local recurrence rates of 11–45% and in many studies, inferior survival to radical resection. Other investigators have shown that adjuvant therapy after the local excision of a T2 cancer with either radiation or chemoradiation improves local recurrences. There is a current ACOSOG trial looking at neoadjuvant chemoradiation for patients with T2 rectal tumors that then undergo transanal surgical resections. With the improvement of systemic therapy for rectal cancer, there is considerable interest in a neoadjuvant approach for T3 lesions followed by local excision, however further trials need to be done.

In summary, radical resections of rectal tumors that widely excise the primary tumor and a complete mesorectal excision is still the gold standard, however in selected early, localized tumors, local excision may be equal. Inclusion criteria for local excision include well and moderately differentiated adenocarcinoma limited to the mucosa (T1, N 0 by EUS) without any sign of distant metastasis. Tumors need to be in the distal 6–8 cm of the rectum and not have poor histological prognostic factors which include lymphovascular invasion or mucinous histology. If the final pathology indicates more advanced tumor invasion, including T2, T3, T4 or any nodal involvement or any poor histological variable, the patient should be offered a radical resection.

Transphincteric Approach

The sphincter of the rectum may be divided as advocated by York-Mason, the tumor size, as in the transanal approach, and the sphincter pared meticulously in layers. Later morbidity resulting from scarring in some patients makes this approach less appealing than the transanal approach. The transphincteric route also requires complete division of the anal sphincter, which may result in fecal incontinence. At present, there is no reason for performing this approach.

Kraske's Approach

A combination of per anal excision, low anterior resection, and coloanal resection, this approach has been relegated largely to historical considerations. It is mentioned because it provides a splendid view of the retrorectal anatomy.

The patient is placed prone with a roll beneath the pelvis. The skin incision extends from the coccyx to just outside the anus. The anococcygeal ligament is incised vertically, and the levator ani deep to that is divided in the midline (vertically). Beneath the perirectal fat lies the posterior wall of the rectum, which can be entered or a sleeve of the rectum can be excised.

After the repair of the rectum, the tissues divided originally are reapproximated. This procedure has been associated with fecal fistula in approximately 10% of cases.

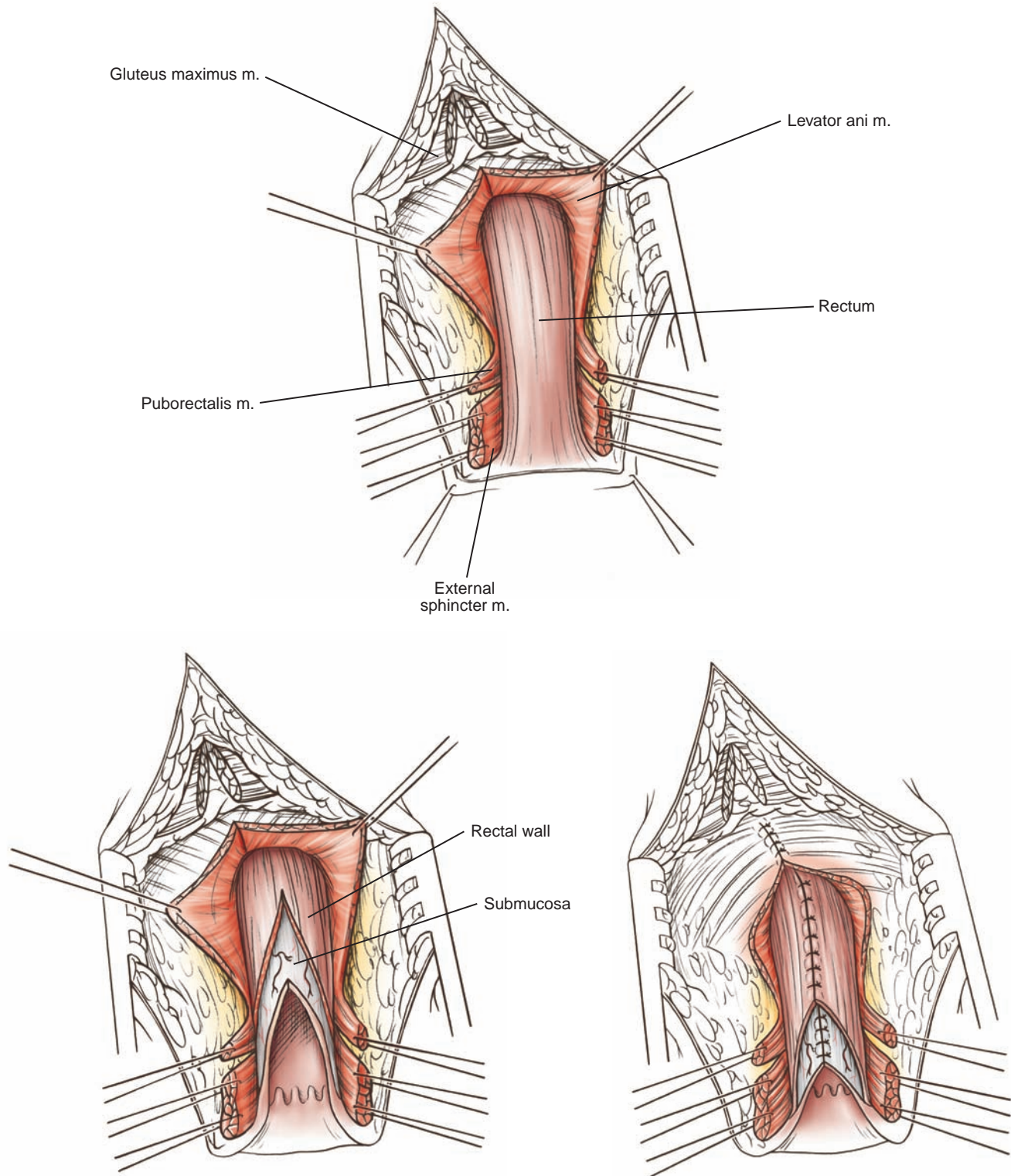


Figure 9.25

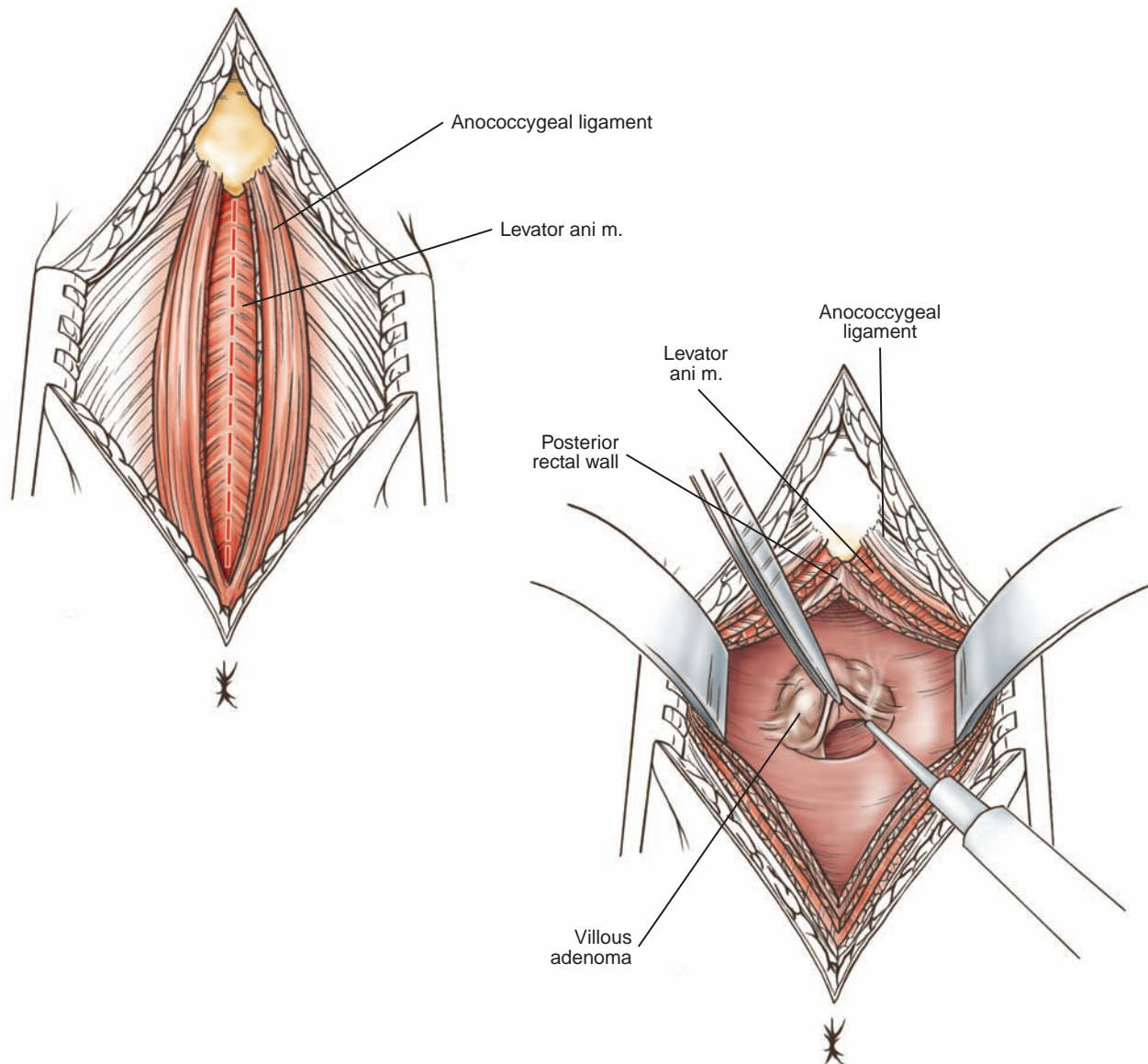


Figure 9.26

Anatomic Basis of Complications

- Exact location of the level of rectal tumor and assessment of its mobility allow use of the resection procedure with least morbidity.
- Injury to the hypogastric nerves diminishes sexual function.
- Failure to resect the mesorectum and achieve full radial clearance increases the likelihood of local recurrence of tumor.
- Resection of the presacral fascia increases the risk for bleeding from sacral veins.
- Incorrect positioning in lithotomy or poor placement of rigid retractors can result in neuropathies in the legs.

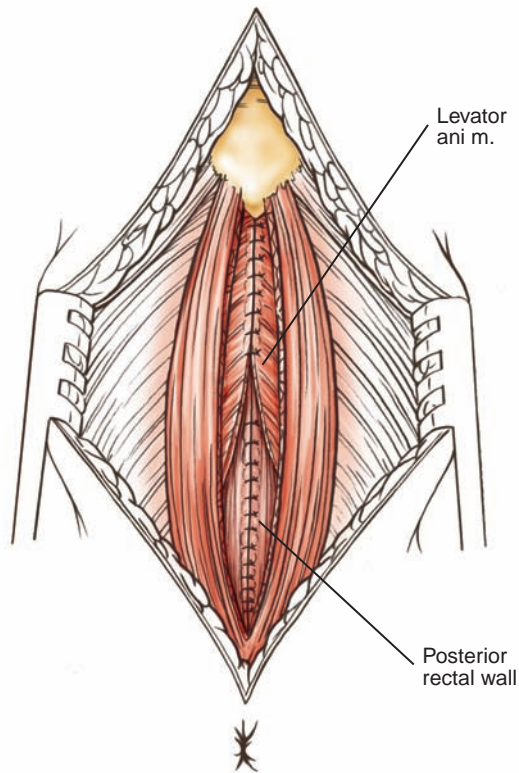


Figure 9.27

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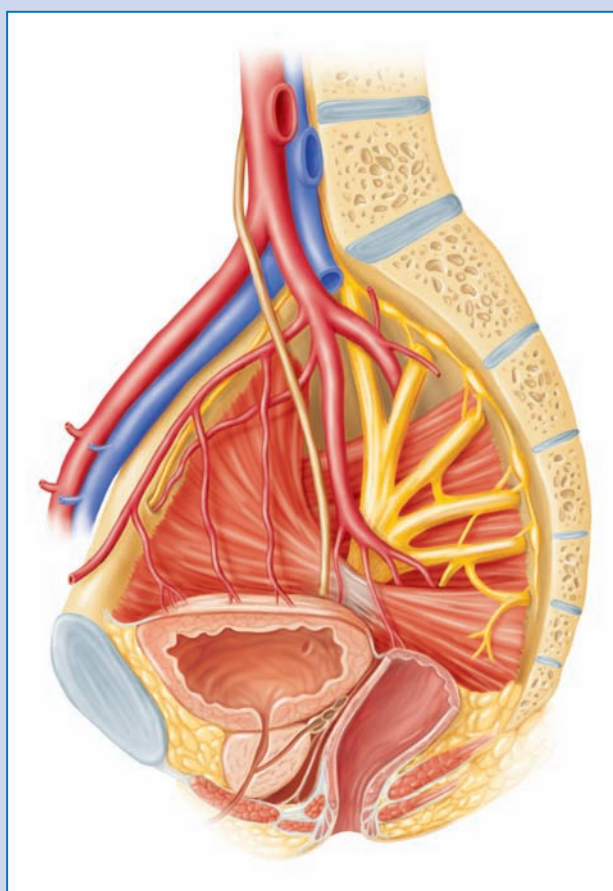
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Pelvis

Shervin V. Oskouei,
David K. Monson,
Albert J. Aboulafia



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Introduction

It is estimated that approximately 2,000 new cases of bone sarcomas and 5,700 cases of soft tissue sarcomas are diagnosed annually in the United States. Approximately 5–10% of these tumors primarily involve the pelvis. Major advances in our understanding of sarcoma biology have led to advances in chemotherapy and surgical techniques that offer the patients with nonmetastatic disease the potential for long-term disease-free survival and cure rates exceeding 50%. This is especially true for the two most common bone sarcomas, osteosarcoma and Ewing's sarcoma. In addition, advances in preoperative imaging studies have allowed surgeons to define the anatomic extent of disease more accurately, and thereby plan surgical procedures with curative intent more precisely. However, these rates of cure for malignant tumors involving the pelvis are often lower than those involving the extremities. This may be due to the complexity of the anatomy of the pelvis making resection with wide margins very difficult.

Until recently, hemipelvectomy was considered the standard surgical procedure for the management of patients with pelvic sarcoma. The procedure, however, is disabling and sacrifices a viable extremity to achieve local tumor control. Predicated on an understanding of sarcoma biology, surgeons have developed limb-sparing procedures that are intended to achieve local tumor control while maximizing function. New reconstructive procedures allow for a complete or partial resection of the innominate bone, often termed internal hemipelvectomy, with preservation of the extremity. There are also other variants of hemipelvectomies based on the need to resect visceral soft tissues such as the rectum or the bladder, or to simultaneously include bony resections involving the spine and/or the sacrum.

Sarcomas grow in centrifugal fashion, forming a central core. As they grow, they tend to compress the normal cells and form a pseudocapsule composed of compressed tumor cells and a fibrovascular zone of reactive tissue. This pseudocapsule gives the appearance of a well-encapsulated tumor. The pseudocapsule is surrounded by grossly normal-appearing tissue that may have tumor cells within it, known as a satellite or micrometastatic lesion. These lesions are believed to be the cause of local recurrence after wide excision. With sufficient knowledge of tumor biology and local anatomy, wide surgical excision (i.e., resection beyond the reactive zone) can be planned, with the goal of maximizing function while at the same time obtaining local tumor control.

Surgical Anatomy

Topography

The pelvis is the region of the trunk below the abdomen and immediately above the lower extremities. The iliac crest can be felt along its entire length from the anterior superior iliac spine to the posterosuperior iliac spine. The pubic symphysis is in the

midline anteriorly, near the distal insertion of the rectus abdominis muscles. The sacral spinous processes are posterior in the midline, within the upper portion of the gluteal cleft, and the coccyx lies in the lower portion of the gluteal cleft behind the anus. The lateral contours of the pelvis are formed by the hip abductor muscles and the greater trochanter of the proximal femur.

Each common iliac artery ends at the level of the sacral promontory in front of the sacroiliac joint by dividing into the external and internal iliac arteries. The external

Blood Supply

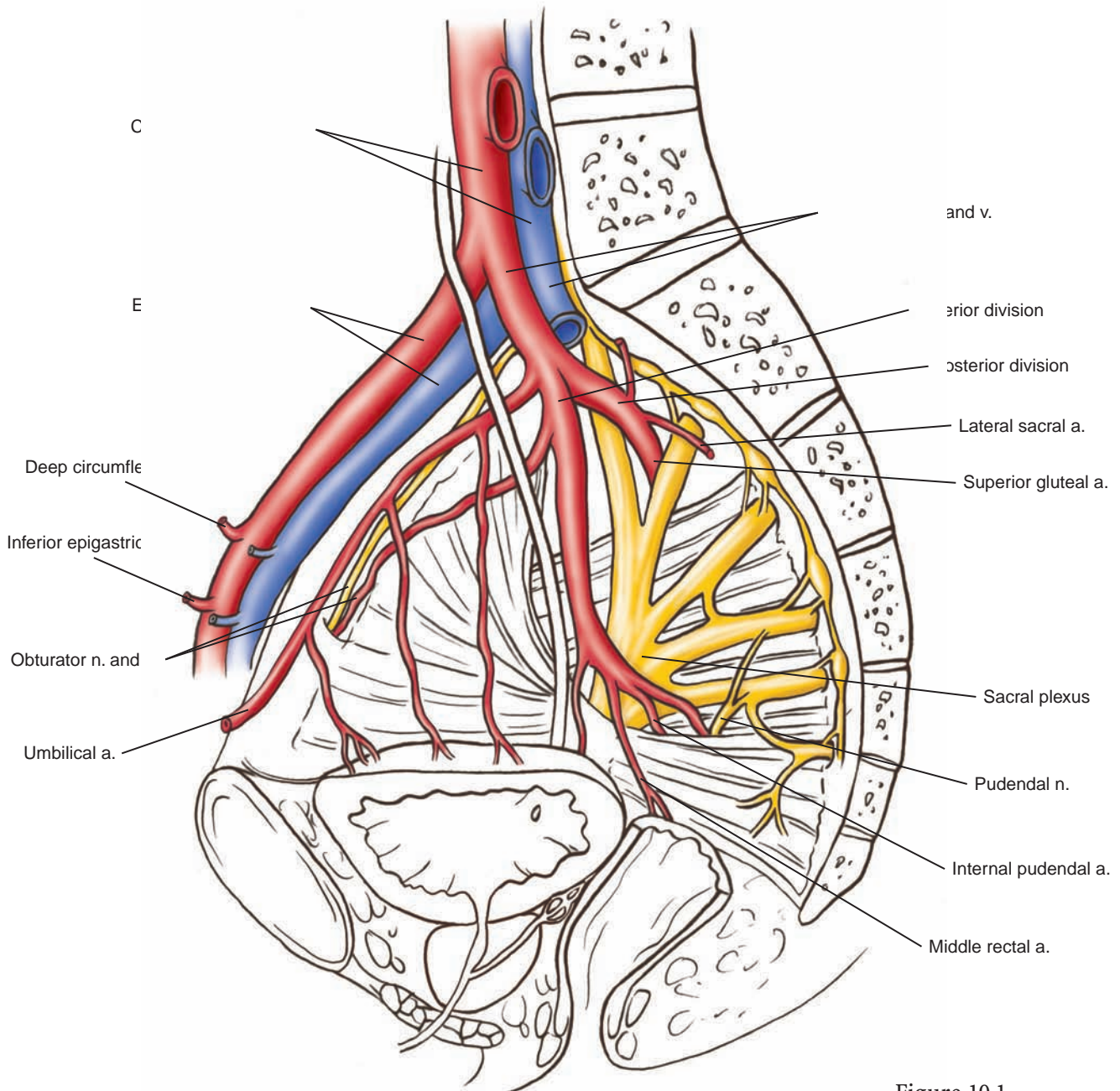


Figure 10.1

iliac artery continues along the medial border of the psoas muscle, giving rise to the deep circumflex iliac and the inferior epigastric branches. It then leaves the false pelvis behind the inguinal ligament to become the femoral artery.

The internal iliac artery passes into the true pelvis to the upper margin of the greater sciatic foramen, dividing into anterior and posterior divisions. Branches of these divisions supply the buttocks, the pelvic walls, the pelvic viscera, and the perineum. Branches of the anterior division include the inferior gluteal, obturator, internal pudendal, umbilical, inferior vesical, middle rectal, uterine, and vaginal arteries. Branches of the posterior division include the superior gluteal, iliolumbar, and lateral sacral arteries.

The external iliac vein receives the inferior epigastric and deep circumflex iliac veins. It runs along the medial aspect of the external iliac artery and is joined by the internal iliac vein to form the common iliac vein. The venous tributaries corresponding to the branches of the internal iliac artery join to form the internal iliac vein, which passes upward in front of the sacroiliac joint to join the external iliac vein.

Nerve Supply

The major nerves of the pelvis include the sacral plexus and the sciatic, femoral, pudendal, obturator, genitofemoral, and lateral femoral cutaneous nerves.

The sacral plexus lies on the posterior pelvic wall in front of the piriformis muscle. It is formed from the anterior rami of the fourth and fifth lumbar nerves and the first, second, third, and fourth sacral nerves. The sciatic nerve and other branches to the lower limb leave the pelvis through the greater sciatic foramen.

The pudendal nerve arises from the second, third, and fourth sacral nerves and exits through the greater sciatic foramen deep to the coccygeus muscle and the sacrospinous ligament. It then reenters the pelvis through the lesser sciatic foramen and courses in the pudendal canal within the obturator internus fascia to the urogenital diaphragm. Essentially, all pelvic resections involving the ischium result in the sacrifice of the pudendal nerve, and it is important to inform patients preoperatively about the anticipated sensory losses.

The femoral nerve is the largest nerve of the lumbar plexus, emerging from the lateral border of the psoas muscle within the abdomen and running between the psoas and the iliacus muscles of the false pelvis before exiting the pelvis behind the inguinal ligament to enter the thigh lateral to the femoral vessels and the femoral sheath. The femoral nerve can sometimes be preserved in the resection of soft tissue or bone sarcomas arising within the iliac fossa, thereby maintaining intact function of the important quadriceps muscle group within the thigh.

The obturator nerve arises from the lumbar plexus along the medial border of the psoas muscle in the abdomen and crosses the front of the sacroiliac joint to enter the pelvis. It continues forward along the pelvic wall in the angle between the internal and external iliac vessels until it reaches the obturator canal and leaves the pelvis to enter the adductor compartment of the thigh. This nerve can often be preserved in the resection of soft tissue sarcomas arising within the iliac fossa or bone sarcomas not requiring excision of the obturator ring.

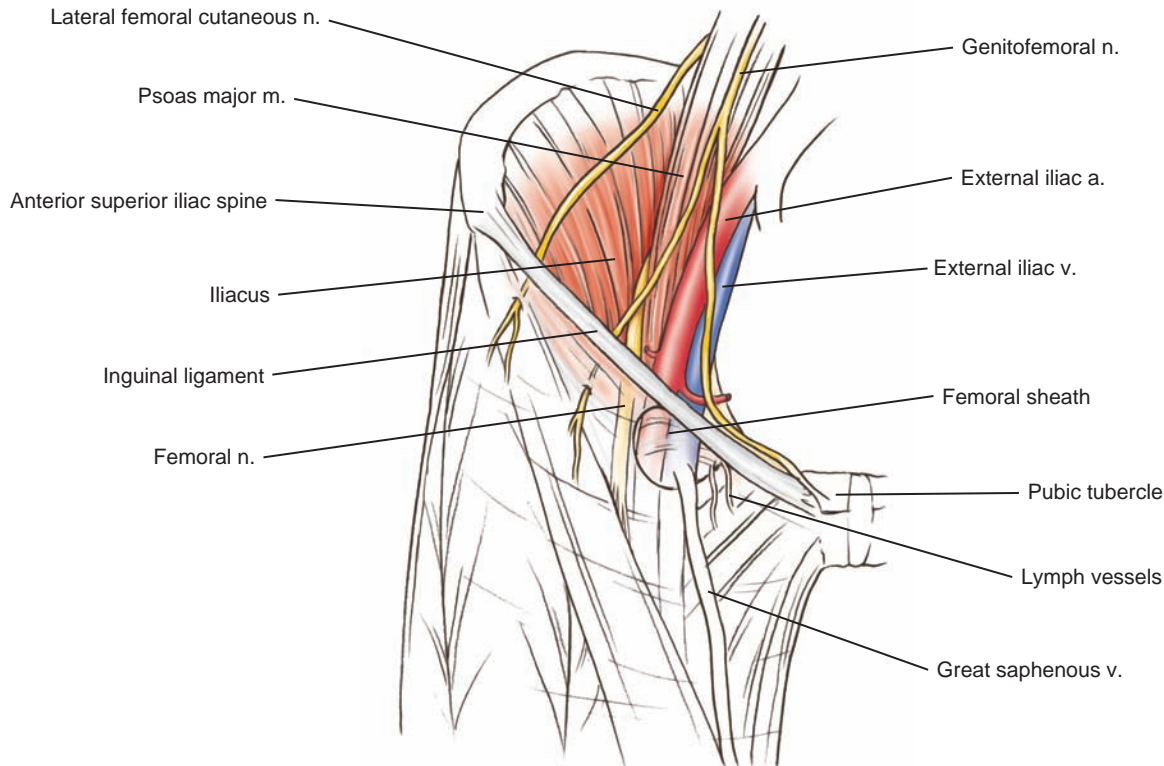


Figure 10.2

The lateral femoral cutaneous nerve crosses the iliac fossa anterior to the iliac muscle and exits the pelvis behind the lateral end of the inguinal ligament.

The external, internal, and common iliac nodes are arranged in a chain along the major blood vessels after which they are named.

Regional lymph node metastases are generally considered uncommon in patients with bone and soft tissue sarcomas. In a review of 2,500 cases of soft tissue sarcomas, Weingrad and Rosenberg found a 5% incidence of nodal metastasis during the course of treatment. However, the incidence of regional node metastasis is much higher in certain histologic subtypes, such as epithelioid sarcomas (20%), synovial sarcomas (17%), malignant fibrous histiocytomas (17%), rhabdomyosarcomas (12%), and clear cell sarcomas. The diagnosis of metastatic melanoma or carcinoma must be excluded in patients with regional node metastasis.

Lymphatic Drainage

The bony pelvis consists of two innominate bones and the sacrum and coccyx. The innominate bones are divided into three regions: the ilium, the ischium, and the pubis. The two innominate bones are joined anteriorly by the pubic symphysis, and are joined to the sacrum posteriorly at the sacroiliac joints. The pelvic brim is formed by the sacral promontory posteriorly, the iliopectineal line laterally, and the pubic symphysis anteriorly. The false pelvis is above the brim and forms part of the abdominal cavity while the true pelvis lies below.

Bony Pelvis

Ligaments The sacrotuberous ligament extends from the lateral part of the sacrum and coccyx and the posterior inferior iliac spine to the ischial tuberosity. The sacrospinous ligament lies anterior to the sacrotuberous ligament and extends from the lateral part of the sacrum and coccyx to the ischial spine. These ligaments prevent upward rotation of the lower sacrum and coccyx at the sacroiliac joints and divide the sciatic notch into the greater and lesser sciatic foramina.

The iliolumbar ligament is a posterior structure connecting the tip of the fifth lumbar transverse process to the iliac crest. The posterior sacroiliac ligament and interosseous sacroiliac ligaments stabilize the posterior aspect of the sacroiliac joint; the anterior sacroiliac ligament lies across the anterior aspect of the joint. These structures are important to posterior pelvic stability and must be identified and divided in all the resections carried out through the sacroiliac articulation.

The inguinal ligament is formed by the inferior margin of the external oblique muscle aponeurosis. It extends from the anterosuperior iliac spine laterally to the pubic tubercle medially and inferiorly.

Musculature The medial wall of the ilium is covered by the psoas and iliac muscles, which are further separated from the deeper pelvic structures by a distinct fascial plane. The origin of the iliac muscle from the iliac crest serves as a natural barrier to tumor extension, both into the flank superiorly and the central pelvic structures medially. The gluteal muscles of the buttocks and the tensor fascia lata muscle cover the lateral wall of the ilium. Their investing fascia and origins from the iliac crest also serve to contain tumor growth external to the ilium. However, tumor extension may occur beneath the caudal edge of the gluteus maximus muscle into the proximal portion of the posterior thigh or through the sciatic notch into the pelvis. The muscles arising from or inserting into the ischium and the pubis provide poor containment of potential tumor extension and do little to impede tumor growth into the proximal thigh or the ischiorectal fossa, or along the retroperitoneal space.

Within the true pelvis, the piriformis muscle arises from the front of the sacral lateral masses and passes through the greater sciatic foramen to leave the pelvis. The obturator internus muscle arises from the intrapelvic surface of the obturator foramen and the medial wall of the acetabulum to emerge from the pelvis through the lesser sciatic foramen. The parietal pelvic fascia overlies these muscles and assists in tumor containment.

Ureter The ureter lies in the interval between the peritoneum and the psoas fascia. It enters the pelvis by crossing the bifurcation of the common iliac artery in front of the sacroiliac joint, then lies anterior to the internal iliac artery down toward the ischial spine. It may be displaced by large tumor masses extending medially into the pelvis, but can usually be mobilized away from the medial tumor mass along with the peritoneum, to which it is loosely attached. Direct tumor involvement is rare because of the containment of tumor by the psoas fascia.

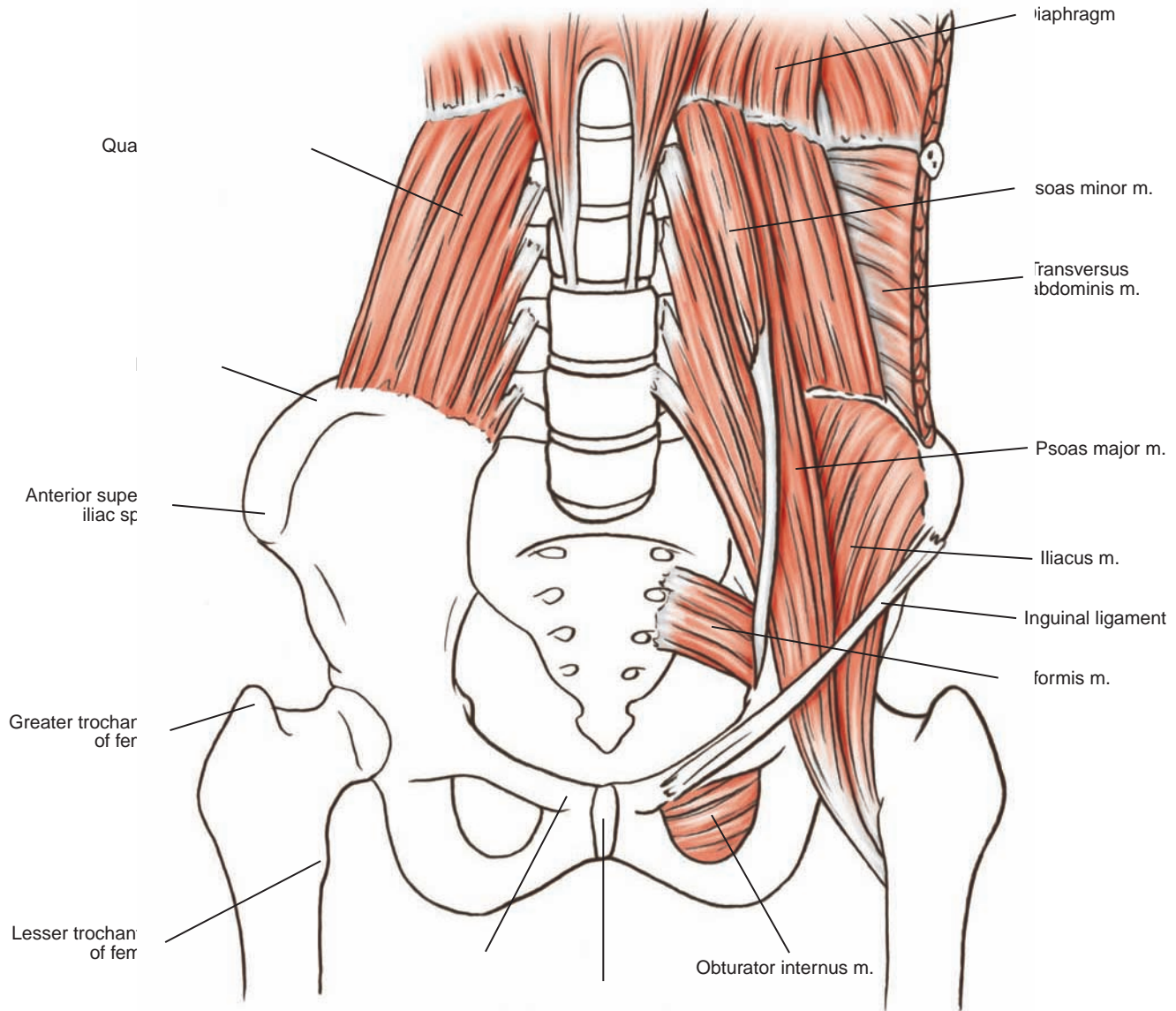


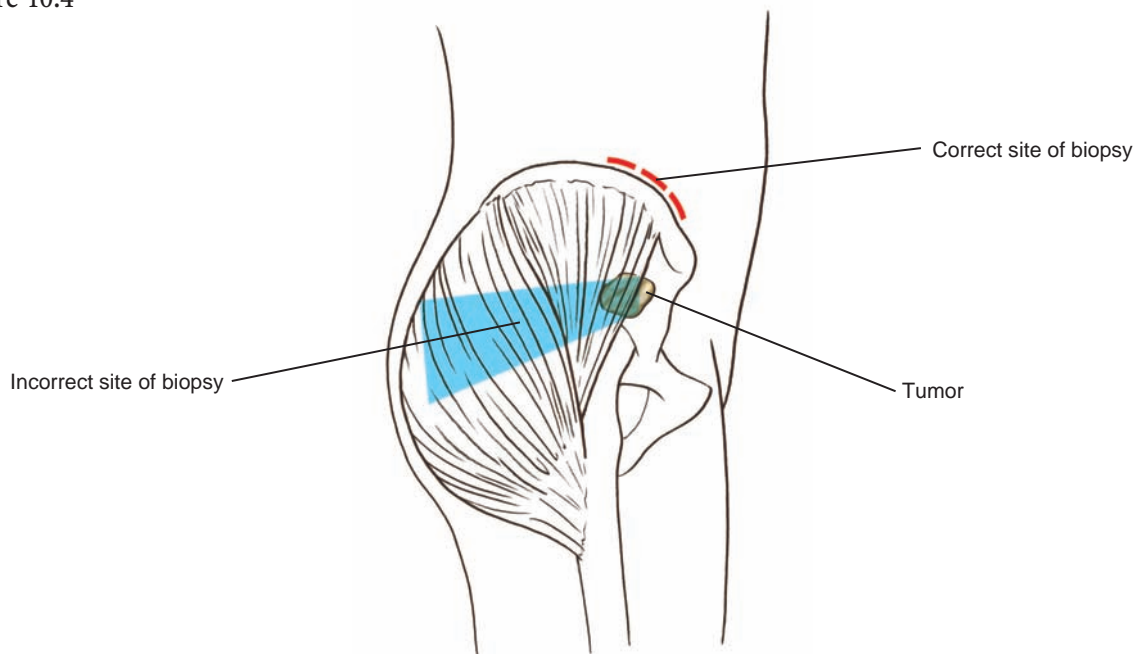
Figure 10.3

Surgical Applications

Complications resulting from poorly planned biopsies adversely affect subsequent surgery and compromise local tumor control. The biopsy site should be chosen such that it can be excised en bloc with the tumor when definitive surgery is performed. In addition, soft tissue compartments not involved with the tumor should not be violated. This requires that the person performing the biopsy be familiar with the various surgical procedures for the management of pelvic sarcomas. The biopsy should be thought of as the first stage of surgery. Therefore, it cannot be overemphasized that the person performing the biopsy should be prepared to do the definitive surgical

Biopsy

Figure 10.4



resection. Even seemingly innocuous procedures, such as computed tomography (CT)-directed biopsy, contaminate tissue planes and must be performed carefully. It is extremely important that there is generous communication between the surgeon and the radiologist to ensure the appropriate placement of the needle during CT-guided biopsies.

A biopsy performed through the buttock for a pelvic sarcoma can contaminate tissue compartments that would otherwise be preserved and used for wound closure during definitive tumor resection. A patient with a pelvic sarcoma who might be managed with a limb-salvage procedure, such as internal hemipelvectomy, may require an anterior flap hemipelvectomy after contamination of the buttock and gluteal musculature following a poorly planned biopsy.

Such complications resulting from poorly planned biopsy of suspected sarcomas compromising optimum treatment are well documented. This is especially true for pelvic sarcomas because surgeons are less likely to be familiar with the surgical procedures associated with limb sparing than in other extremity sites.

Prior to performing a biopsy, imaging studies such as plain radiographs, CT scans, and magnetic resonance imaging (MRI) studies are obtained to give a three-dimensional representation of the tumor and the surrounding anatomy. Performing staging studies prior to biopsy has several distinct advantages. First, characteristics of bone sarcomas evident on plain radiographs or other imaging studies may provide diagnostic clues to the nature of the lesion. Likewise, appropriate imaging of soft tissue lesions may lead to diagnostic considerations of soft tissue masses that mimic sarcoma. Hence, preoperative imaging studies obtained prior to biopsy can alter the prebiopsy differential diagnosis and provide additional information for the pathologist in establishing a diagnosis based on clinical, radiographic, and histologic

correlation. In many cases, the biopsy serves to confirm what is suspected on the basis of clinical and radiographic information. In such a situation, after intraoperative frozen-section confirmation, definitive surgery can be accomplished in the same operative setting if clinically indicated. Second, preoperative imaging may indicate a soft tissue component of a bone sarcoma, obviating the need to biopsy the bone and allowing for biopsy of the soft tissue component of the tumor. By obtaining the biopsy from the soft tissue component of a bone sarcoma, a stress riser in the bone that can potentially predispose to a pathologic fracture is prevented. Third, prebiopsy imaging studies can localize tumor to specific compartments, allowing for directed biopsy to be performed without unnecessarily contaminating unaffected compartments. Fourth, after biopsy, imaging studies, such as technetium bone scans or MRI studies, to determine the extent of tumor may be different, making accurate assessment of tumor extent more difficult.

While the need for the biopsy of suspected pelvic sarcomas prior to initiating treatment is well accepted, it is not the case with the optimal technique for obtaining the tissue for diagnosis. Once the decision to proceed with biopsy has been made, the surgeon must decide on the most appropriate biopsy technique. Four basic biopsy techniques are described. Factors related to the size, consistency, and location of the tumor, as well as institutional preference and experience, may affect the ultimate choice of biopsy technique.

Fine-needle aspiration biopsy of carcinomas is a widely used and successful diagnostic technique, but its role in the evaluation of pelvic bone and soft tissue sarcomas is controversial. Fine-needle aspiration biopsy was first described in the 1850s. The technique involves the use of a fine needle to aspirate cells from a tumor. This is its fundamental difference from other biopsy techniques, which are intended to obtain tissue rather than cells. The procedure offers many advantages over other biopsy techniques: it is simple, with little potential for complications, and can be performed in an office setting with minimal equipment needs. The equipment needed for the aspiration of superficial masses includes sterile gloves, alcohol swabs, 10 or 20 mL syringes, an aspiration needle holder, 22- to 25-gauge disposable needles of varying lengths, saline solution, sterile gauze, Coplin jars containing 95% alcohol, nonfrosted slides, and local anesthetic (optional). “Thin” needles (22 gauge or smaller) are used to decrease the amount of the obscuring blood obtained, ensure a cytologic, and not histologic, specimen, and minimize complications. The work area is prepared with the Coplin jars and saline solution vials opened and ready. Slides are labeled with the patient’s name or an identifying number, or both. A 10 or 20 mL syringe with attached needle is placed in the aspiration holder. The use of various size needles, from 18 to 25 gauge, has been described for fine-needle aspiration of sarcomas. Once the biopsy site is determined, the skin is prepared and anesthetized. A needle, attached to a syringe, is introduced into the tumor. When the needle is within the tumor the plunger is drawn back, creating negative pressure (suction) in the syringe. With continuous negative pressure, the needle is vigorously moved within the tumor mass using a sawing motion.

Fine-Needle Aspiration Biopsy

When the material is noted in the needle hub, negative pressure is released and the needle is removed. Firm pressure is applied over the site to minimize the potential for hematoma formation.

Attention is then directed to the preparation of the slides. This step is extremely important to optimize the chances of obtaining an interpretable specimen. The needle is removed from the syringe, a small amount of air is introduced into the syringe, and the needle is reattached. The bevel of the needle is placed directly on the slide surface and a small drop of the material is expressed onto the center of the slide. Usually three to six slides can be prepared with each aspiration pass. With a second “spreader” slide gently placed crosswise over the drop of material, the specimen is gently smeared in one smooth motion down the diagnostic slide. The slide is then immediately placed in 95% alcohol fixative. Rapid fixation is extremely important. Several air-dried smears can be made for Romanovsky staining. The needle and the syringe are then rinsed with saline solution and collected in a saline solution–filled tube to ensure salvage of all cellular material. Other slides are then made for additional cytologic studies, such as thin smear, cytopsin, and cell block. The aspiration procedure can be repeated to ensure optimal sampling of various sites of the mass or to obtain material for flow cytometry and microbiologic cultures. The slides are stained with hematoxylin-eosin, Papanicolaou’s stain, or Romanovsky’s stain.

The role of fine-needle aspiration biopsy in the evaluation of carcinomas and the documentation of recurrent tumor or metastatic disease involving the pelvis is well accepted. However, the success of obtaining tissue for diagnostic purposes in primary bone and soft tissue sarcomas is less than that achieved with core needle or open biopsy. In addition to its other advantages, fine-needle aspiration biopsy can be easily used to biopsy deep-seated tumors, particularly in the retroperitoneum, with CT assistance. While the diagnostic accuracy for malignancy approaches 90% for fine-needle aspiration biopsy performed at experienced institutions, the accuracy rate is lower for specific tumor type and grade. Establishing the grade and type of tumor is not simply an academic exercise but has important implications for planning surgical resections as well as neoadjuvant and adjuvant treatment. For example, a low-grade liposarcoma may be treated with a marginal resection to preserve vital structures, whereas a high-grade liposarcoma requires at least a wide margin resection or preoperative irradiation. Similarly, a high-grade osteosarcoma is usually treated with neoadjuvant and adjuvant chemotherapy, whereas high-grade chondrosarcoma usually is not.

Because fine-needle aspiration biopsy is used to obtain cells rather than tissue and does not preserve tissue architecture, many believe that it should not have a primary role in the diagnostic evaluation of primary bone and soft tissue sarcomas. The use of a fine needle technique is not recommended to biopsy masses that are felt to be a sarcoma.

Core Needle Biopsy

Core needle biopsy, like fine-needle aspiration biopsy, is performed percutaneously, usually in an office setting with local anesthesia. Unlike fine-needle aspiration biopsy, in core needle biopsy, a core of tissue rather than cells is obtained and the tumor

architecture is preserved. As a result, the diagnostic accuracy of core needle biopsy is superior to that reported for fine-needle aspiration biopsy and is the preferred method for closed biopsy of sarcomas at most centers. Various needles have been used to obtain core specimens from soft tissue or bone. The Tru-cut needle is most useful for the biopsy of soft tissue sarcomas or the soft tissue component of bone sarcomas. On occasion, if the cortex of the bone has been sufficiently weakened by tumor, a Tru-cut needle can be used to biopsy the bone. The use of other core needles, such as the Craig needle, designed to biopsy pathologic bone, generally requires sedation or general anesthesia.

Biopsy with a Tru-cut needle is usually performed in an office setting, with local anesthesia and generally without radiographic assistance. However, readily available mini fluoroscopic imaging may be used if deemed helpful. Compared with open biopsy, which is usually performed in an operating room, closed biopsy is less expensive and more convenient. Additional advantages of closed biopsy over open biopsy include (1) less risk for wound complications and infection, and (2) neoadjuvant chemotherapy or radiation therapy, which are an integral part of treatment for pelvic bone and soft tissue sarcomas, can begin immediately, even before wound healing. Closed biopsy may be associated with less risk for hematoma formation and local tumor contamination, than that of open biopsy.

Despite the simplicity of core needle biopsy, the procedure should be performed only by physicians familiar with the surgical procedures involved in managing pelvic sarcomas. Once the decision for closed biopsy of a suspected pelvic sarcoma has been made, the surgeon selects the most appropriate site for biopsy, so that the biopsy site can be excised en bloc with the definitive surgical resection while preventing the contamination of compartments not involved with the tumor. The individual performing the biopsy should mark the planned skin incision for resection and incorporate the biopsy with the skin markings. If the person who is planning to perform the biopsy is unable to mark out the skin incision that may be used for future surgery, the biopsy should be deferred and consultation be obtained from the surgeon who would likely perform the definitive resection. Additional considerations in selecting the biopsy site include integrity of the skin and avoidance of sampling error. Thin and tented skin overlying a tumor should be avoided because it is prone to delayed

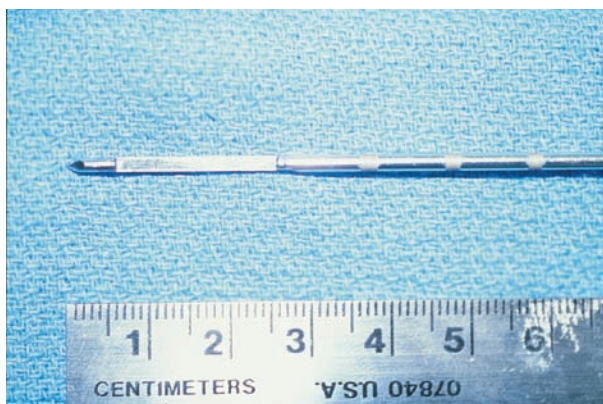


Figure 10.5

healing. Similarly, the center of the tumor is likely to be the most necrotic portion, and so samples should be obtained from the periphery of the mass, which is more likely to yield viable tissue.

The skin is prepared with povidone-iodine (Betadine) and infiltrated with local anesthetic. A small puncture wound is made in the skin with a No. 11 blade. This allows the needle to pass freely into and out of the soft tissue and creates a small scar marking the biopsy site for later identification so that it can be excised en bloc with the tumor. The needle is then introduced beneath the skin while the trocar is kept closed. The tip of the needle is advanced to the periphery of the tumor. With one hand holding the needle in place, the surgeon uses the other hand to advance the trocar into the tumor, thereby opening the sample tray. Next the cutting sleeve is advanced, closing the sample tray over a piece of tumor. The entire needle is withdrawn and the specimen sterilely retrieved. Several specimens can be retrieved and multiple sites of the tumor can be sampled by repeating the technique and redirecting the needle to other portions of the tumor. Tumor may then be placed in fresh saline solution and given to the pathologist. If adequate tissue is available, frozen sections may be obtained to confirm that the diagnostic tissue has been used. Additional portions of tumor may be saved for special studies, such as electron microscopy, cytogenetics, or flow cytometry. Firm pressure is applied to the biopsy site for several minutes to prevent hematoma formation. A single nonabsorbable suture may be used to close the skin and mark the biopsy site.

There is a reported nondiagnostic rate of 20% in the literature. However, this rate is highly dependent on the experience of the physician performing the biopsy and perhaps more importantly of the pathologist interpreting the biopsy material. Despite the high diagnostic yield achieved with closed biopsy, a study that is negative for tumor should not always be interpreted as absence of tumor. If there is a strong clinical suspicion for the existence of a tumor, open biopsy may be indicated.

Open Biopsy

Open biopsy may be incisional or excisional. Incisional biopsy is performed to obtain a small piece of tumor for diagnostic purposes, whereas excisional biopsy is performed with the intention of removing the entire tumor. Selecting the most appropriate procedure for a suspected pelvic sarcoma may depend on the surgeon's experience and ability in determining preoperatively if a given lesion is malignant. Primary resection for suspected soft tissue sarcomas has been described, but because of the magnitude of this procedure, it would be ill advised for a benign lesion. Similarly, excision along the pseudocapsule of a malignant tumor is likely to result in local recurrence. Given that the optimal surgical procedure for a suspected pelvic sarcoma depends on accurate histologic diagnosis and grade preoperatively, excisional biopsy is generally reserved for selected situations. If open biopsy of a suspected pelvic sarcoma is necessary, incisional biopsy is usually the procedure of choice. Excisional biopsy of pelvic soft tissue tumors should be reserved for small (less than 5 cm) subcutaneous masses with a low probability of malignancy or when MRI studies show the mass to have characteristics of a lipoma on all sequences. Bone tumors may likewise be managed with excisional biopsy when the preoperative diagnosis

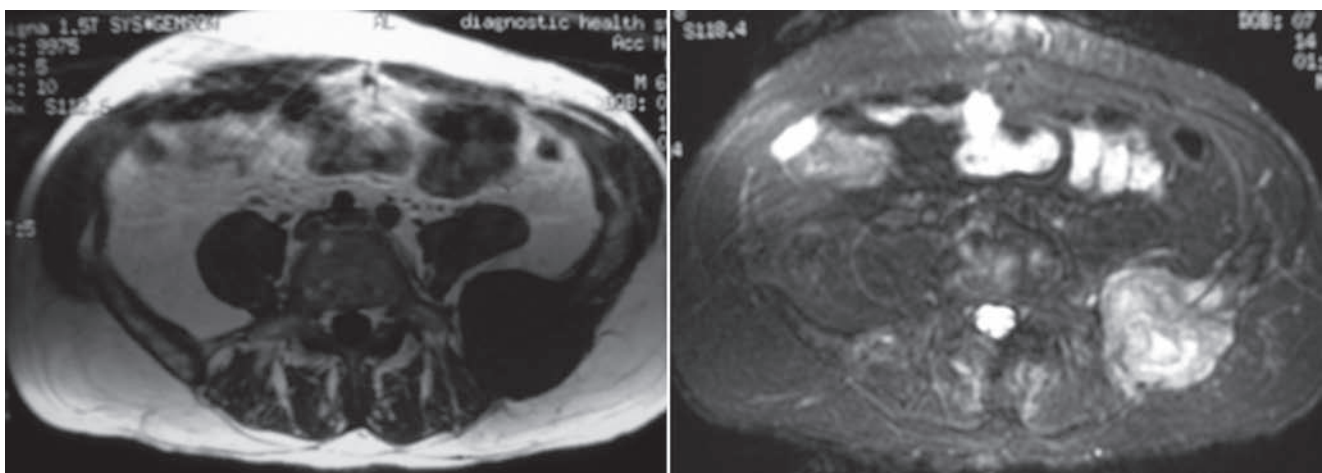
of benign tumor is almost certain, as in the case of an osteochondroma. Excisional biopsy of malignant bone lesions may be performed in selected cases, such as low-grade chondrosarcomas, which are not usually treated with neoadjuvant agents and may have characteristic findings on preoperative imaging studies.

Incisional Biopsy

Despite the technical ease of incisional biopsy, the procedure requires knowledge and understanding of the complex anatomy of the pelvis and of the surgical procedures used to treat pelvic sarcomas. The hazards of open biopsy of extremity sarcomas are well documented. The incidence of major errors in diagnosis, nonrepresentative or technically poor biopsies, and problems with skin, soft tissue, or bone resulting from open biopsy are alarmingly high. These complications are three to five times more common when the biopsy is performed by someone other than the surgeon who perform the definitive resection. Complications resulting from the biopsy of extremity sarcomas compromise future limb-sparing procedures and adversely affect patient outcome. The complex anatomy of the pelvis and the lack of experience of most surgeons with resections in this area increase the potential for complications.

Prior to selecting the site of biopsy all preoperative imaging studies should be carefully reviewed. The biopsy site should be chosen not necessarily for the shortest route but with the idea that the biopsy should be placed in line with the incision that will be used for the definitive resection. Consequently, the surgeon performing the biopsy must be familiar with the various pelvic resection procedures used for sarcomas. The biopsy should be considered the first part of the surgery and not simply as a procedure performed to enable diagnosis. In addition, the site should be selected in an area where skin complications are not likely to result. The temptation to make an incision directly over skin tented from the underlying tumor should be avoided.

Figure 10.6



The imaging studies, such as plain radiographs, CT scans, and MRI studies, are reviewed to select the most appropriate part of the tumor to be biopsied. For bone tumors the least differentiated or mineralized portion of the tumor is most likely to yield diagnostic tissue. Areas of reactive bone should be avoided lest a mistaken diagnosis of osteosarcoma be rendered. For most malignant bone tumors, there is a soft tissue component of the tumor that is frequently best seen with MRI. It is preferable to biopsy the soft tissue component of the bone tumor rather than the bone, so that the risk for weakening the bone and the resultant pathologic fracture is avoided. In cases of soft tissue sarcomas the MRI studies may reveal areas of necrosis, which are less likely to provide viable tumor when biopsied. The pelvic tumor seen in the MRI above can be easily biopsied through a posterior approach. The biopsy tract can then be readily excised as part of the definitive surgery involving the sacroiliac resection.

Preoperative antibiotics are usually withheld until after cultures have been obtained if there is any possibility that the diagnosis will be an infection rather than a neoplasm. The incision should be as small as possible, yet adequate. Vigorous retraction of the skin in an effort to keep the incision small is ill advised and may lead to delayed wound healing, dehiscence, or infection. Similarly, the incision must be adequate to allow visualization so that the vital structures are avoided and meticulous hemostasis can be obtained. Following the incision, but prior to reaching the tumor, the surgeon encounter the pseudocapsule. The pseudocapsule is primarily composed of compressed normal tissue. In muscle it appears salmon colored. Soft tissue sarcomas are usually gray or white. This distinction is important to ensure that the most viable portion of the tumor located at its periphery adjacent to the pseudocapsule-tumor interface is sampled. It is generally advisable to obtain the biopsy with a scalpel to avoid electrocautery artifact. Of course, this must be followed with excellent hemostasis to prevent postoperative hematoma which could spread the tumor. The specimen is handled carefully to avoid crush artifact. A suture may be placed in the tumor a wedge cut around the portion secured by the suture to avoid unnecessary handling of the tumor. The specimen should then be sent fresh for frozen section analysis to determine that the tissue is diagnostic.

Tissue is obtained for cultures of aerobic, anaerobic, and fungal organisms, and mycobacteria (tuberculosis) if indicated, and systemic prophylactic antibiotic is administered. The specimen is given to the pathologist, who performs a touch prep and frozen-section analysis of the tumor to ensure that viable tissue has been obtained before the patient leaves the operating room. If the tissue is nondiagnostic or inadequate, additional material is obtained immediately to obviate the need for repeat surgical procedure and delay in diagnosis. Portions of the tumor are then saved for permanent section analyses and special studies, such as electron microscopy and flow cytometry, if needed. Meticulous hemostasis is obtained to prevent hematoma, and thus the spread of any viable tumor contained therein. Bone wax, polymethyl methacrylate, or gelatin sponges (Gelfoam) may be used to plug the holes created in the bone. The wound is closed in layers, with special attention to minimize trauma to the skin. Use of closed suction tubes is recommended, especially after the biopsy of deep-seated tumors of the pelvis. The tubes should be brought out through the skin

in line with and adjacent to the incision so that the tumor can be excised en bloc with the biopsy material. The diagnostic accuracy of frozen-section analysis is reported to be 90% when performed by a team of experienced surgeons and pathologists. When the frozen-section diagnosis agrees with the clinical and radiographic preoperative diagnosis, immediate surgery may be indicated. If the lesion is confirmed as benign, infectious, or metastatic, definitive surgery may proceed. However, for many sarcomas, it may be preferable to delay surgery until after neoadjuvant chemotherapy or radiation therapy. If there is any doubt regarding the definitive diagnosis after frozen-section analysis, definitive surgery should not be performed.

Excisional Biopsy

Excisional biopsy may be either marginal or wide. For sarcomas, marginal excision, an excision through the pseudocapsule, requires wide local repeat excision or local recurrence is likely. The surgeon who undertakes wide local repeat excision of a sarcoma that has been inadequately excised will likely need to remove more tissue than would otherwise have been necessary initially. First, the surgeon must excise the biopsy tract and any tissue contaminated by the dissection or subsequent hematoma formation. Second, because the tumor margins are no longer apparent clinically or radiographically, the surgeon must “guess” their location. Consequently, excisional biopsy for suspected sarcomas is rarely indicated except for small (2 cm or smaller) subcutaneous lesions that can be widely excised with less morbidity than with marginal excision.

Classic hemipelvectomy involves disarticulation through the sacroiliac joint posteriorly and the symphysis pubis anteriorly. Modified hemipelvectomy refers to amputation through the pelvis in which the plane of bony resection posteriorly, is anterior and lateral to the sacroiliac joint, thereby preserving a variable portion of the ilium. Extended hemipelvectomy involves resection of the pelvis in which the posterior bony resection is medial to the sacroiliac joint and through the sacral neural foramina; consequently, the sacroiliac joint is included in the resection. Internal hemipelvectomy refers to limb-sparing resection of the pelvis with partial or complete resection of the innominate bone. Compound hemipelvectomy involves resection of the visceral organs such as the bladder or rectum.

Various surgical techniques have been described for hemipelvectomy. In many cases the surgical technique chosen will depend on the location and the extent of the tumor rather than simply the surgical preference. Tumors extending into the buttock involving the gluteal muscles are not amenable to posterior flap hemipelvectomy and may require management with an anterior flap hemipelvectomy.

Early descriptions of hemipelvectomy (during the first half of this century) reported a mortality of 60%. The major complication from surgery was shock

Hemipelvectomy

secondary to blood loss. More recent reports have shown that hemipelvectomy can now be performed safely with an operative mortality of approximately 1%. In some cases, especially in patients who refuse blood products because of religious reasons, it may be possible to perform the procedure without the need for blood transfusion.

The physical and psychological effects of hemipelvectomy are substantial. Some patients may benefit from the opportunity to visit with other patients who have undergone similar surgery. The procedure and potential consequences, including bowel, bladder, and sexual dysfunction, should be thoroughly discussed with the patient so that informed consent can be obtained. Psychological support should be offered by appropriate persons, including family, clergy, social workers, and other patients. Preoperatively, the patient's metabolic and hematologic status should be optimized. Bowel preparation is done to decrease bacterial count. A diet of clear liquids only, for 24 h, is used, and enemas are administered prior to the procedure to decrease the chances of fecal contamination of the wound during surgery. Although the operative blood loss is usually less than 1,500 mL, packed red blood cells should always be available. In obese patients or in technically difficult hemipelvectomies, when operative blood loss is expected to be high, it is also advisable to have fresh-frozen plasma and platelets available. Techniques such as hemodilution and hypotensive anesthesia are advised to minimize transfusion requirements. If time permits, patients may give blood for autotransfusion.

Posterior Flap Hemipelvectomy

The primary indications for posterior flap hemipelvectomy include primary malignant neoplasms of the innominate bone or femur that have invaded the hip joint and sarcomas involving the upper thigh and extending through the obturator foramen to invade the pelvic wall and those that involve the pelvic wall primarily. A general anesthetic is administered, and a Foley catheter is inserted into the bladder. An arterial catheter is inserted for continuous hemodynamic monitoring, and a central venous catheter is advisable. One or more large-bore peripheral venous catheters are secured in place. A rectal tube is inserted and sutured in place to avoid fecal contamination

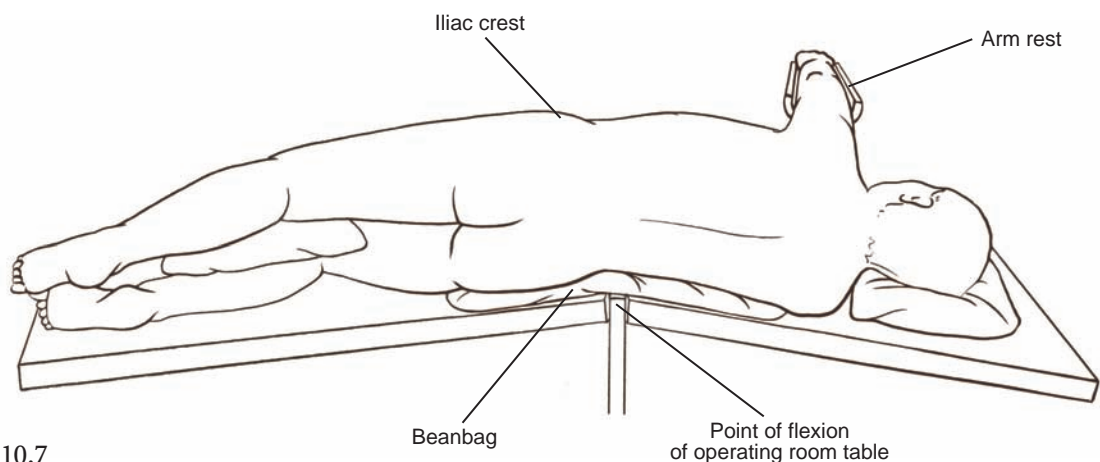


Figure 10.7

of the wound. A nasogastric or orogastric tube is inserted and attached to suction to decompress the gastrointestinal tract.

The patient is held in a semilateral position, which allows for more accurate orientation for division of the sacroiliac joint by allowing access to the anterior and posterior portions of the joint. The patient is placed in the lateral position with the affected side up and the contralateral iliac crest centered over the point of flexion of the operating room table. Care is taken to protect the axilla and the bony prominences of the contralateral side, and the ipsilateral upper extremity is placed on a Krasky arm rest or pillow. The operating room table is then extended beneath the iliac crest to allow greater access between the iliac crest and the vertebral column on the involved side. A beanbag is placed beneath the patient and kept well below the midline posteriorly and anteriorly to help secure the patient in position. By keeping the beanbag well below the midline posteriorly and anteriorly, the patient can be easily rolled slightly forward during the posterior dissection and backward during the anterior dissection.

A U drape is used to isolate the perineum, the genitalia, and the anus from the operative field. The skin is prepared from the distal aspect of the great toe to the level of the xiphoid proximally and beyond the midline anteriorly and posteriorly. The extremity must be included in the preparation so that it can be manipulated during the procedure, permitting tissues to be divided under tension. The involved extremity is exsanguinated using an Esmarch bandage from proximal to distal for “auto-transfusion” in the extremity to be sacrificed. The Esmarch bandage should remain distal to the tumor.

Anterior Dissection

Anteriorly, the incision approximately 5 cm proximal to the anterosuperior iliac spine and 2 cm medially. The incision curves gently, distally and medially, paralleling the inguinal ligament to the symphysis pubis. The lateral incision is made beginning at the proximal portion of the incision and continued distally and laterally to the anterosuperior iliac spine, over the anterior portion of the greater trochanter, and then continuing posteriorly distal and parallel to the gluteal groove, to the perineum, and around the proximal thigh to meet the anterior incision at the superior border of the symphysis pubis.

Previous biopsy sites are incorporated with the incision and widely excised en bloc with the tumor. Attention is directed first to the anterior portion of the dissection. While the surgeon is positioned anterior to the patient, the patient is rolled back into a semilateral position, giving greater exposure anteriorly and facilitating medial retraction of the abdominal contents. By keeping the beanbag below the midline anteriorly and posteriorly, the patient can be log rolled forward or backward as needed. The incision is deepened through the subcutaneous tissue, Scarpa's fascia, and the external oblique aponeurosis. The internal oblique and transversus muscles

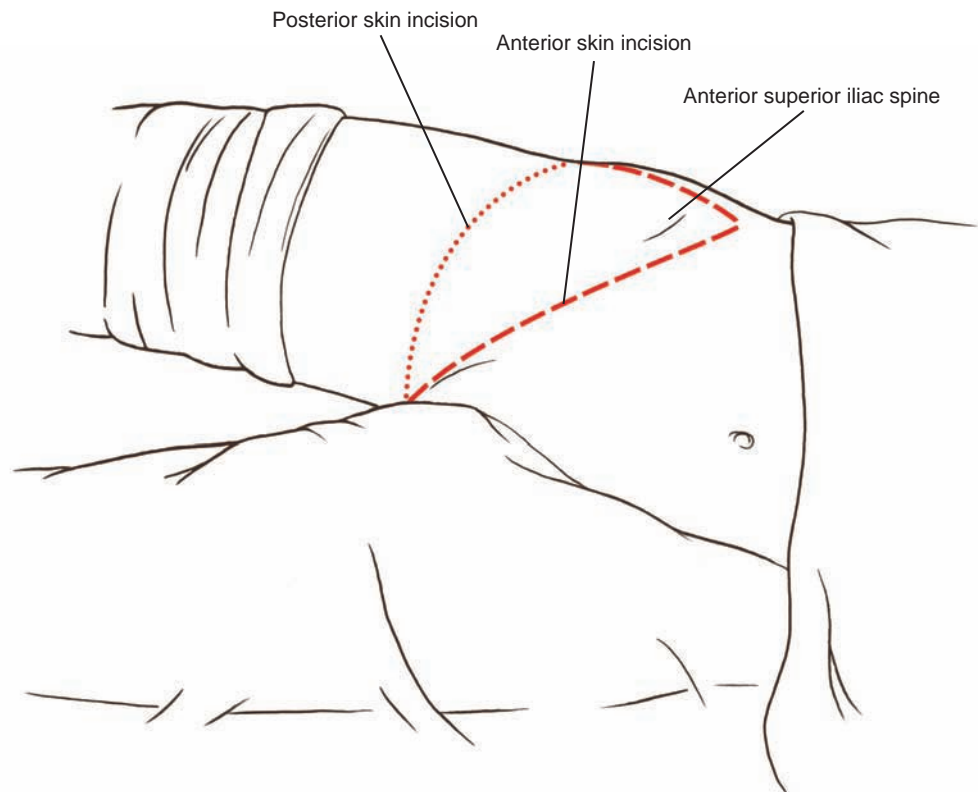


Figure 10.8

are cut under tension, and the deep epigastric artery and vein are ligated. The spermatic cord in male patients or the round ligament in female patients is identified, and a Penrose drain is placed around it and retracted medially.

The ipsilateral rectus abdominis muscle is freed from its insertion on the pubic symphysis. The inguinal ligament is released from its medial and lateral pelvic attachments along the pubis and the anterosuperior iliac spine, respectively. The anterior abdominal wall is thereby freed from its attachments to the pelvis, forming the anterior flap. The iliac fossa is exposed by bluntly dissecting the extraperitoneal fat from the fascia over the iliac and psoas muscles, and the urinary bladder is retracted medially and downward.

The external iliac artery and vein are identified and traced proximally to the common iliac artery and vein. The ureter is identified as it crosses the external iliac artery at the common iliac bifurcation and is retracted medially with the peritoneum. The common iliac vessels are then ligated and divided. The bladder and the rectum are gently retracted medially while lateral traction is applied to the internal iliac artery and vein, and its branches to the pelvic side wall, rectum, and bladder are identified under tension, ligated, and transected. Then the iliolumbar and lateral sacral vessels and the superior and inferior gluteal vessels, and the internal pudendal, and middle hemorrhoidal and inferior and superior vesicular arteries are divided. The bladder and the rectum are now free from the pelvic sidewall, and the sacral nerve roots to the bladder and rectum are visualized and preserved, if possible, to minimize the risks for bowel, bladder, and sexual dysfunction. The anterior wound is then packed with moist sponges, and attention is directed to the posterior incision.

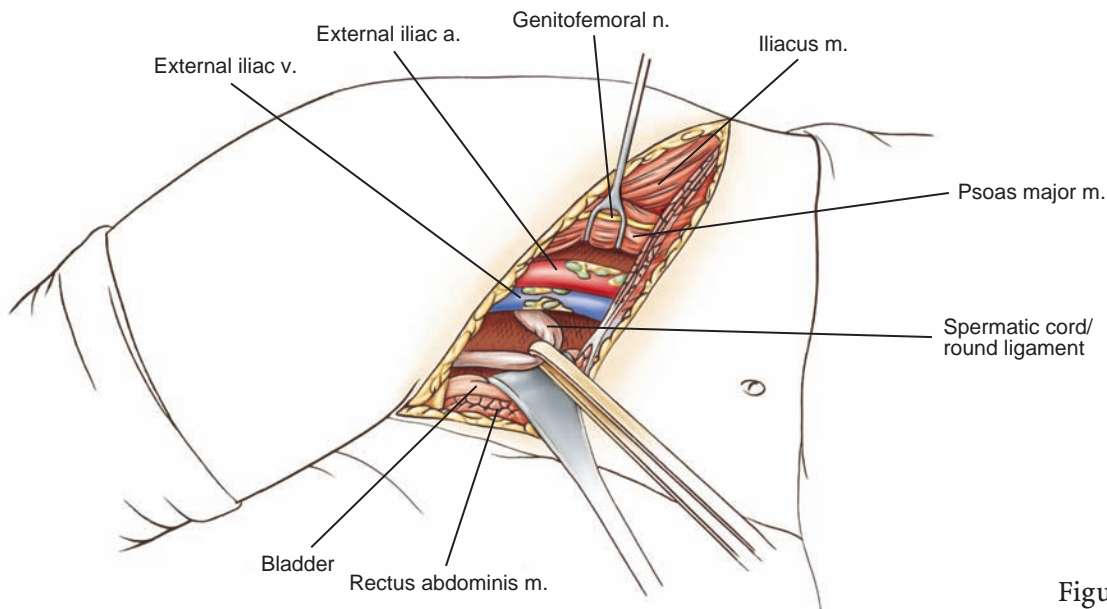


Figure 10.9

Posterior Dissection

The surgeon moves to the posterior side of the patient, and the posterior incision is carried deep to the gluteal fascia. The skin incision is extended between the perineum and the thigh to join the anterior incision. The hip is flexed and adducted, placing tension on the gluteal muscles, and the incision is deepened through the gluteal fascia. The attachments of the gluteal fascia to the iliotibial tract and the tensor fascia lata are released, and a fasciocutaneous flap with the gluteal fascia is created. While placing traction on the posterior flap, it is elevated proximal to the iliac crest, and the dissection proceeds until the posterosuperior and posteroinferior iliac spines are visualized.

A variable amount of the gluteus maximus muscle may be preserved with the flap if tumor margins permit. The muscular attachment along the ilium, namely, the external oblique aponeurosis and the erector spinae, latissimus dorsi, and quadratus lumborum muscles, are released. Transection of these muscles as close to the bone as possible using an electrocautery minimizes blood loss. The inferior margin of the gluteus maximus muscle is identified, and a gloved digit is placed deep to the muscle and superficial to the sacrum. While maintaining tension on the muscle, it is released from its attachments on the sacrum, coccyx, and sacrotuberous ligament. The hip is then placed in neutral position and the psoas muscle is isolated. The genitofemoral nerve is identified on the anterior surface of the muscle and transected. While keeping tension on the muscle it is transected, and muscular vessels are cauterized as they are encountered. The proximal cut ends of the psoas muscle are ligated using a 0-silk suture. Deep to the psoas muscle, the obturator and femoral nerves are transected, as is the lumbosacral nerve trunk.

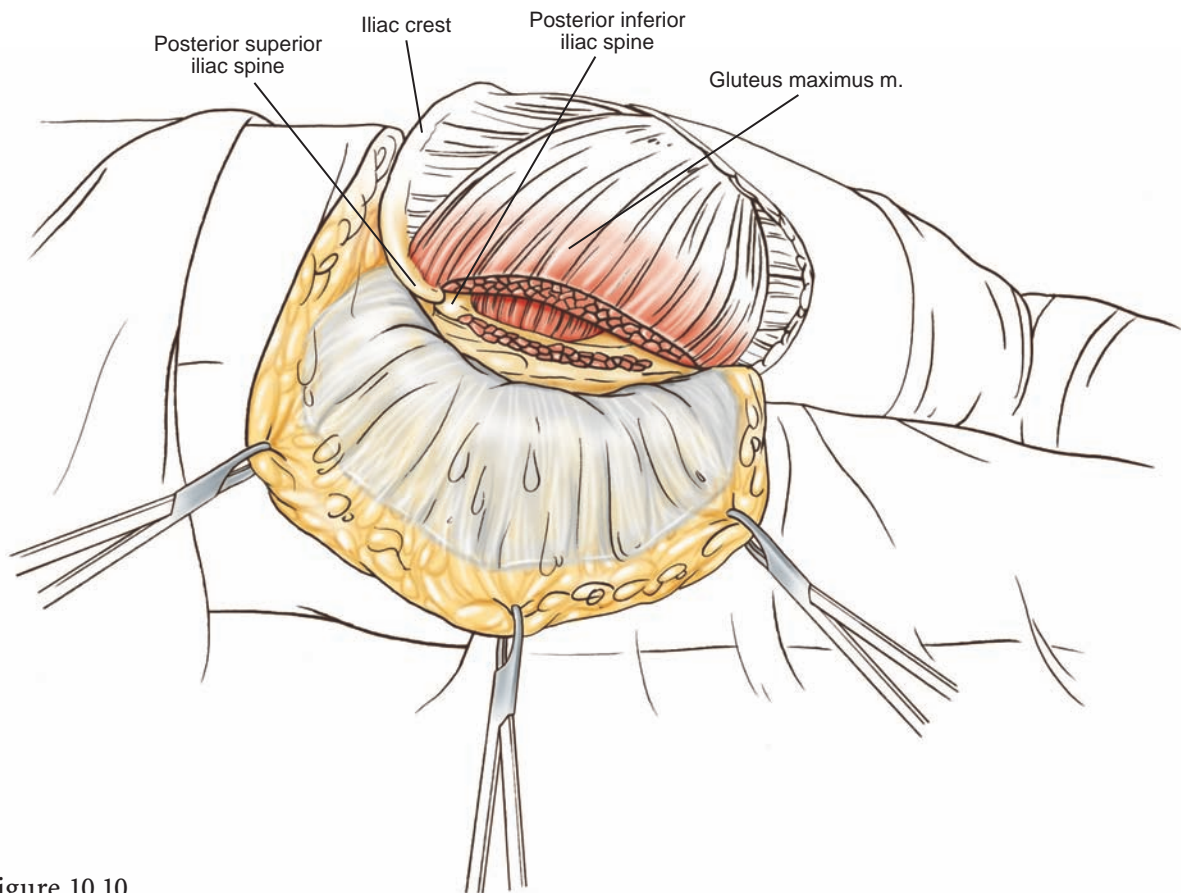


Figure 10.10

The hip is flexed and abducted and externally rotated by placing tension on the ligaments of the symphysis pubis. The retropubic space is identified, and a gloved digit or a narrow ribbon retractor is placed beneath the symphysis to protect the urethra, the prostate gland, and the bladder. The symphysis is divided using a Gigli wire saw or osteotome. The sacral nerve roots are transected approximately 2 cm distal to the sacral foramina while preserving the *nervi erigentes*.

The iliac muscle is reflected laterally, and a downward pressure is applied to the anterosuperior iliac spine to expose the anterior portion of the sacroiliac joint. The capsule of the sacroiliac joint is then opened. An osteotome may be needed to enter the sacroiliac joint if a synostosis exists between the sacrum and the ilium, which is not uncommon, especially in older patients. The iliolumbar ligament is identified as it courses from the transverse process of the fifth lumbar vertebra to the ilium, a clamp is passed beneath the ligament, and the ligament is transected.

All that remains to complete the amputation is the transection of the pelvic diaphragm. This is facilitated by the assistant constantly pulling upward on the extremity while the patient's hip is maximally flexed, placing the structures of the urogenital diaphragm and levator ani muscles under tension.

Starting at the symphysis and continuing toward the ischial tuberosity, the muscles of the urogenital diaphragm and the pubococcygeus muscles are divided at their

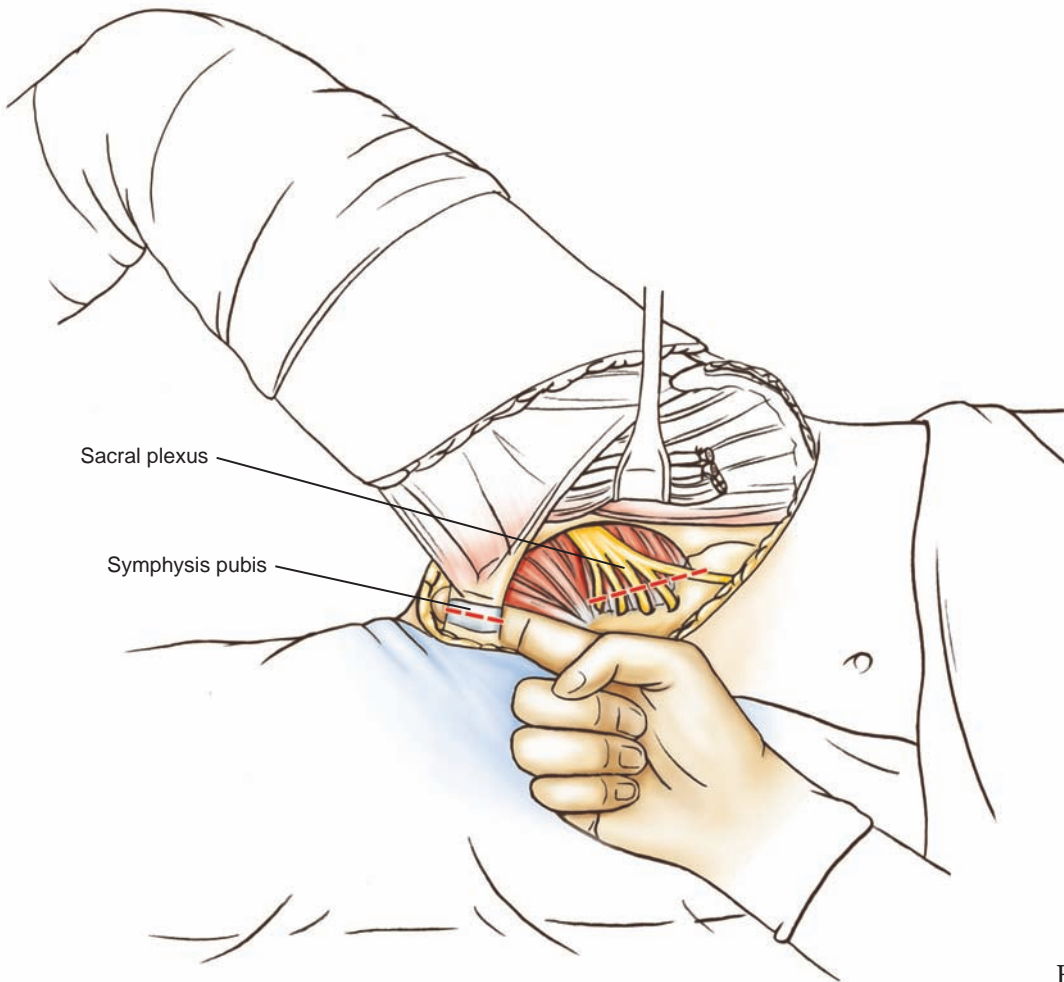


Figure 10.11

origins along the inferior pubic ramus. A gloved digit is placed in the ischiorectal fossa to prevent inadvertent injury to the rectum. The remaining muscular and ligamentous structures are transected, namely, the ischiococcygeus, iliococcygeus, and piriformis muscles and the sacrotuberous and sacrospinalis ligaments.

The hip is then flexed and adducted to expose the posterior portion of the sacroiliac joint, which is divided with an osteotome, thereby completing the amputation.

The wound is irrigated with copious quantities of solution, and bleeding sites are cauterized or ligated as needed. Sharp bony prominences, if present, are removed with a rongeur or file. Avitene powder or other hemostatic agents may be spread in the wound, and bone wax is applied to cut the surfaces of bone to minimize postoperative bleeding.

Closed-suction catheters are placed deep within the wound and are brought out through the skin without violating the posterior skin flap. The gluteal fascia is sutured to the fascia of the abdominal wall with interrupted sutures.

The skin is closed in layers with minimal handling of the posterior skin. A bulky sterile dressing is applied and covered with a circular woven elastic wrap (Ace bandage), providing a well-padded compression dressing. The patient is transferred to a

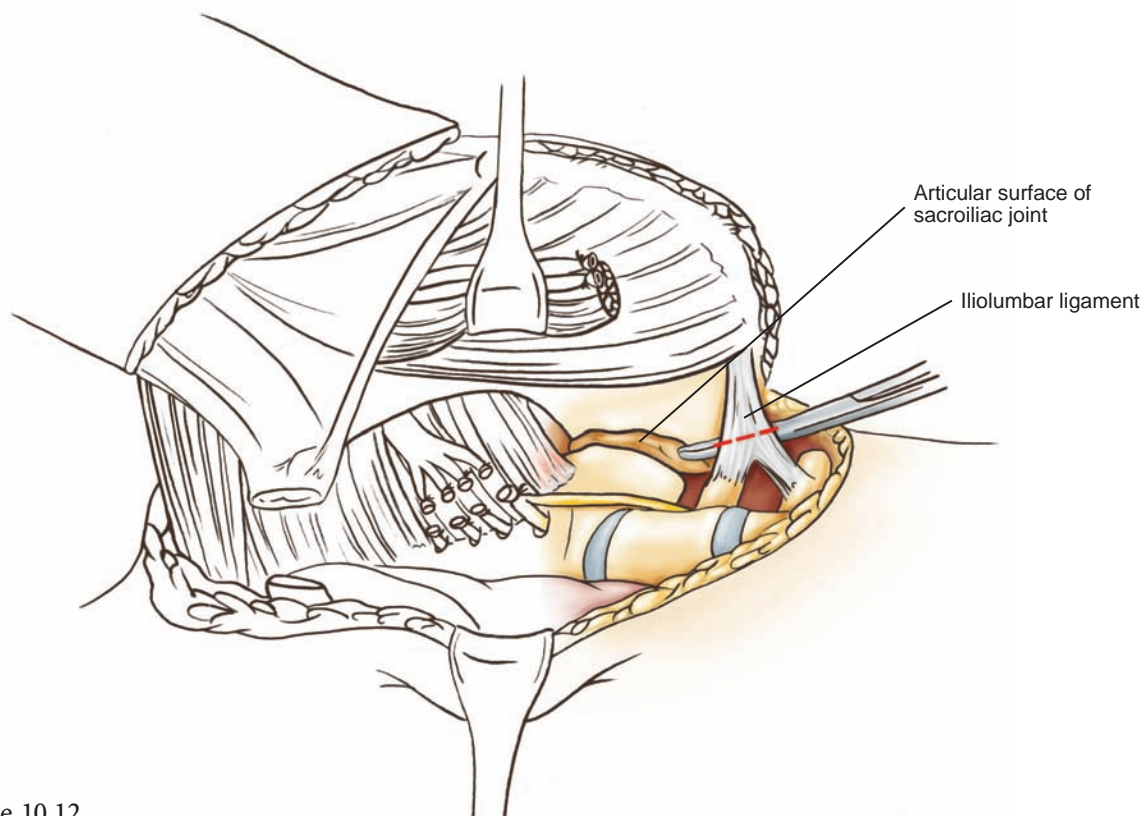


Figure 10.12

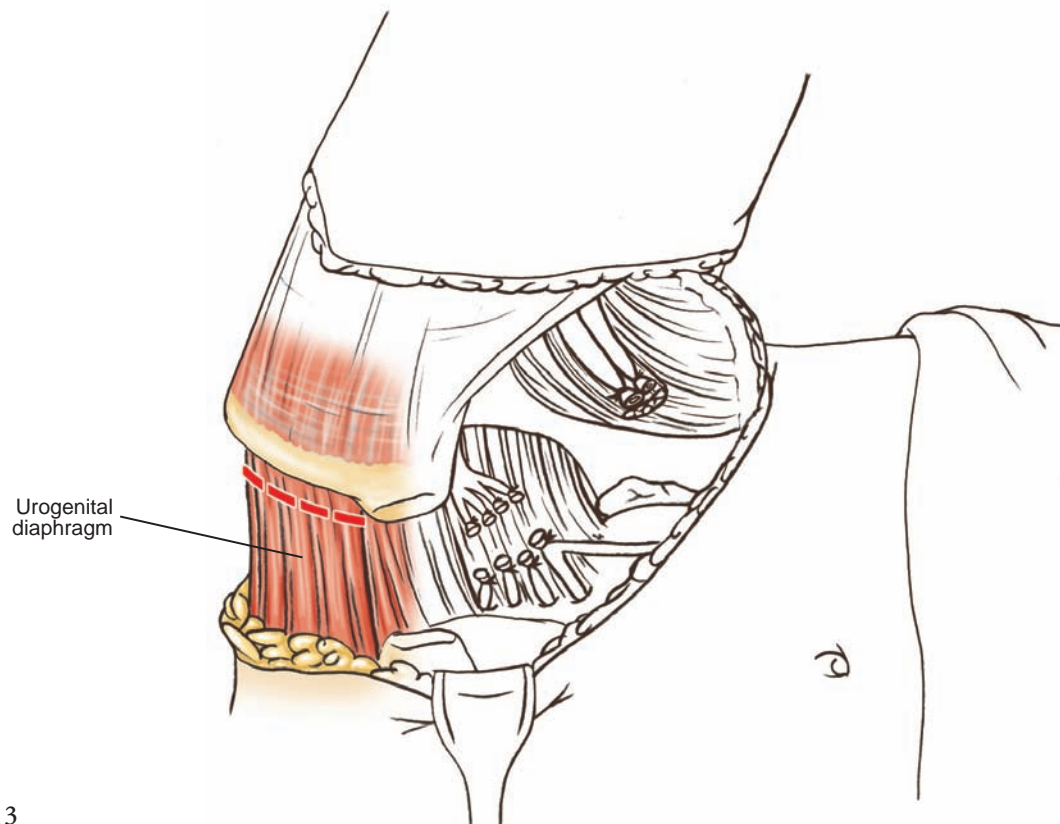


Figure 10.13

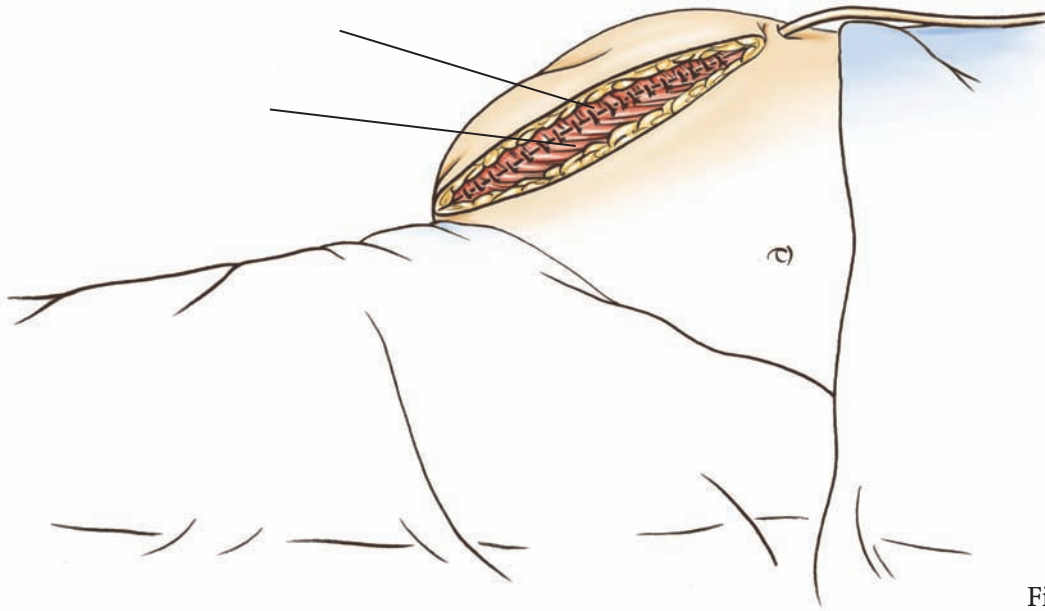


Figure 10.14

well-padded bed or the one with an air mattress, with an overhead trapeze to minimize excessive pressure on the posterior flap and to encourage mobility and facilitate positioning.

Anterior flap hemipelvectomy in patients with sarcoma is indicated when tumor involves the upper thigh or the buttock and cannot be managed by local excision. This situation is commonly encountered when tumor recurs after prior buttockectomy or previously irradiated posterior skin. The anterior flap hemipelvectomy utilizes a myocutaneous flap, based on the preserved external iliac and superficial femoral artery.

Anterior Flap Hemipelvectomy

The patient is prepared for surgery and placed on the operating table as previously described and illustrated for posterior flap hemipelvectomy. If an Esmarch bandage is used, it should not extend proximal to the knee joint. The skin incision is marked to ensure that an adequate skin flap is obtained anteriorly for wound closure and the surgical margins are free of tumor. The skin incision in the thigh is along the postero-medial and posterolateral aspects, and is joined by a transverse incision proximal to the patella. Anteriorly, the incision begins 2 cm proximal and posterior to the anterosuperior iliac spine and parallels the inguinal ligament to the pubic tubercle, approximately 1–2 cm proximal to the inguinal ligament. Laterally, the incision parallels the iliac wing, passing medially and distally to the anterosuperior iliac spine, and is then directed distally along the lateral aspect of the thigh, to the level of the tendinous portion of the quadriceps muscle, just proximal to the superior pole of the patella. Beginning at the origin of the anterior incision near the anterosuperior iliac spine, the incision is continued posteriorly along the proximal edge of the posterior iliac wing beyond the posteroinferior iliac spine. The incision is then continued distally

and medially towards the midline of the sacrum, passing just lateral to the anus, and stopped in the perineal region just distal to the gluteal crease.

The iliac crest and the sacrum are skeletonized by releasing the muscular attachments of the external oblique, latissimus dorsi, quadratus lumborum, erector spinae, and gluteus maximus muscles.

A gloved digit is placed deep to the remaining fibers of the distal origin of the gluteus maximus muscle, along the coccyx and sacrotuberous ligament, to identify the

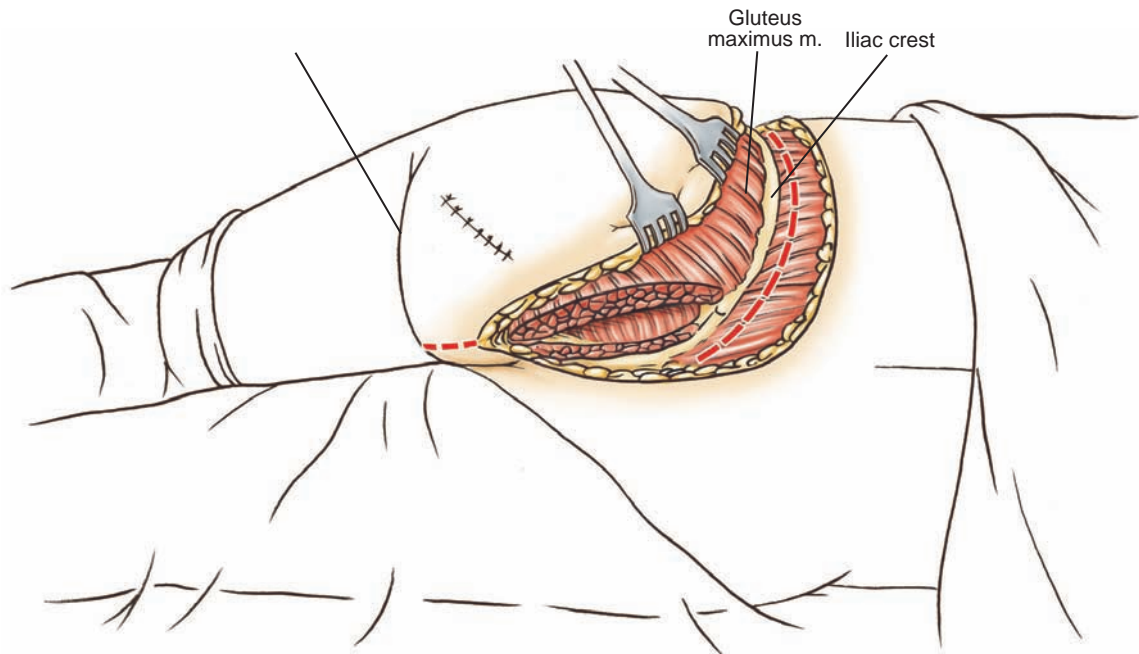


Figure 10.15

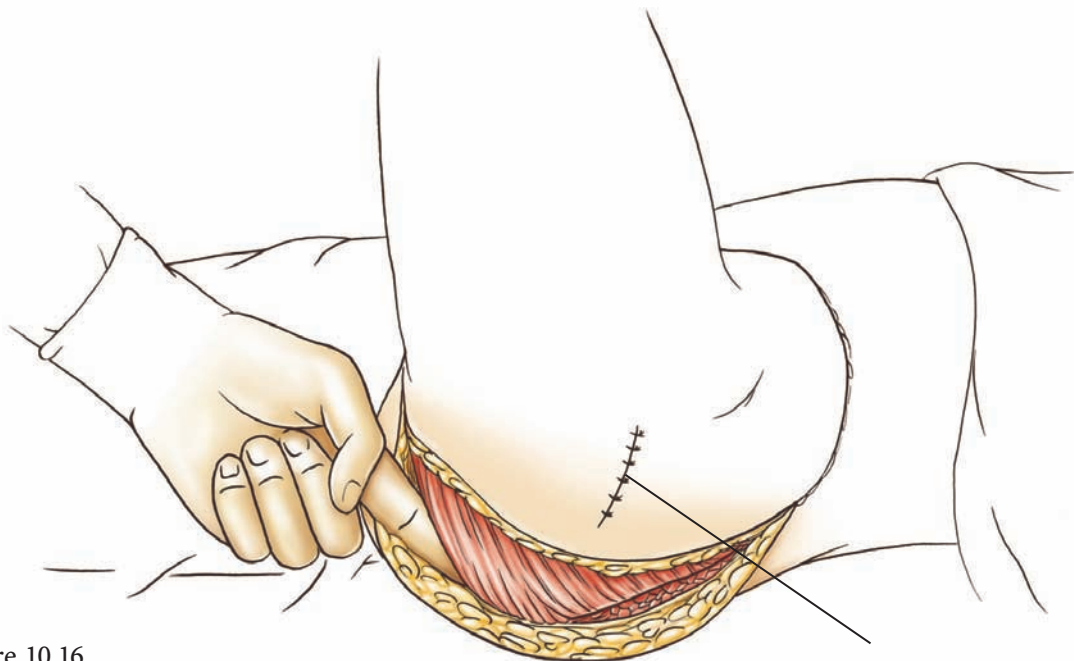


Figure 10.16

ischiorectal fossa. These structures are placed under tension by the assistant, flexing the patient's hip while applying gentle internal rotation. The remaining fibers of the gluteus maximus muscle are then transected using an electrocautery, and the rectum is protected by a gloved digit in the ischiorectal fossa.

The surgeon moves to the opposite side of the table to stand anterior to the patient. The transverse skin incision is carried distally through the skin, subcutaneous tissue, fat, and the entire quadriceps muscle to expose the anterior surface of the distal femur. The incision is then continued proximally along the lateral thigh towards the greater trochanter, terminating at the medial portion of the anterior skin incision, just medial and distal to the anterosuperior iliac spine. The iliotibial band is incised in line with the skin incision, and the tensor fascia lata is separated from the investing fascia and retracted posteriorly to be resected en bloc with the specimen. The lateral edge of the vastus lateralis muscle is identified by placing traction on the muscle medially. While maintaining a medial traction on the muscle, the plane between the vastus lateralis and the biceps femoris muscles posteriorly is identified, and the fascial covering of the vastus lateralis muscle is freed to its origin on the greater trochanter.

The vastus lateralis muscle is then released from its insertion along the linea aspera on the posterior surface of the femur. The vastus lateralis muscle is kept in continuity with full-thickness skin, subcutaneous tissue, and fascia overlying it on the anterior thigh. Attention is then directed to the distal medial aspect of the thigh, where the anterior transverse incision joining the medial and lateral thigh incision has been created. The medial incision is extended proximally to the pubic crest. The sartorius muscle is identified, and the vastus medialis muscle is retracted anteriorly and medially to expose the subsartorial canal. The femoral artery and vein are traced proximally to the adductor hiatus, where they are ligated and divided. Proximal

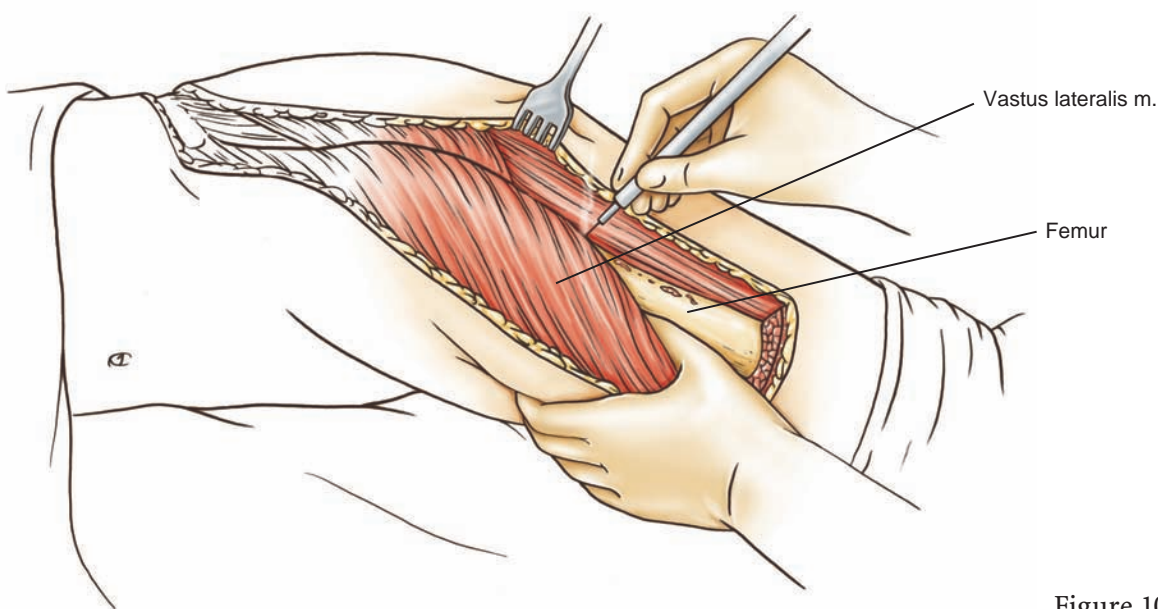


Figure 10.17

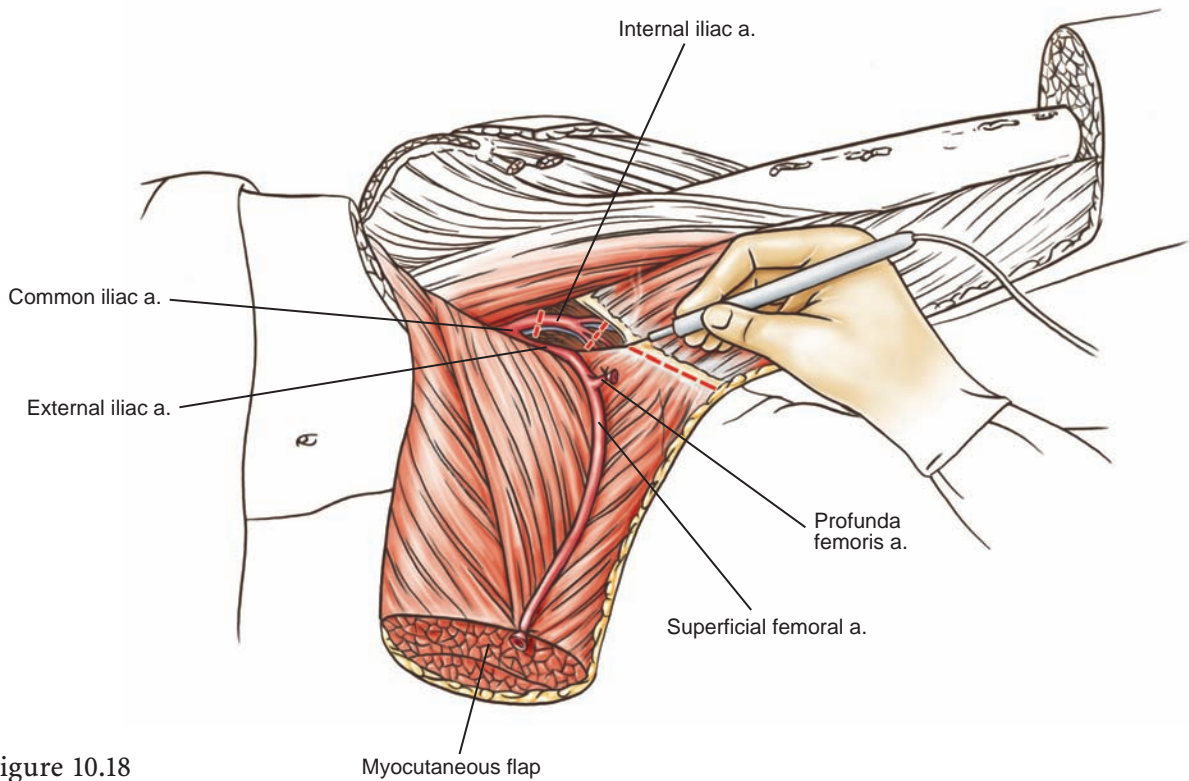


Figure 10.18

traction is placed on the anterior flap, and the origins of the vastus medialis and intermedius muscles are released from their attachments along the shaft of the femur. The dissection remains anterior and medial to the adductor magnus and adductor longus muscles, which are ultimately sacrificed with the specimen.

As the dissection continues proximally, the profunda femoris artery is encountered as it passes behind the femoral artery and the adductor longus muscle, approximately 4 cm distal to the inguinal ligament. The vessels are ligated and divided just distal to the common femoral artery and vein. After the quadriceps muscles are released from the femur, attention is directed to the release of the anterior myocutaneous flap from its attachments to the pelvis. The flap is continually retracted proximally and inverted, so that the superficial femoral artery can be visualized and protected while maintaining continuity with the flap. The abdominal muscles are released from their attachments along the iliac crest, then the sartorius muscle is released from its origin on the anterosuperior iliac spine, and the rectus femoris, from its origin on the anteroinferior iliac spine. The femoral canal is identified and the femoral sheath divided. Dissection is continued proximally, and the remaining origin of the rectus femoris muscle on the pubis is identified and transected. Blunt dissection is continued proximally along the femoral nerve to enter the pelvis. The symphysis is divided as previously illustrated while protecting the bladder and the urethra. With the hip flexed, abducted, and externally rotated, medial traction is applied on the pelvic viscera, allowing exposure of the internal iliac artery. The internal iliac artery and vein are traced proximally to the common iliac vessels, where the ureter is identified and

protected. The internal iliac vessels are then ligated and transected near their origin from the common iliac vessels. As in posterior flap hemipelvectomy, branches of the internal iliac vessels are ligated and divided.

The lumbosacral nerve and sacral nerves 1 through 4 are visualized on the anterior surface of the levator ani muscle. The femoral nerve is retracted with the myocutaneous flap, and the psoas muscle is identified and divided under tension. Muscular bleeds are cauterized as they are encountered, or the cut ends of the psoas muscle may be ligated with 0-silk suture. The lumbosacral nerve and sacral nerve roots S1–S4 are transected near the sacral foramina.

The hip is flexed and abducted to place the medial structures of the pelvic diaphragm under tension. The urethra, bladder, and rectum are protected with one hand, applying medial and proximal traction on the intrapelvic structures while the urogenital diaphragm, pubococcygeus, and piriformis muscles are divided near their pelvic attachments. Attention is then directed posteriorly in preparation for the division of the sacrum. Then the surgeon moves to stand posterior to the patient.

While reaching around the coccyx, the S5 neural foramina along the anterior sacrum are palpated. An osteotome is used to divide the coccyx and the sacrum through the sacral foramina. The lumbosacral ligament extending from the transverse process of L5 to the sacrum is transected, completing the amputation.

Hemostasis is obtained, and rough or pointed bony prominences are smoothed in preparation for wound closure. Suction drains are placed deep within the wound and brought out through the skin, avoiding the flap. The anterior flap is folded posteriorly

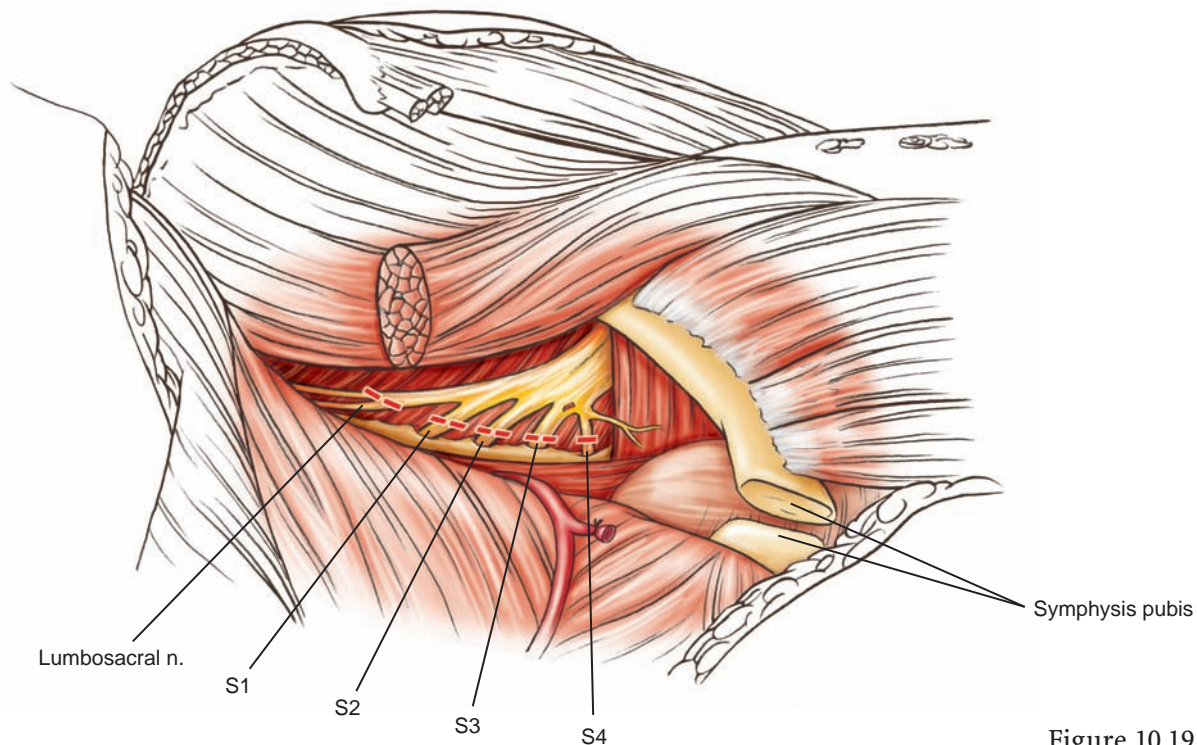


Figure 10.19

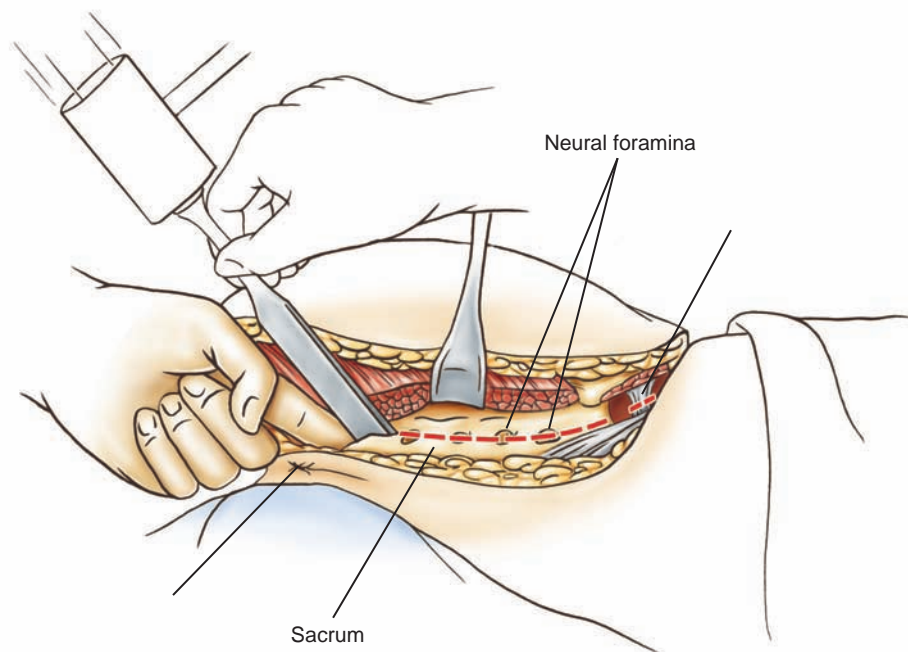


Figure 10.20

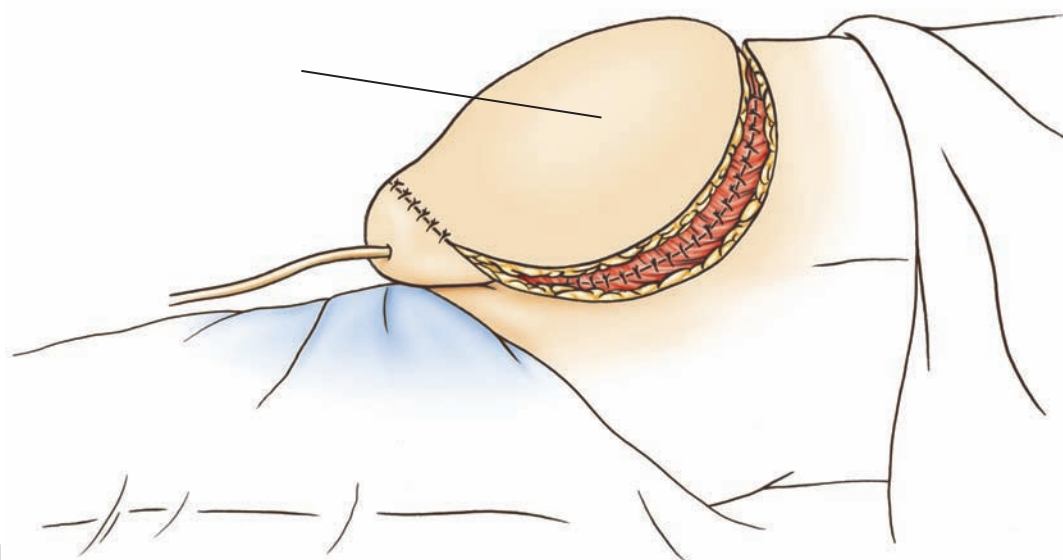


Figure 10.21

with the most distal end oriented toward the most posterior aspect of the defect. The fascia of the quadriceps muscle is reapproximated to the fascia of the anterior abdominal wall, to the quadratus lumborum muscle, the sacrum, and the muscles of the levator ani. The skin and the subcutaneous tissue are closed with interrupted sutures.

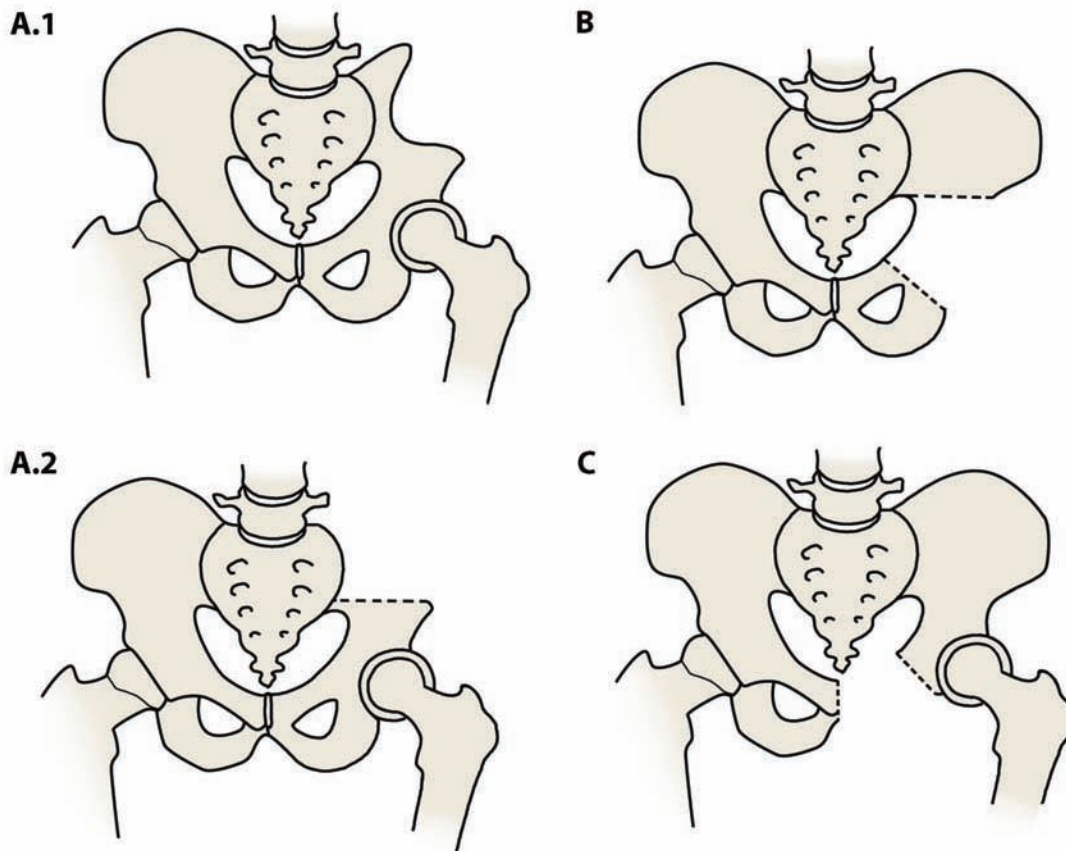
Partial Pelvic Resection

Partial pelvic resection involves the removal of a portion of the innominate bone, with preservation of the lower extremity.

The surgical goal is to obtain a wide surgical margin to control local tumor. Depending on the extent of the soft tissue portion of the tumor, a variable amount of

soft tissue is resected with a portion of the resected bone. Based on anatomic, surgical, and functional considerations, the innominate bone can be divided into three parts.

The first part is the iliac wing, extending from the sacroiliac joint to the neck of the ilium just proximal to the acetabulum. The second portion of the innominate bone is the periacetabular portion, which extends from the neck of the ilium to the lateral portion of the pubic rami and includes the ischium. The third portion of the innominate bone extends from the lateral margin of the obturator foramen to the symphysis pubis. Various portions of the innominate bone can be removed singly or in combination. Removal of the first part of the innominate bone is classified as a Type I pelvic resection; Type I pelvic reconstructions can be either partial (1), in which only part of the ilium is transected, or complete (2). Removal of the second part of the innominate bone is referred to as a Type II pelvic resection, and removal of the third part of the innominate bone, a Type III pelvic resection. When two portions of the pelvis are resected in combination (e.g., first and second parts of the innominate bone), the resection is classified as a Type I/II resection. When all the three parts of the innominate bone are resected (Type I/II/III) with limb preservation, the procedure is called internal hemipelvectomy. Partial pelvic resections without the involvement of the acetabulum (Type I and Type III) do not usually require any bony reconstruction. When the acetabulum is resected either singly (Type II) or in combination with the



ilium (Type I/II) or pubis (Type II/III), reconstruction can be accomplished using a variety of techniques.

Patient positioning and surgical incision depend on the portion of the pelvis and the soft tissue to be resected. For access to the entire innominate bone, the patient is positioned supine with a sandbag or 3 L fluid bag, beneath the lower thoracic spine and the proximal buttock on the affected side to help roll the patient anteriorly during posterior dissection. This “floppy lateral” position allows the patient to be rolled back into a supine position during anterior dissection, and forward during posterior dissection. The skin is prepared from the distal aspect of the great toe on the involved side to the level of the xiphoid proximally, and beyond the midline anteriorly and posteriorly. For type III pelvic resections, the patient is placed in the supine position.

A utilitarian incision that provides access to the inner and outer aspects of the innominate bone, and the lower part of the abdomen and hip joint, can be used for partial pelvic resection involving the acetabulum, and for internal hemipelvectomy. The incision begins at the posteroinferior iliac spine and follows the crest of the ilium to the anterosuperior iliac spine, where it curves to parallel the inguinal ligament to the symphysis pubis. The second arm of the incision begins just anterior to the anterosuperior inferior iliac spine and extends distally with a gentle curve, directed posterior to the greater trochanter.

For type I pelvic resection, only the first portion of the incision is needed. Anteriorly, the lateral attachment of the inguinal ligament is released, as are Scarpa’s fascia, the external oblique aponeurosis, and the internal oblique and transversus abdominis muscles. The femoral vessels are identified distal to the inguinal ligament and protected. The parietal peritoneum is elevated, the inferior epigastric vessels ligated, and the retroperitoneum exposed. The femoral nerve is identified and protected, and retracted medially with the abdominal contents. The iliac muscle is identified and transected to

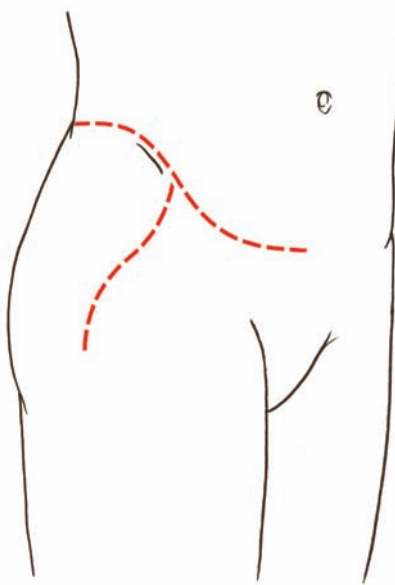


Figure 10.23

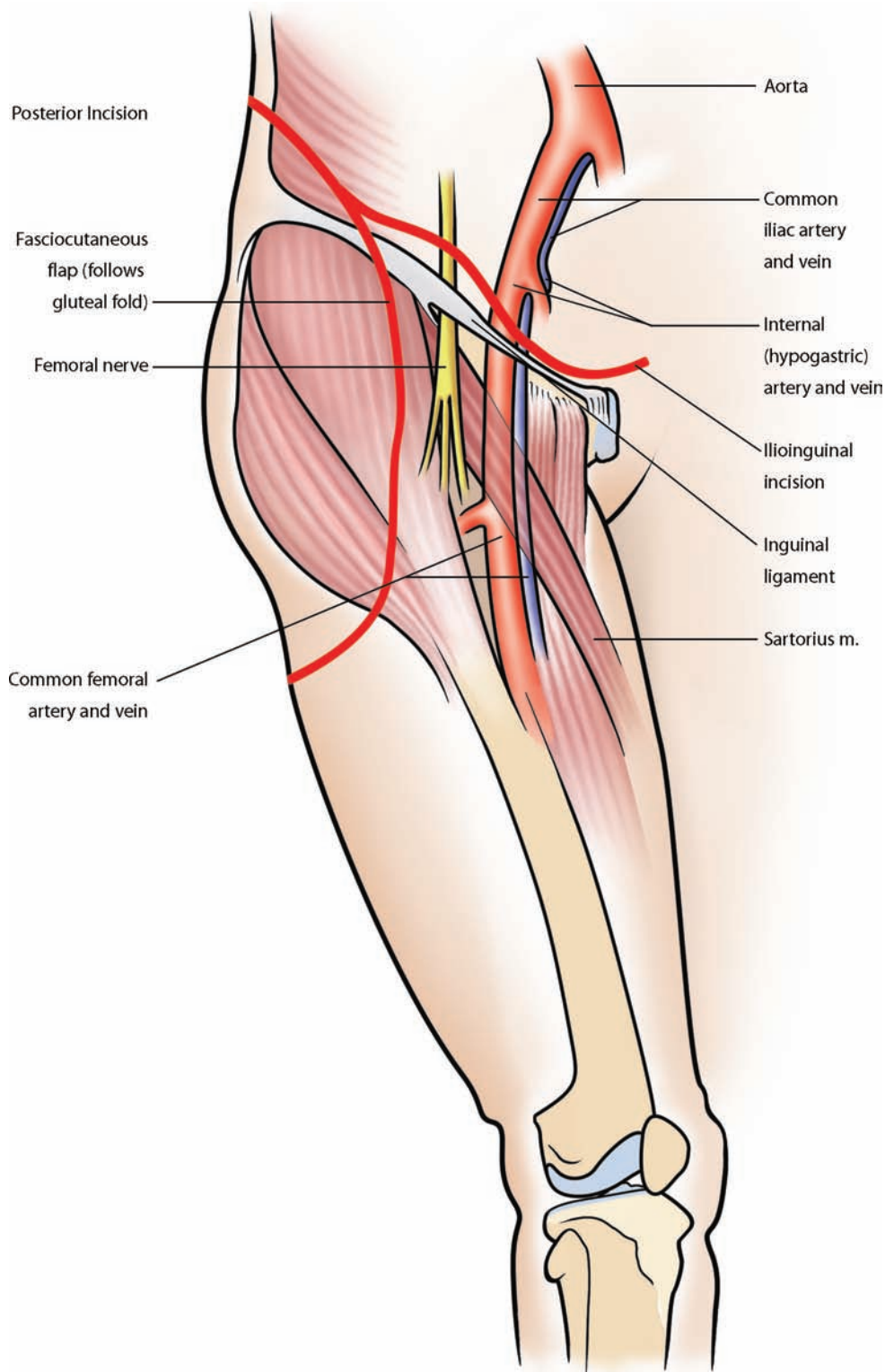


Figure 10.23

expose the inner portion of the iliac wing. The origins of the sartorius, tensor fascia lata, and rectus femoris muscles are divided near their respective origins along the anterosuperior iliac spine, anterior outer lip of the iliac crest, and anteroinferior iliac spine to allow access to the supra-acetabular portion of the iliac wing. Blunt dissection from lateral to medial along the inner table of the iliac wing enables identification of the

greater sciatic notch. Attention is directed posteriorly where the origins of the gluteus maximus, medius, and minimus muscles are released from their attachments on the outer surface of the ilium, exposing the greater sciatic notch and the sacroiliac joint posteriorly. The neck of the ilium is transected with a Gigli wire saw. The Gigli wire saw is passed anterior to posterior, around the greater sciatic notch under direct visualization to prevent injury to the superior gluteal nerve. By directing the line of transection from the greater sciatic notch to the anterosuperior iliac spine, the resection will be across the supra-acetabular portion of the pelvis, thereby preserving the hip joint.

The sacroiliac joint is transected with an osteotome directed from posterior to anterior, with the lumbosacral trunk and sacral roots are visualized and protected. The sacrotuberous and sacrospinous ligaments are transected, thereby completely releasing the ilium, which is then removed.

Internal Hemipelvectomy

The utilitarian incision described for partial pelvic resection involving the acetabulum is used for internal hemipelvectomy. In contrast to iliac resection, internal hemipelvectomy involves the removal of the entire innominate bone, from the sacroiliac joint to the symphysis pubis, with limb preservation. The utilitarian incision allows exposure

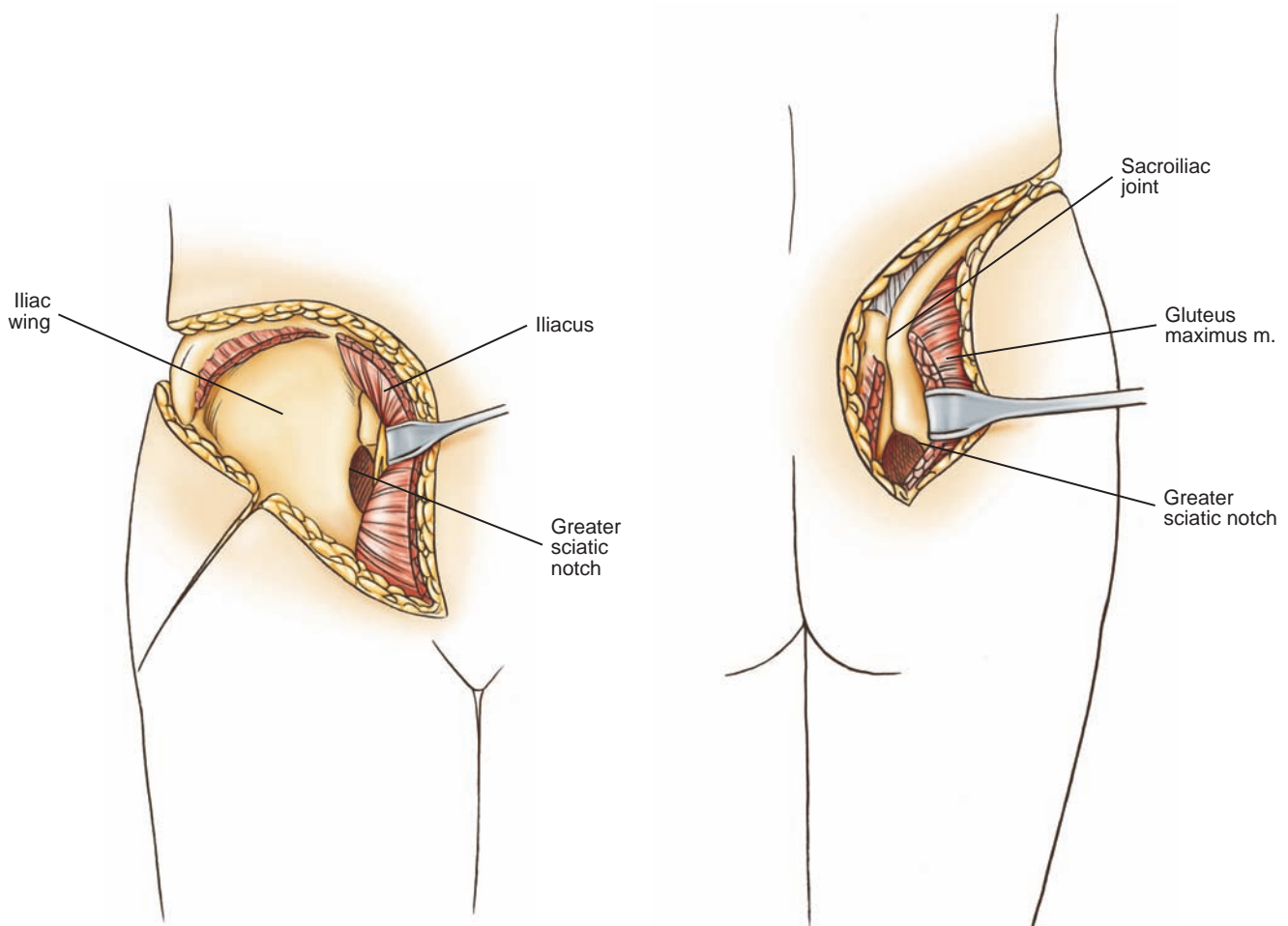


Figure 10.24

of the entire innominate bone as well as the major motor nerves (femoral and sciatic nerves). The incision is begun along the posteroinferior iliac spine and extended to the anterosuperior iliac spine, then continued along the inguinal ligament to the symphysis pubis (as described for type I pelvic resection). To visualize and remove the portion of innominate bone extending from the neck of the ilium to the symphysis pubis, while preserving the femoral and sciatic nerves, a second incision is made. This incision is begun just anterior to the anterosuperior inferior iliac spine and extended distally with a gentle curve directed posterior to the greater trochanter. The anterior incision is deepened through the skin and the subcutaneous tissue, Scarpa's fascia, and the external oblique aponeurosis. The origins of internal oblique and transversus abdominis muscles are cut under tension, and the deep epigastric artery and vein are ligated. The rectus abdominis muscle is released from its insertion, as is the inguinal ligament from its medial and lateral attachments to the pelvis. The round ligament in female patients or the spermatic cord in male patients is identified and protected, and retracted medially. Blunt dissection behind the retroperitoneal fat allows medial retraction of the abdominal contents with the round ligament or spermatic cord and the identification of the iliac vessels and the femoral nerve. A large vessel loop is placed around the common iliac vessels to assist with their mobilization.

Arising from the medial and lateral aspects of the common femoral artery are the external pudendal and superficial circumflex iliac arteries, which are ligated and divided to allow mobilization of the femoral vessels. The iliopectineal fascia separating the vessels from the iliopsoas muscle and nerve is identified. The vessels are bluntly dissected from the medial aspect of the iliopectineal fascia, thereby preserving the lymphatic vessels. The femoral nerve and the ilio-psoas muscle are retracted laterally, and the iliopectineal fascia incised to the pectineal eminence, thereby further mobilizing the femoral vessels.

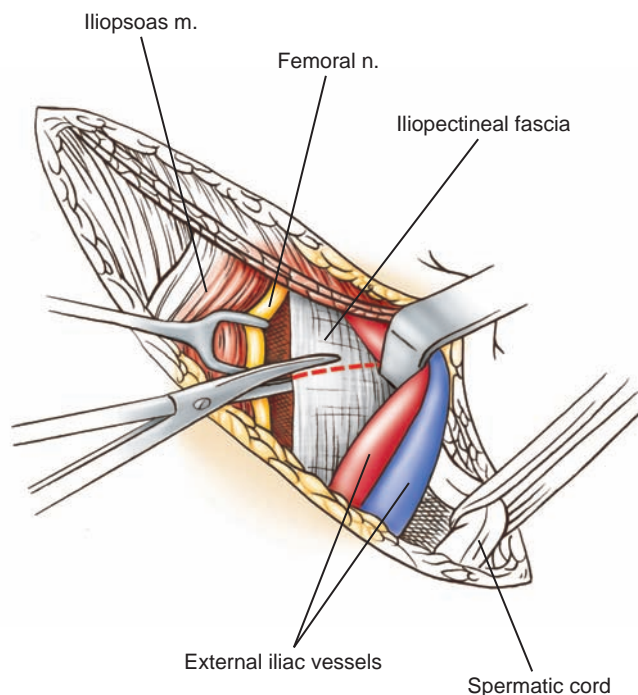


Figure 10.25

In some patients an anastomosis between the femoral and obturator vessels exists, and it should be identified and ligated. The femoral nerve is traced proximally in the groove between the psoas and iliacus. A Penrose drain is repositioned around the psoas muscle along with the neurovascular bundle if the psoas muscle is to be preserved. The neurovascular bundle is retracted laterally, and dissection is continued to expose the adductor muscle origins along the pubic symphysis, pectineal line, pubic tubercle, and outer surface of the inferior pubic ramus. The gracilis, adductor longus, pectineus, adductor brevis, and adductor magnus muscles are released from their insertions on the pelvis. The obturator vessels and nerve, which divide into anterior and posterior branches that run along the anterior and posterior surfaces of the adductor brevis muscle, are transected. The dissection along the anterior and inferior pubic rami is continued distally to expose the origin of the obturator externus muscle on the medial margin of the obturator foramen, which is left intact and removed with the specimen. The most posterior fibers of the origin of the adductor magnus muscle arising from the ischial tuberosity cannot be visualized from the anterior incision and are released later in the procedure, after the lateral arm of the incision is fully developed.

The lateral arm of the incision is developed through the skin and the subcutaneous tissue. The tensor fascia lata and sartorius muscles along with the straight head of the rectus femoris muscle are released from their insertions on the anterior part of the outer lip of the iliac crest and anterosuperior iliac spine, respectively. The reflected

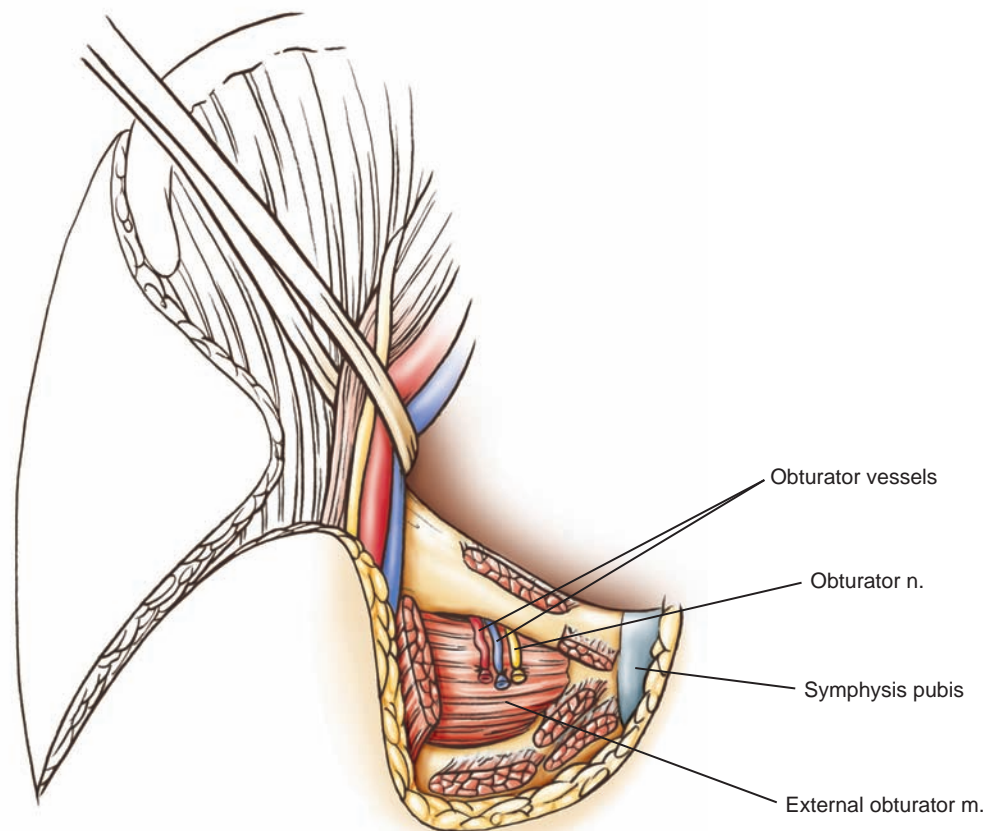


Figure 10.26

head of the rectus femoris muscle is released from its insertion on the groove on the upper brim of the acetabulum, exposing the anterior hip capsule. The capsule is incised to expose the femoral neck. If tumor extends into the hip joint, the femur is transected at a level distal to the intertrochanteric line to ensure that the hip joint, is not opened, risking tumor contamination into the operative field. Alternatively, if tumor does not extend into the hip joint, an intra-articular resection is carried out either by transecting the femoral neck or by cutting the ligamentum teres. Exposure of the ligamentum teres is facilitated by placing longitudinal traction on the extremity, while maintaining the hip in extension and external rotation. Posteriorly, the dissection is continued on top of the surface of the fascia lata, and gluteus minimus and medius, muscles. The origin of the gluteus maximus muscle from the posterior gluteal line near the sacroiliac joint is divided, exposing the sacroiliac joint. The gluteus maximus muscle is retracted in continuity with the posterior flap. The iliotibial tract is incised, as is the tendinous insertion of the gluteus maximus muscle. The sciatic nerve is identified and retracted posteriorly and medially. The piriformis muscle is divided near its insertion in the upper border of the greater trochanter of the femur, as are the insertions of the gluteus minimus and medius, obturator internus and externus, inferior and superior gemelli, and quadratus femoris muscles from their respective insertions in

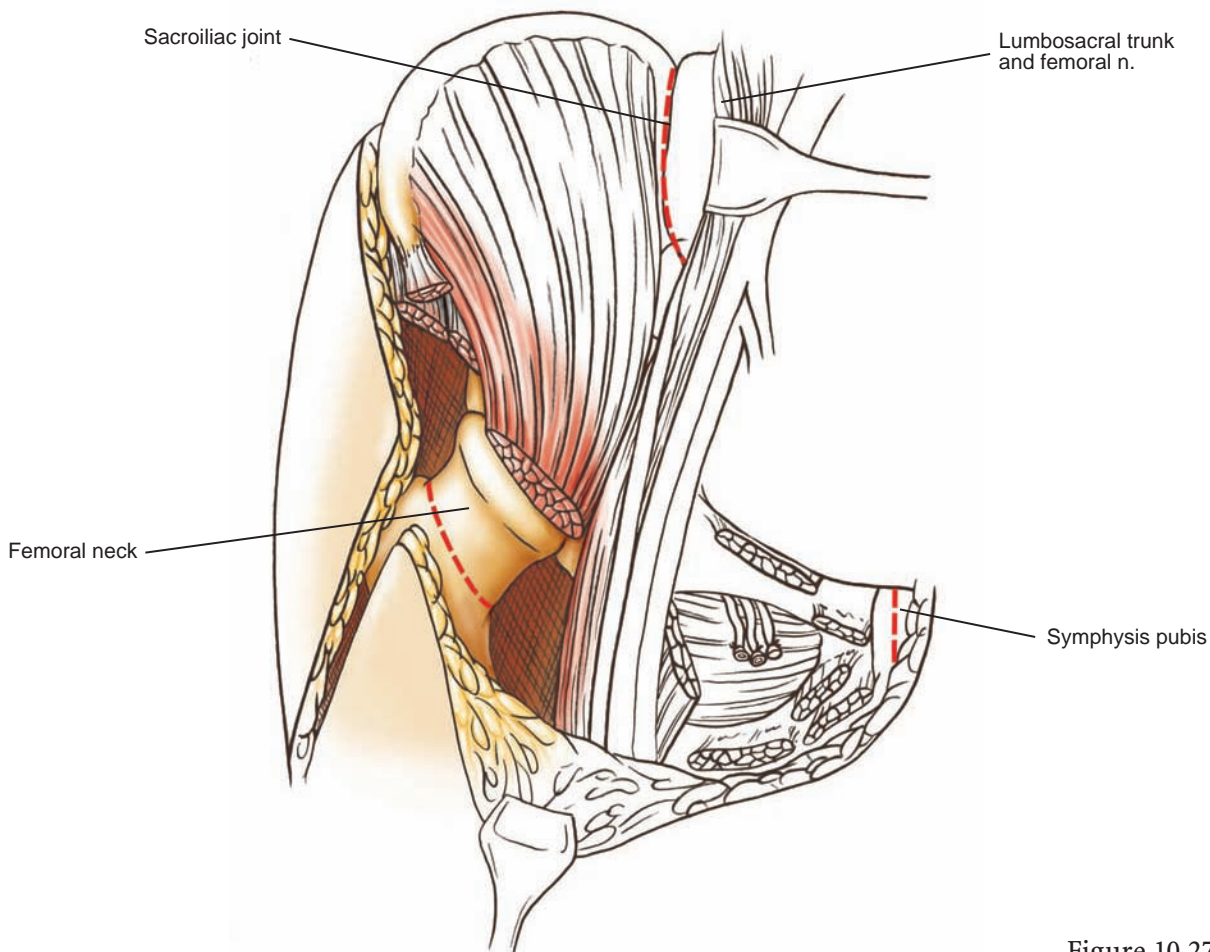


Figure 10.27

the proximal femur. The ischial tuberosity is exposed to release the biceps femoris, semitendinosus and semimembranosus muscles, the remaining fibers of the adductor magnus muscle, and the attachment of the sacrotuberous ligament. The bladder and the rectum are retracted medially away from the obturator internus muscle. The anterior aspect of the sacroiliac joint is identified along its most proximal portion. The L5 nerve root is identified and retracted medially along with the lumbosacral trunk.

The sacroiliac joint is divided with an osteotome under direct vision with a hand on the opposite side of the joint to ensure proper orientation of the line of transection. The remaining sacrospinous ligament is then transected. The pubic symphysis is divided, after identifying the retropubic space of Retzius, and protecting the bladder and urethra with either a gloved digit or ribbon retractor. The pelvis is thereby released and the specimen is removed. The skin and the subcutaneous tissue along with any remaining fascia are closed in layers over drains. Postoperatively, the patient is placed in skeletal traction to allow wound healing.

Reconstruction Following Internal Hemipelvectomy

Reconstruction procedures following complete or partial internal hemipelvectomy are designed to maximize function. Generally for partial internal hemipelvectomy in which the acetabulum and hip joint are preserved (types I and III), no reconstructive procedures are needed to maintain reasonable function. For pelvic resection in which the acetabulum is removed (type II), a variety of reconstructive procedures have been described in an attempt to maximize function. Reconstructive options for type II pelvic resections include simple soft tissue closure, pelvic allograft, autoclaved allograft, composite allograft, custom and noncustom endoprosthetic replacement, and iliofemoral and ischiofemoral arthrodesis. In cases where the ischium is sacrificed with the acetabulum but a portion of the ilium can be preserved (types II and III resection), the saddle prosthesis may be a reconstructive option.

Anatomic Basis of Complications

- A high rate of posterior flap necrosis was noted in early reports of hemipelvectomy. Ligation of the external iliac artery, rather than the common iliac artery, was recommended in an effort to preserve blood supply to the posterior flap. The authors and Karakousis have had no problems with posterior flap necrosis with ligation of the common iliac artery, when the gluteal fascia is preserved with the gluteus maximus muscle.

- Postoperative bleeding from the cut edges of bone and muscle may occur. This can be prevented by cutting the muscles close to their tendinous origins and insertions whenever possible. When the psoas muscle is transected, Kelly clamps can be placed around the muscle, which is placed under tension, and bleeds are cauterized as they are encountered. The cut ends of the muscle are then ligated with a 0-silk suture (see p. 482). Bone wax is applied to the cut surfaces of bone to minimize bleeding from exposed cut bone surfaces.
- Skin flap necrosis is decidedly rare with anterior flap hemipelvectomy. Viability of the flap is ensured with meticulous attention to maintaining the overlying skin and fascia in continuity with the muscle mass of the quadriceps mechanism.
- Transient sciatic and femoral nerve palsy may result from vigorous traction on the nerve during the procedure. Permanent nerve injury may result from injury to the lumbosacral trunk of the sciatic nerve during division of the sacroiliac joint as the nerve courses over the sacral ala.
- Postoperative extremity swelling may occur as a result of the disruption of lymphatic drainage during dissection, in the region of the common femoral vessels. This can be minimized by bluntly dissecting the common femoral vessels, along with their lymphatic vessels, from the medial portion of the iliopectineal fascia.

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Chretien PA, Sugarbaker PH. Surgical technique of hemipelvectomy in the lateral position. *Surgery* 1981;90:900–909

The authors describe in detail an orderly sequence of steps used to perform hemipelvectomy. Each portion of the procedure is described in detail with excellent accompanying diagrammatic illustrations. Throughout the article, the authors emphasize two important surgical principles: maintaining tissues to be divided under tension and dividing muscles as close to their origin or insertion as possible to minimize blood loss.

Enneking WF, Dunham WK. Resection and reconstruction for primary neoplasms involving the innominate bone. *J Bone Joint Surg.* 1978;60A:731–46

The article describes the authors' criteria to select patients for hemipelvectomy vs. resection (partial or complete internal hemipelvectomy). The types of resection and the methods of reconstruction are described, as are the functional outcomes and incidence of local recurrence for the two procedures.

Hoffman C, Goshager G, Gebert C, Jurgens H, Winkelmann W. Functional results and quality of life after treatment of pelvic sarcomas involving the acetabulum. *J Bone Joint Surg.* 2006;88(A):575–82

The authors assess the functional evaluation and quality of life of forty-five of eighty-one patients who underwent acetabular resection for pelvic sarcoma at a single institution. They compared endoprosthetic reconstruction with hip transposition following resection. They found that hip transposition had a low complication rate and better functional results ($p = 0.017$), and quality-of-life assessment results ($p = 0.043$) when compared to endoprosthetic reconstruction. They recommend hip transposition as

the optimal procedure for treating pelvic sarcoma patients where acetabular resection is necessary.

Huth JF, Eckardt JJ, Pignatti G, et al. Resection of malignant bone tumors of the pelvic girdle without extremity amputation. *Arch Surg.* 1988;123:1121–4

The authors review their experience with 53 patients who were evaluated for non-amputative surgery during a 12-year period. Three patients were considered to have unresectable tumor, 17 underwent wide local excision, 27 underwent internal hemipelvectomy, and six underwent classic hemipelvectomy with amputation. The incidence of local recurrence was 11.8% for wide local excision, 7.4% for internal hemipelvectomy, and 33% for classic hemipelvectomy. The authors conclude that internal hemipelvectomy has the advantage of preserving a functional lower extremity, with acceptable hip stability and function.

Mack LA, Temple WJ. Extended pelvic resection for sarcoma or visceral tumors invading musculoskeletal pelvis. *Surg Oncol Clin N Am.* 2005;14(2):397–417

This is a good overview of the current literature and techniques, both surgical and nonsurgical, in treatment of pelvic sarcomas and visceral carcinomas invading the pelvis. The authors discuss the morbidity and mortality of these surgical procedures and emphasize the use of a team approach in a specialized center.

Mankin HJ, Mankin CJ, Simon MA. The hazards of biopsy: the biopsy, revisited. For the Members of the Musculoskeletal Tumor Society. *J Bone Joint Surg.* 1992;78A:656–63

In a 1982 study, the hazards of biopsy in 329 patients with primary malignant musculoskeletal sarcomas showed alarmingly high rates of complications when the biopsy was performed outside the treating institution. Ten years later, in the present study of 597 patients, the authors found that complications, errors, and changes in the patient course and outcome were significantly greater when the biopsy was performed outside of the treating institution. The authors emphasize the importance of planning the biopsy, and recommend that surgeons who are not prepared to proceed with definitive treatment should refer patients with suspected sarcomas to a treating center prior to biopsy.

Simon MA, Biermann JS. Biopsy of bone and soft-tissue lesions. In: Schafer M, editor. *Instructional course lectures.* USA: American academy of orthopaedic surgeons; 1994. p. 521–6

The authors outline the appropriate management of patients with musculoskeletal tumors as it relates to biopsy. Prebiopsy strategy, tissue handling, biopsy site, and techniques are discussed.

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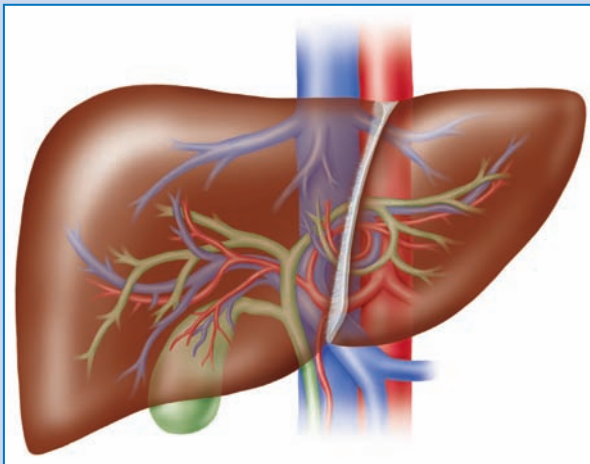
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Liver, Biliary Tree, and Gallbladder

Juan M. Sarmiento,
John R. Galloway,
George W. Daneker



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Introduction

Surgical resection remains the mainstay therapy for primary cancer of the liver and for most of the metastatic disease affecting this organ. There is a renewed interest in operative approaches to the liver mainly with regard to great developments in staging (imaging technique) and the availability of complex surgical strategies, and predictability of hepatic functional tolerance. At present, the 5-year survival rate following successful resection of metastatic colorectal cancer and hepatocellular carcinoma ranges from 40% to 60%, and the operative mortality after resection is less than 5%.

An additional tool aside from resection is the delivery of regional therapy via hepatic artery infusions of chemotherapeutic agents; the latter strategy was at its peak early this decade and was indicated in patients with unresectable metastatic colorectal cancer to the liver. Presently, the use of this strategy has declined as systemic chemotherapeutic agents have become more effective against this disease.

For an organ with eight segments, each one of which is irrigated by a portal pedicle and drained by a hepatic vein tributary, there are numerous approaches that can be used in resective therapy. The one dictum that always comes up in this area is the absolute importance of a detailed knowledge of the anatomy of the liver, coupled with an accurate correlation with the imaging techniques on an individualized approach. Therefore, this chapter aims to deliver the specific information necessary to perform complex operations in the liver and the biliary tract. Armed with this, the surgeon would have already covered the main premise on the HPB Surgery.

Surgical Anatomy

Topography

The liver, which is the largest glandular organ in the body, principally occupies the right subcostal and epigastric regions and extends into the left subcostal region and downwards into the right lumbar region. It lies directly beneath the diaphragm and is covered partially by the rib cage over most of its lateral surface. A small part of the liver's anterior surface is in contact with the anterior abdominal wall.

The anterosuperior surface of the liver is convex and molded to the diaphragm but is accessible within the free abdominal cavity. Similarly, the visceral or inferior surface of the liver conforms to the surrounding intra-abdominal organs. The inferior surface is covered by a continuation of the peritoneal lining of the lesser omentum. The interface between the abdominal cavity and the liver is susceptible to surface implantation of free intra-abdominal tumor, and this must be kept in mind when assessing "superficial" hepatic metastasis.

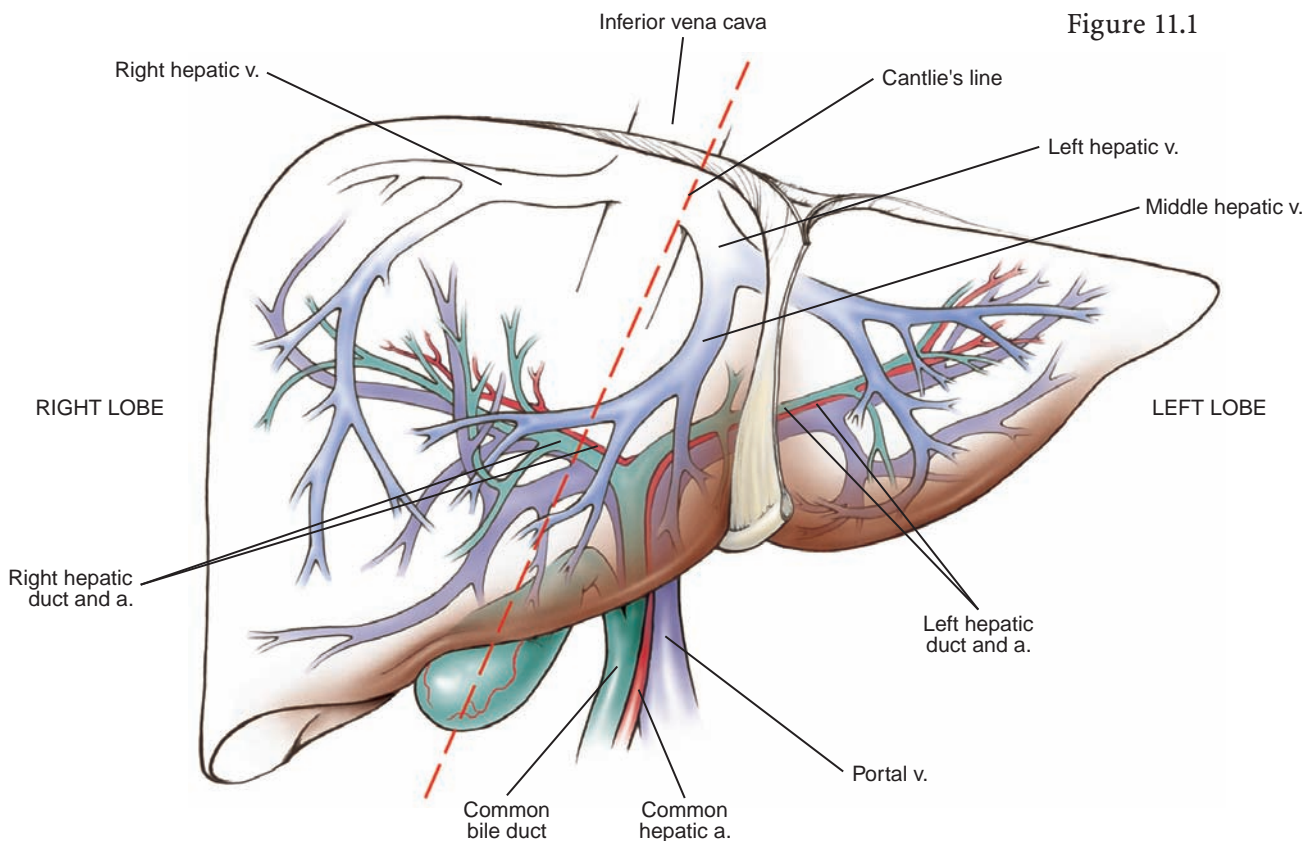
The right lateral surface of the liver lies beneath the costal margin in the midaxillary line. It rests against the diaphragm and is adjacent to the costodiaphragmatic pleural recess and a portion of the thoracic wall composed of the seventh to eleventh ribs.

The posterior surface of the liver, in contrast to other surfaces, is covered partially by the peritoneum. The peritoneal covering of the anterosuperior, inferior, and lateral surfaces of the liver reflect onto the diaphragm, leaving most of the right lobe's posterior surface and a strip of the left lobe's posterior surface in direct contact with the diaphragm. This "bare area" of the liver is contained within these peritoneal reflections, called the coronary ligaments, and the lateral fusion of the coronary ligaments, called the triangular ligaments. It is of surgical significance that the inferior vena cava (IVC) and hepatic veins are fully contained within the liver's bare area.

Functional Hepatic Anatomy

The liver is functionally divided into lobes and segments based on its hepatic arterial blood supply, portal venous blood supply, and biliary drainage (these three forming the portal pedicles), and its hepatic venous drainage. The major divisions of the liver are the right and left lobe. Each lobe or hemiliver, is defined by the branching of the proper hepatic artery, portal vein, and common bile duct into major right and left divisions. The topographic division between these lobes follows a plane running vertically through the liver and connects the gallbladder fossa anteriorly to the left side of the IVC posteriorly (Cantlie's line).

The right and left lobes can be further subdivided into sections based on the distribution of the portal pedicles and hepatic veins. The planes of division along each of



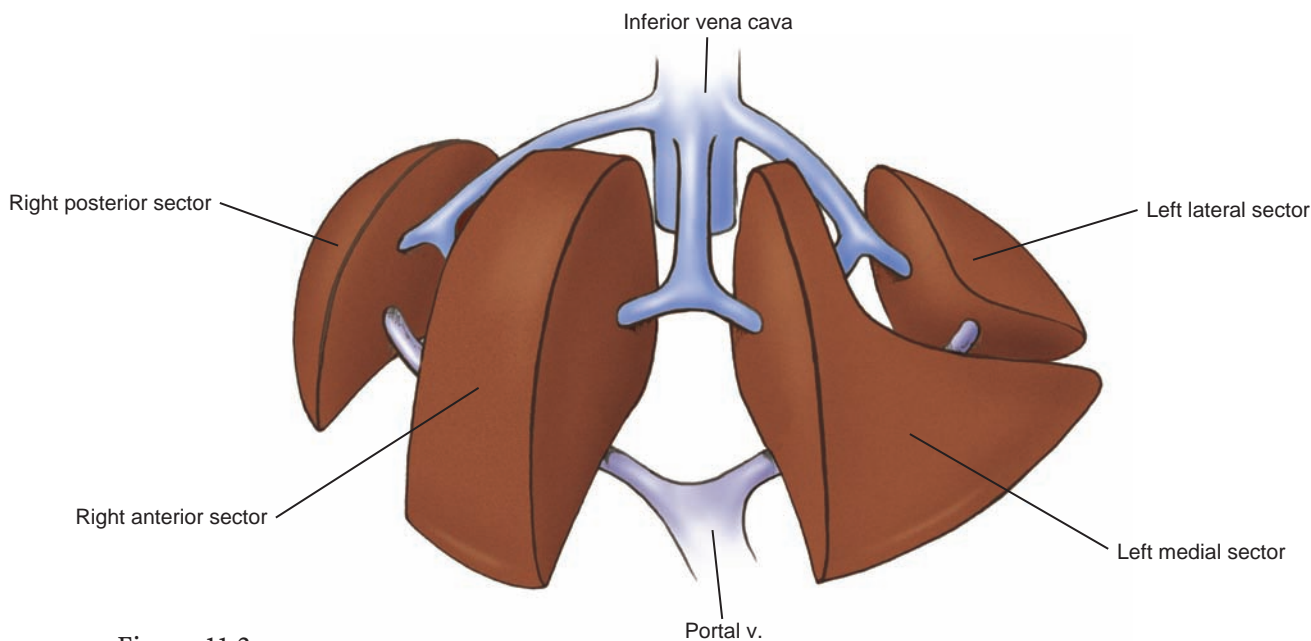


Figure 11.2

the three main hepatic veins are called scissura. These scissura are used to divide the liver into four sections, known as the right anterior, right posterior, left medial, and left lateral sections, each supplied by a portal pedicle comprising a named hepatic artery branch, portal vein branch, and bile duct branch. No clear topographic features or morphologic boundaries exist between the sections in the right lobe. Within the left lobe, the umbilical fissure and falciform ligament are used to define the plane of division between the medial and lateral sections.

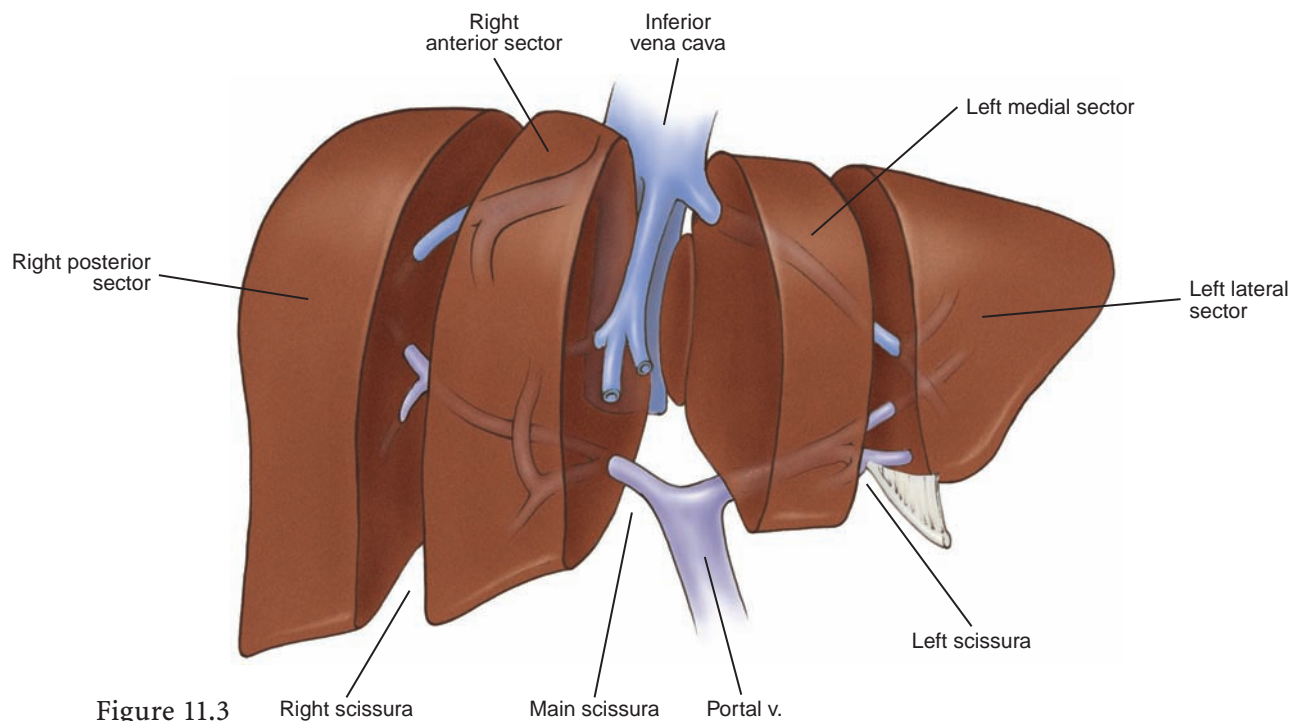


Figure 11.3

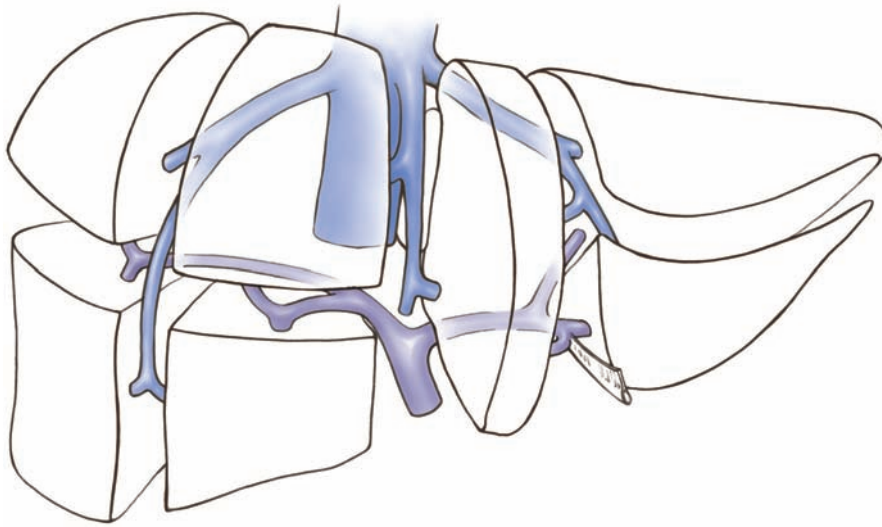


Figure 11.4

Although this plane of division has been commonly adopted, it is not completely correct; in this case, the portal pedicle contents are the main structures within this plane and not the left hepatic vein (as has been defined above).

However, the ease of identification and manipulation has redefined, in a way the classical definition, and most surgeons adopt the umbilical fissure as the boundary between the left and medial sections of the left lobe.

Each hepatic section can be further subdivided into numbered segments, as described by Couinaud. There are eight liver segments, including the caudate lobe, segment I, which is a separate lobe (having its own independent portal pedicle and hepatic venous drainage). This segmentation is one step beyond the division of the liver into lobes and sections and is based on the major bifurcation of each portal pedicle within the sections. The logic of remembering the liver's segmental anatomy is as follows. Clockwise from the vena cava, the first segment encountered is the superiorlaterally situated segment II. The more inferiorly situated segment III, together with segment II, comprises the liver to the left of the falciform ligament. Segment IV is the portion of the liver between the falciform ligament and Cantlie's line (sometimes referred to as the quadrate lobe). Segment IV is often divided into a superior half (segment IVA) and an inferior half (segment IV-B). Segments V, VI, VII, and VIII make up the right lobe and are labeled according to this clockwise system. Segments V and VIII comprise the right anterior section, and segments VI and VII comprise the right posterior section.

Segment I, or the caudate lobe, is considered as an autonomous segment from the viewpoint of functional anatomy; this segment receives branches from both hepatic arteries and portal veins, although the majority of the blood supply comes from the left-sided vessels. Venous drainage is not through the hepatic veins but through a variable number of branches that drain directly into the IVC.

Again, it must be remembered that no hepatic topographic features or morphologic boundaries delineate the majority of sections or segments. The sectional-segmental anatomy of the liver has practical significance because it can be determined in the



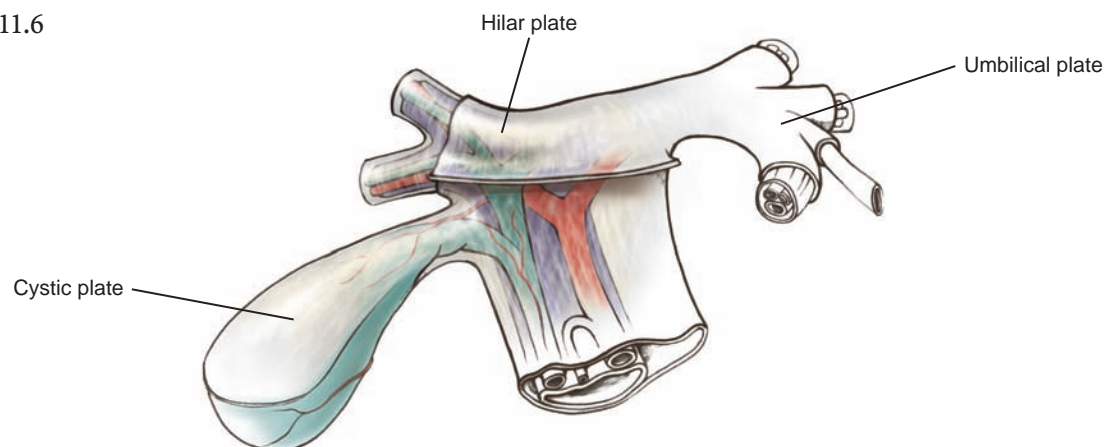
Figure 11.5

operating room with intraoperative ultrasonography. With ultrasound, the surgeon can not only examine the hepatic parenchyma for lesions, but can also see and mark the exact anatomy of the corresponding segmental divisions.

Portal Anatomy

The liver is covered by a thin layer of connective tissue known as Glisson's capsule. This capsule surrounds the parenchyma and extends into the porta hepatis, where it forms sheaths that envelop the bile duct, hepatic artery, and portal vein (the so-called portal pedicle). At the level of the liver hilum, the capsule and vasobiliary sheaths coalesce and thicken to form a series of fibrous plates that surround the portal structures. Division of these plates is required to gain access for mobilization, control, and division of the portal pedicles in the course of a liver resection. The vasobiliary sheaths then continue to invest the intrahepatic portal components up to the level of the sinusoid. This continuation of Glisson's capsule produces a hyperechoic ring around each portal component when visualized with intraoperative ultrasonography. These rings are clinically important because they can be used

Figure 11.6



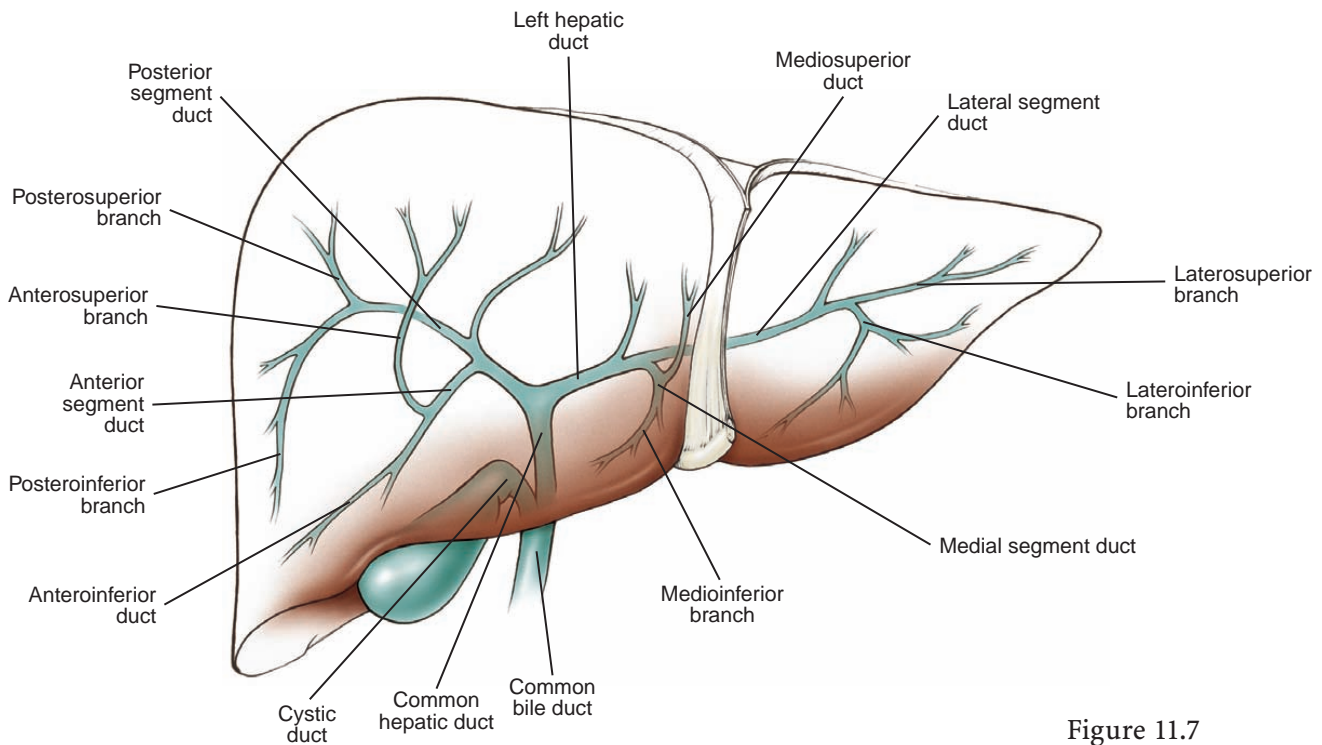


Figure 11.7

to differentiate intrahepatic portal structures from the hepatic veins, which have no capsule or fascial covering.

The common hepatic duct branches into the main right and left hepatic ducts at the right side of the liver hilum, anterior to the portal vein bifurcation and overlying the origin of the right main portal trunk. It is important to state that the right hepatic artery (coming from left to right) passes underneath the ductal confluence in a vast majority of cases. This is an important issue because biliary reconstructions using the confluence of the hepatic ducts carry no risk of arterial lesions, except in those rare cases where the right hepatic artery crosses on top of the hepatic duct. The bifurcation is usually at or above the level of the hilar plate; thus dissection of the hepatic ducts often requires lowering of the plate for exposure of the ducts, especially the left one. The right hepatic duct is short and rapidly ascends into the parenchyma after the bifurcation. In 28% of cases, one of the right segmental ducts crosses Cantlie's line to join the main left hepatic duct. The left hepatic duct is longer, with a more horizontal orientation and has an approximate extrahepatic course of 3 cm. This fact is very useful when biliary reconstructions need a wide anastomotic segment; i.e., the Hepp-Couinaud procedure.

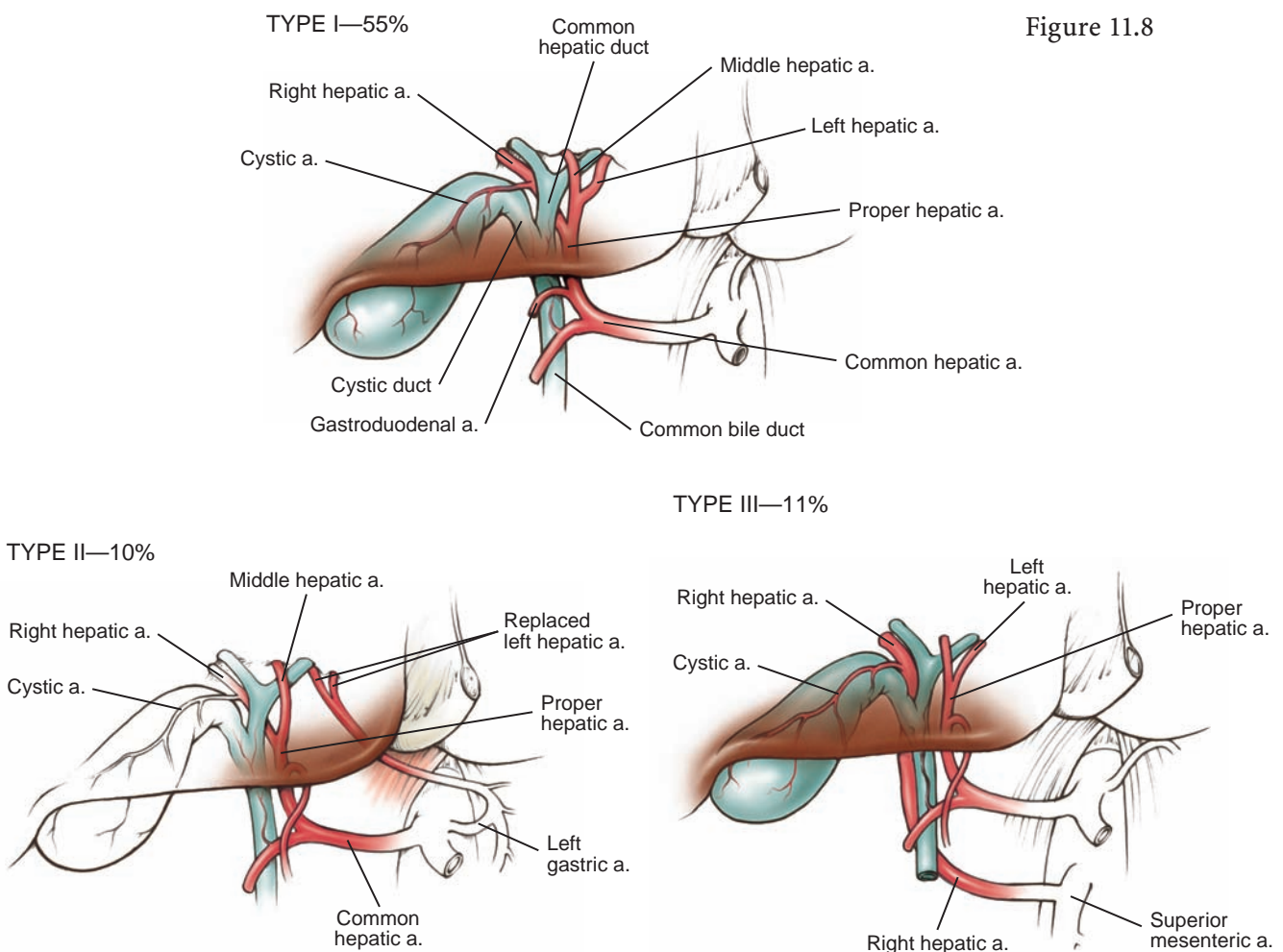
The liver receives its blood from two sources: the hepatic artery and the portal vein. The hepatic artery provides 25% and the portal vein contributes about 75% of the blood flow to the liver. Of all the portal components, the hepatic arterial blood supply is the most variable, with ten different vascular patterns identified. The most modern description of the blood supply is that of VanDamme and Bonte.

Blood Supply

Hepatic Artery Variations		
	Type I	The right hepatic, midhepatic, and left hepatic arteries come from the celiac axis (55%).
	Type II	The right hepatic and the midhepatic come from the celiac axis, the left one comes as a replaced left hepatic from the left gastric artery (10%).
	Type III	The midhepatic and left hepatic come from the celiac axis, the right one comes as a replaced right hepatic from the superior mesenteric artery (SMA) (11%).
	Type IV	The midhepatic is from the celiac axis, the right is a replaced right hepatic from the SMA and the left is a replaced left hepatic from the left gastric artery (1%).
	Type V	The right hepatic, midhepatic, and left hepatic come from the celiac axis, and an accessory left hepatic comes from the left gastric artery (8%).
	Type VI	The right hepatic, midhepatic, and left hepatic come from the celiac axis, and an accessory right hepatic comes from the SMA (7%).
	Type VII	The right hepatic, midhepatic, and left hepatic come from the celiac axis, an accessory right hepatic comes from the SMA, and an accessory left hepatic comes from the left gastric artery (1%).
	Type VIII	Patterns are combined. A replaced right hepatic and an accessory left hepatic, and an accessory right hepatic and a replaced left hepatic (2%).
	Type IX	Native hepatic artery coming from the celiac axis is absent. The entire hepatic trunk comes from the SMA (4.5%).
	Type X	Native hepatic artery coming from the celiac axis is absent. The entire hepatic trunk comes from the left gastric artery (0.5%).
	Type X	Double hepatic arteries come from the celiac axis (no common hepatic artery).
	(variant)	The right hepatic comes from the proximal celiac axis and the left hepatic comes from the distal end of the celiac artery.
From Michels NA. Newer anatomy of the liver and its variant blood supply and collateral circulation. Am J Surg. 1966;112:337–47, with permission from Excerpta Medica, Inc.		

The frequency of arterial variability mandates the need for celiac artery and SMA angiograms prior to liver resection, when planning for intra-arterial pump insertion (regional chemotherapy). Typically, the proper hepatic artery divides into the main right and left lobar branches within the porta hepatis outside the liver parenchyma. Usually, the proper hepatic artery branches lower in the porta hepatis than does the bile duct or portal vein. A middle hepatic branch usually arises from the proximal left hepatic artery, but this is not a consistent finding.

This variation of arterial anatomy, known as type I, is the most common and occurs in 55% of patients. Two other common variations are type III (11%), in which the main right hepatic artery arises from the SMA and is situated in the posterolateral porta, and type II (10%), in which the main left hepatic artery arises from the left gastric artery and travels into the liver in the proximal gastrohepatic ligament, and the middle hepatic artery arises from the proximal right hepatic artery. Clinically, it is very easy to identify a replaced right hepatic artery just by palpating the pulsation on the posterolateral surface of the porta hepatis; the left replaced artery is easily seen on the midportion of the gastrohepatic ligament and palpation confirms its presence.



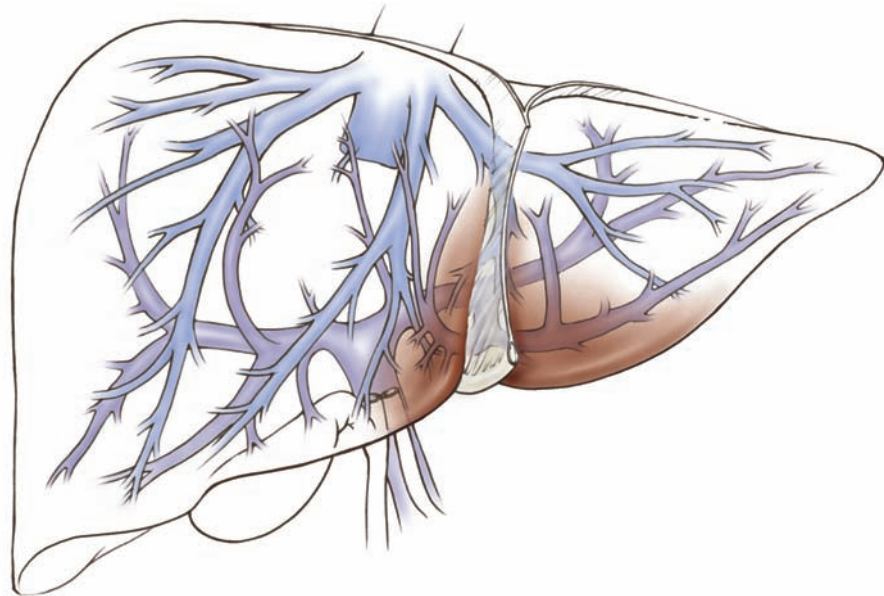


Figure 11.9

Within the liver, arteries follow the course of the bile ducts, dividing into anterior and posterior branches within the right lobe and into medial and lateral branches within the left lobe.

Portal Vein

The portal vein and its branches are the least variable components of the porta hepatis. The portal vein is the most posterior portal structure, situated beneath the bile ducts and hepatic artery. Like the right hepatic duct, the main right portal vein is short and branches soon after it ascends into the parenchyma. The left main portal branch, like the left duct, is relatively long and has a predictable horizontal course before immersing into the liver.

Hepatic Veins

The hepatic veins enter the IVC as it emerges from the liver immediately below the diaphragm. These veins have a short extrahepatic course even though it is relatively straightforward to perform an extrahepatic dissection/division of any of them. The hepatic veins divide the liver into sections. The right hepatic vein is usually single and drains the anterior and posterior sections of the right lobe and obviously divides those two sections. In 61% of patients, the right hepatic vein has no branches for a distance of 1 cm from its origin on the vena cava. In these patients, extrahepatic division of the vein prior to the transection of the liver is less cumbersome. In 61% of patients, there is an additional one large vein draining the posterior or postero-inferior right lobe directly into the infrahepatic IVC (this is called the right inferior hepatic vein). This vein must be transected during the mobilization of the right lobe from the infrahepatic IVC. The middle hepatic vein runs along Cantlie's line and

drains the right anterior and left medial sections. The left hepatic vein drains the left lateral section and a small portion of the left medial section. In 90% of patients, the left and middle hepatic veins form a common trunk. The bifurcation of the common trunk into the left and middle veins usually occurs within 1 cm of its origin from the vena cava. In spite of the tightness of this space, the left hepatic vein is routinely divided extrahepatically in the course of a left hepatectomy whereas the middle hepatic vein is completely surrounded by hepatic parenchyma which makes its extrahepatic dissection more complicated.

Surgical Applications

In the management of primary or secondary hepatic tumors, treatment decisions are made following a sequential evaluation for the presence of extrahepatic tumor and the extent of intrahepatic tumor. After the patient has been deemed operable by the treating surgeon, either a CT scan or MRI provide the best anatomical preoperative assessment. While planning for partial hepatic resection, not only the number and location of the masses should be defined, but also their spatial relationship to the main vessels of the liver. The authors favor the MRI as a diagnostic tool since it has a higher diagnostic accuracy and an extended use on the evaluation of the bile duct, without the inconvenience of ionizing radiation or the limitation on renal patients. It has also shown tremendous utility on identifying extrahepatic disease including peritoneal implants. As with CT scan, its weakness lies in the determination of the status of the regional lymph nodes.

For a lesion to be considered resectable, it has to basically spare a minimum of two contiguous segments of the liver, and in case of normal hepatic function, preserve at least 25% of the entire liver functioning mass; cirrhotic or steatotic livers have less tolerance to major resection and additional efforts should be made to increase the liver remnant volume. A rule of thumb also indicates that at least one main portal pedicle and one hepatic vein needs to be preserved, obviously both being ipsilateral.

Liver resection can be classified as either anatomic or nonanatomic. Nonanatomic resections are based on tumor location and can cross anatomic boundaries. The determination of segmental anatomy is important prior to nonanatomic resection since tumors are rarely confined solely within a single segment (other than segment I), but no formal segmental resection is required to obtain the desired 1-cm margin. Anatomic resections follow defined anatomic features and involve removal of a lobe (sometimes with an additional section), a section, or a segment. The four major types of anatomic resections, in addition to segmental resections, are the right lobectomy or hepatectomy, left lobectomy or hepatectomy, resection of the right lobe and the medial segment (segment IV) of the left lobe (extended right hepatectomy), resection of the left lobe and the anterior segment (segment V–VIII) of the left lobe (extended left hepatectomy). Minor classical resections involve the isolated resection

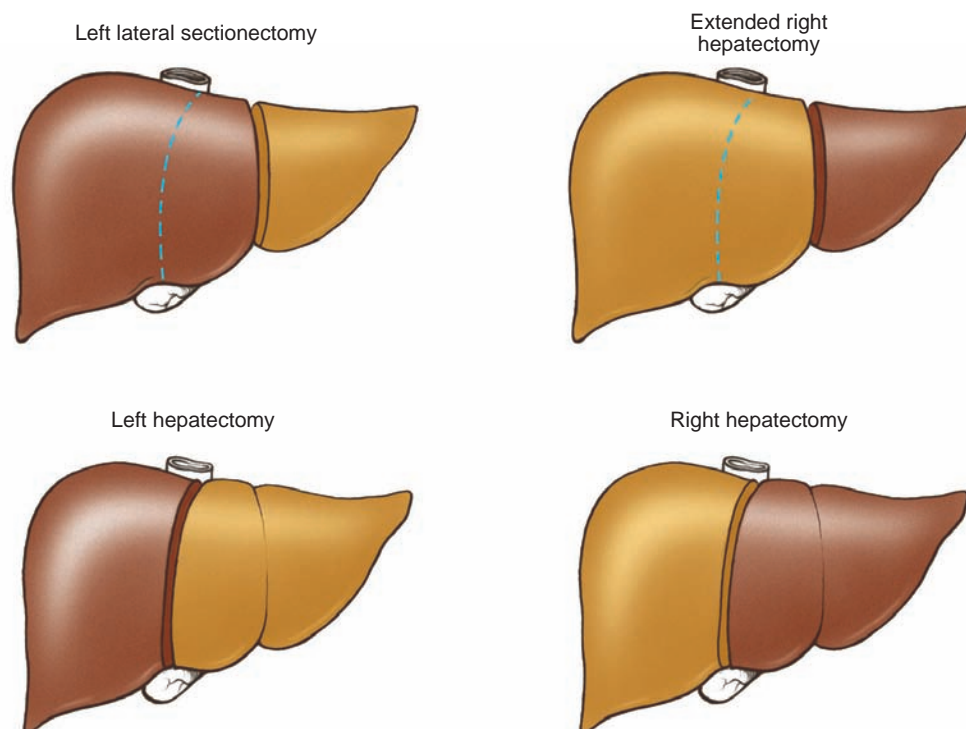


Figure 11.10

of each section of the liver (left lateral section, segment IV, right anterior section and right posterior section). It is also possible to perform an excision of the caudate lobe (segment I) either isolated, or in combination with the left or the right hepatic lobe. In general, anatomic resections are better executed, since the surgeon has the capability of controlling the vascular inflow of the corresponding segment, thereby decreasing the amount of operative bleeding. Either anatomic or nonanatomic resections have a comparable survival, provided they achieve an acceptable margin (1 cm).

PET scan has proven to be a very valuable technique in staging oncologic patients. Notwithstanding the lack of diagnostic accuracy on Hepatocellular carcinoma, PET evaluates the presence of both hepatic and extrahepatic disease; some fusion techniques incorporate the CT or MRI on the PET scan which is a great asset to determine the presence and the exact anatomic location of the tumors. In some unresectable tumors, chemotherapy (either systemic or regional) plays a role in down staging the disease to a point where resection can be attempted.

It is necessary to emphasize the importance of a low CVP during the period of liver transection. A CVP less than 5 cm H₂O reduces backbleeding from the hepatic veins and it is a tremendous aid in situations where control of the vascular outflow can not be achieved before hepatic transection. A low CVP is achieved by restricting pre- and intraoperative IV fluids, and by the use of diuretics or medications to expand the venous vascular capacitance such as nitroglycerine prussiate.

Right Hepatic Lobectomy

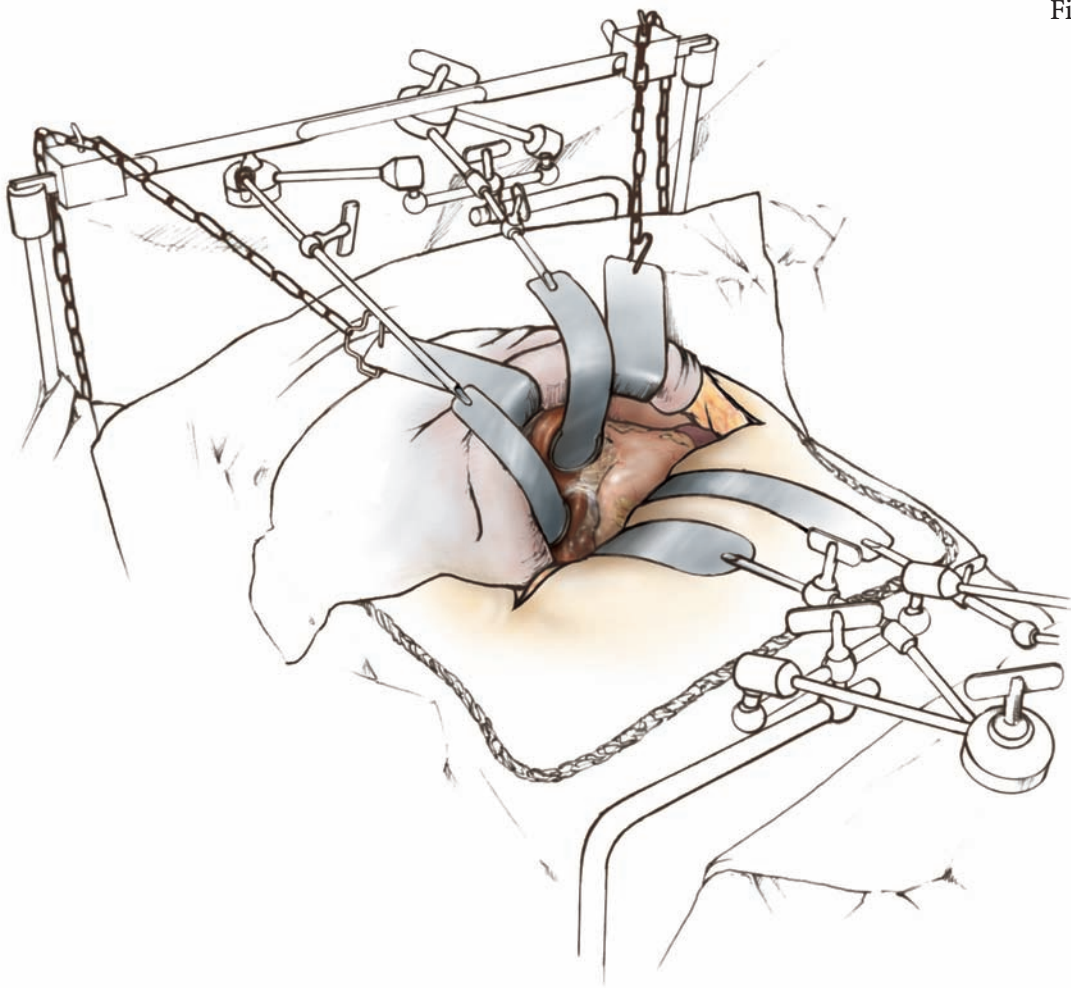
Right hepatic lobectomy involves the removal of segments V, VI, VII, and VIII, which comprise the right hemiliver. Indications are the presence of lesion(s) within the right lobe where (1) resection requires the sacrifice of major portal structures, or major

portal structures and hepatic vein, or (2) metastases are scattered within the lobe and cannot be fully encompassed with a nonanatomic or segmental resection.

Incision and Exposure

The patient is supine on the operating table with the right arm tucked on the side; the rationale being the positioning of the vertical bar of the retractor attached to the base of the operating table. The full abdomen up to the nipples is prepared and draped into the field. During the initial exploration, an incision is made one fingerbreadth below the right costal margin with a small curve oriented superiorly on the most lateral portion of the wound. In patients with a wide costal angle and inferiorly located tumors, an upper midline could be considered. For large, bulky tumors a paraxiphoid midline extension (the Mercedes-Benz incision) is helpful for gaining access to the suprahepatic IVC and hepatic veins. Finally, a thoracoabdominal incision may be contemplated for large posterior right lobe tumors, but in our experience this incision has been rarely needed. A thorough exploration of the abdomen, including close examination of the liver and portal structures, is conducted. An enlarged lymph node in the porta hepatis, either posterior to common bile duct or anterior to the common

Figure 11.11



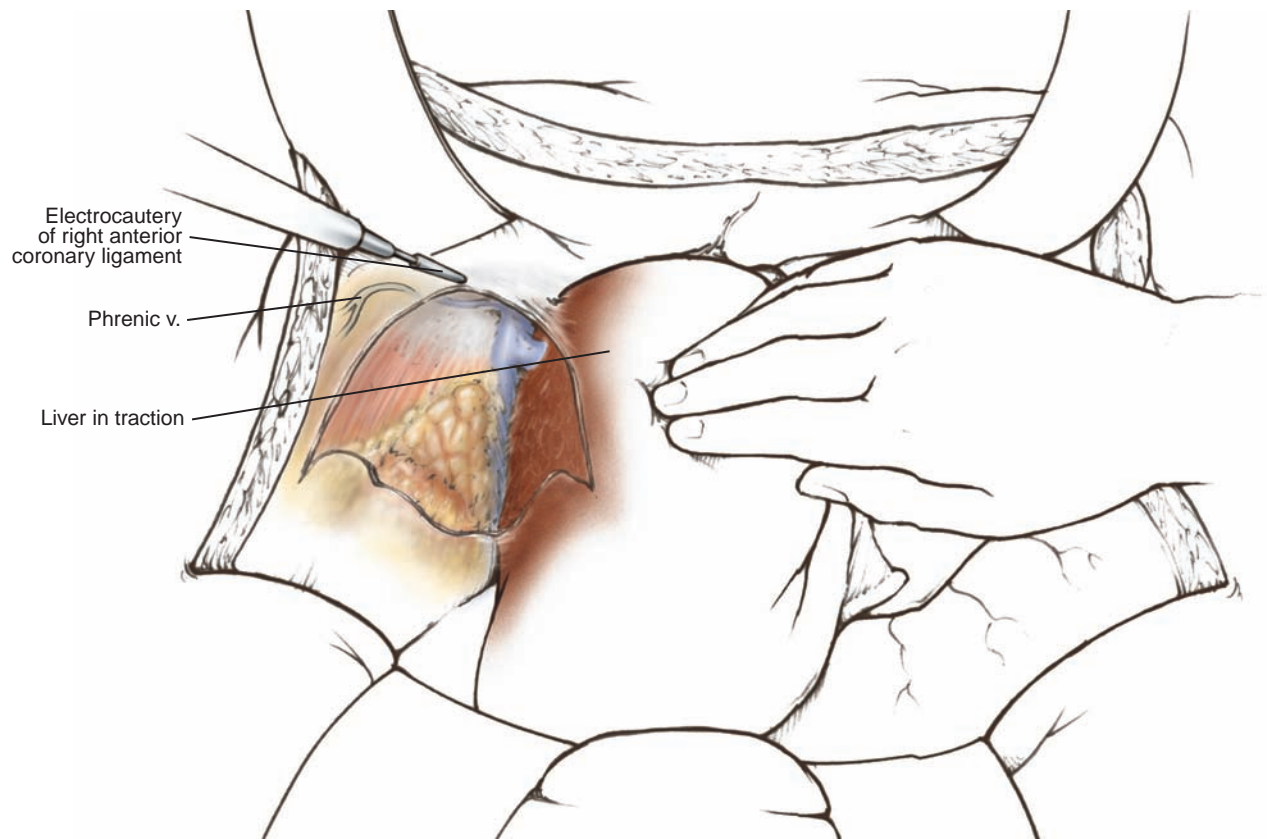
hepatic artery is excised and sent for frozen examination if metastatic involvement is suspected. After ruling out extrahepatic disease, an intraoperative ultrasound is performed to look for previously undetected tumors and to reevaluate the anatomical relation of the tumors with major vasculobiliary structures.

After incision, exposure is secured with self-retaining retractors such as, in the authors' preference, the Thompson retractor. These retractors are suspended from a frame anchored to the operating table at the level of the patient's shoulders. The Thompson retractor also has the capability of placing additional retractors inferiorly, used as countertraction on the intra-abdominal hollow viscera.

Mobilization and Assessment of Resectability

In case of emergency, the round ligament is taken from the liver. The falciform ligament is divided halfway between the abdominal wall and the liver, so that it can be reapproximated at the completion of the resection; this maneuver avoids postoperative torsion of the right lobe which acts as an acute outflow obstruction resulting in liver congestion and death. While the first assistant exerts gentle clockwise traction on the liver, the right triangular, right anterior, and right posterior coronary ligaments are divided medially to the level of the IVC. As these ligaments are divided, the liver can be carefully rotated anteriorly and to the left, exposing the right adrenal gland, the bare area, and the retrohepatic IVC; care must be taken

Figure 11.12



to avoid the injury of the right adrenal vein. If the diaphragm is adherent to the liver in the vicinity of the tumor, it should be resected en bloc with the right lobe. The authors did not find it necessary to divide the left triangular and coronary ligaments. Transverse division of the peritoneum over the suprahepatic IVC is completed and the hepatic veins are identified. A good tip off to find expeditiously, the right hepatic vein is to identify the right phrenic vein, and follow it on its entrance to the hepatic vein. There are usually no vessels contained within the ligaments and bare area of the liver, so the preceding dissection is relatively bloodless. Following mobilization of the liver, thorough inspection and bimanual palpation more clearly shows the relationship of the tumor or tumors to the adjacent landmarks and key structures.

Hilar Dissection

On the authors' preference, the hilar dissection is performed before mobilization of the liver. The rationale behind it is that it is somewhat convenient to have an unstained tissue for the hilar dissection, because oozing can occur during the mobilization of the liver. Additionally, the right lobe will become ischemic and will be drained during the mobilization. This strategy is done always in the Anterior Approach for Right Hepatectomy where only hilar dissection is done before liver transection; this approach is preferred in bulky tumors in the right lobe, especially when they are invading the diaphragm.

The MRI is very accurate in defining the presence of replaced hepatic arteries and operative maneuvers are done to rule out their presence. When found, replaced arteries are actually far from the hilum and their dissection is easier. The cystic artery (usually coming from the right hepatic artery) as well as the cystic duct is taken; many a times, the gallbladder is left in situ to aid in the exposure of deep planes in the right portal pedicle. Dissection of the lateral leaf of the portal peritoneum is proceeded laterally to where the common bile duct and cystic duct are identified. The native hepatic artery is located underneath the right hepatic duct and although the early division of the hepatic duct facilitates arterial dissection, the duct is taken as a last step of the liver transection to avoid inadvertent contralateral injury. Usually by pushing the right hepatic duct to the left, the groove between this and the right hepatic artery is found and the dissection is continued. When encircled, the surgeon must palpate the contralateral artery to be absolutely sure that he is not dealing with the proper hepatic artery. Double ligation is performed with heavy silk sutures and the artery is transected. At this point, a space opens on top of the portal vein. For all purposes, the vein underneath is the main portal vein, and it is the duty of the surgeon to find the bifurcation, usually in a plane cephalad to this one. When finding the bifurcation, the right portal vein is dissected and encircled with a vessel loop. Many a times, there is a small branch from the right portal vein into the caudate process of the caudate lobe that should be taken before complete dissection of the vein. It is the authors' preference to fire an endovascular stapler to control the right portal vein. After this, the right lobe will have ischemic demarcation, usually over Cantlie's line.

There is no need to make an extra effort to find the ductal confluence as no ductal structures are taken until the last stage of the resection.

Venous Dissection

Mobilizing the liver from the IVC commences with the veins at the inferior surface of the liver, especially in the presence of a right inferior hepatic vein (also taken with endovascular staples). While the liver is retracted anteriorly and to the left, 2–12 pairs of short hepatic veins extending from the anterior surface of the IVC are encountered; just those veins to the right of the midline on the IVC are taken. This could be achieved with silk ligatures, or as preferred by the authors, with ultrasonic shears (if 3 mm or less). These veins are fragile and can result in troublesome bleeding if not ligated carefully.

As the dissection is continued cephalad, getting really close to the right hepatic vein, the IVC ligament, which is a fibrotic ligament extending from the caudate lobe to segment VII is encountered. Careful division of this structure is necessary to adequately visualize the main right hepatic vein; it is the authors' preference to encircle it first and then fire an endovascular stapler, as in the majority of cases, there is a bleeding vein that could obscure the subsequent dissection of the right hepatic vein.

Extrahepatic division of the hepatic veins prior to parenchymal transection should be done in every case, unless there is a large tumor next to that vein and to the IVC. This basically provides a vascular isolation to the right lobe and minimizes the operative bleeding during parenchymal transection.

Figure 11.13

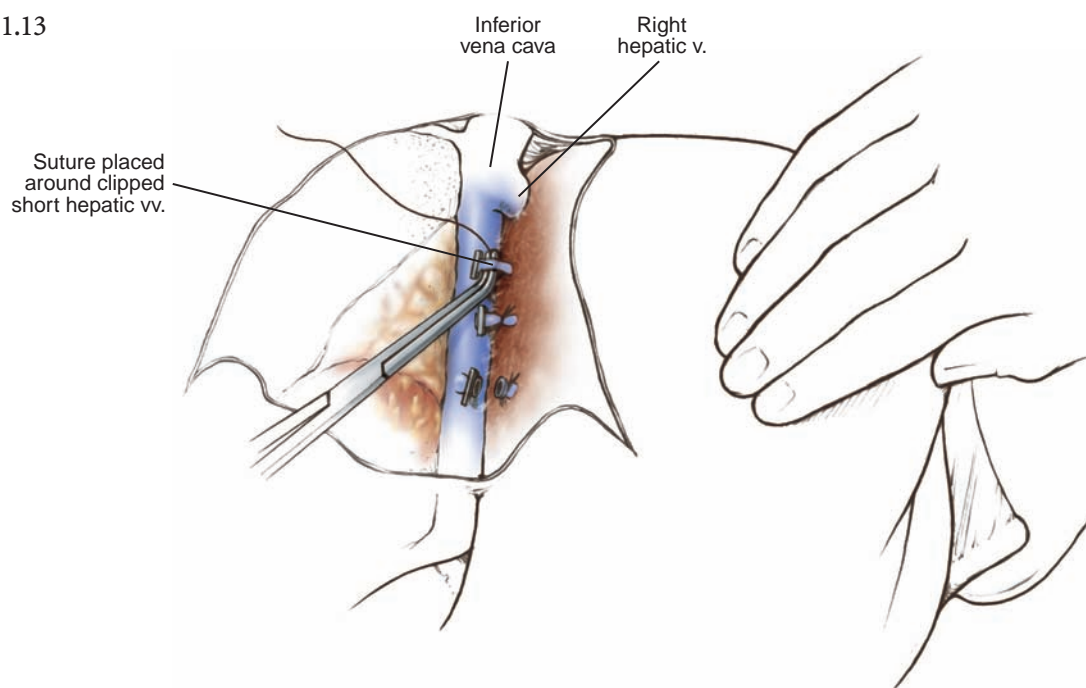


Figure 11.14

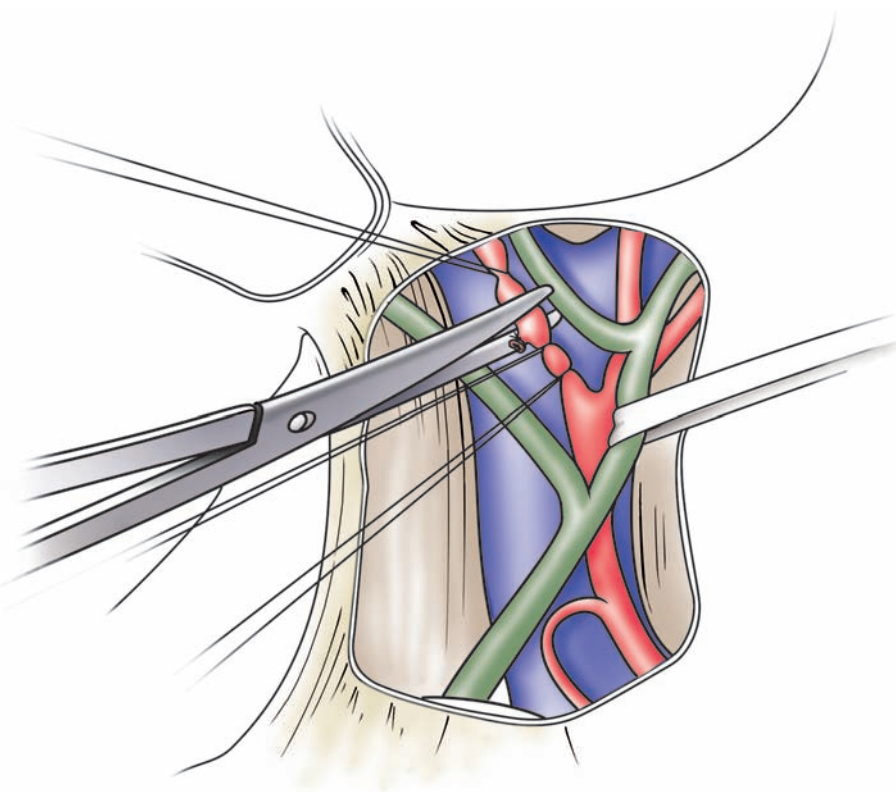
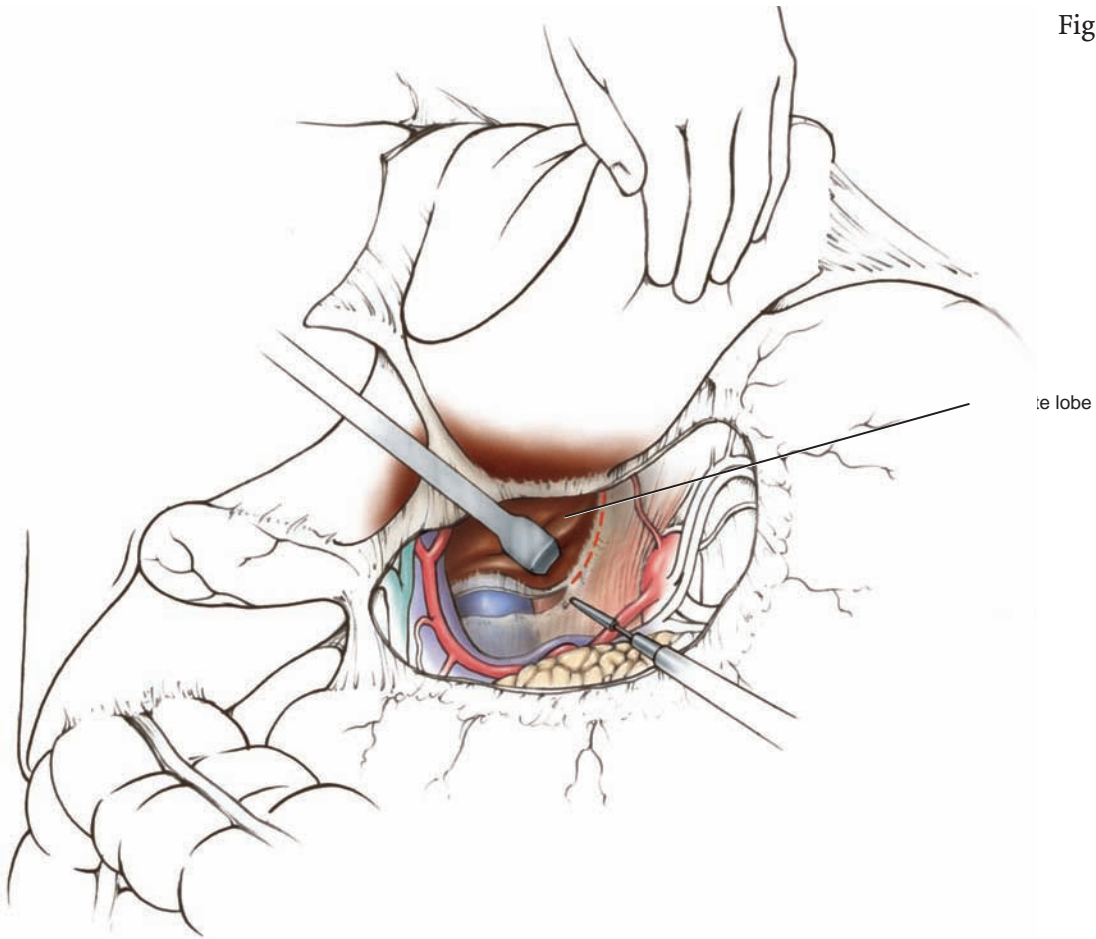


Figure 11.15

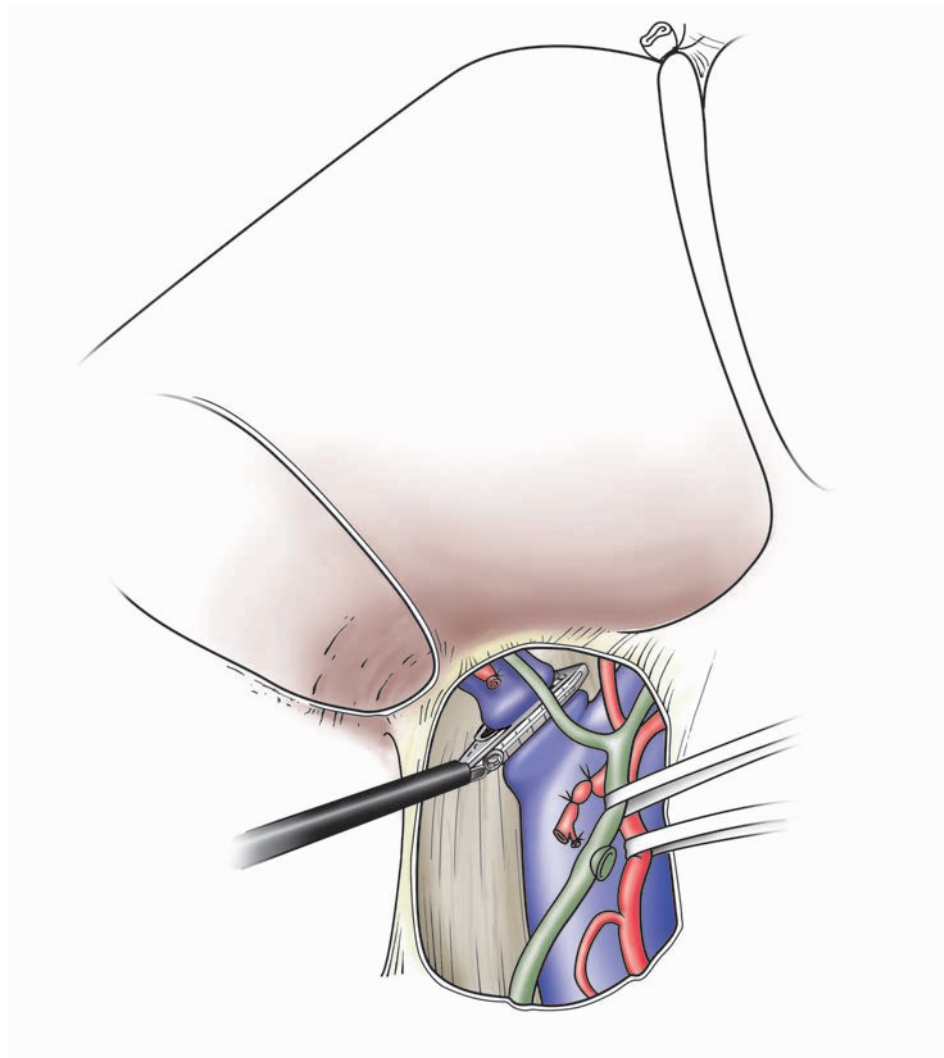


Figure 11.16

The dissection is usually done on a cephalad direction after the transection of the IVC ligament, where the groove medial to the right hepatic vein is developed, and an additional dissection is done on top of the IVC which completes its isolation.

After encircling, an endovascular stapler is fired across and the liver is returned to the normal position. In cases where the dissection could carry risk of bleeding, an alternate strategy to achieve the same goal is to keep the CVP under 5 cm H₂O. In fact, this is the routine strategy used on the Anterior Approach.

Parenchymal Transection

An umbilical tape is placed around the porta hepatis and a Rommel tourniquet is readily installed for clamping; whenever possible the bile duct should be excluded from the tourniquet. The capsule of the liver is scored with an electrocautery at the line of demarcation between the lobes. There are many devices to go across the liver and every surgeon needs to define their preferences. The authors' do a combination of electrocautery, ultrasonic shears, suture-ligature and clips. The ultrasonic shears

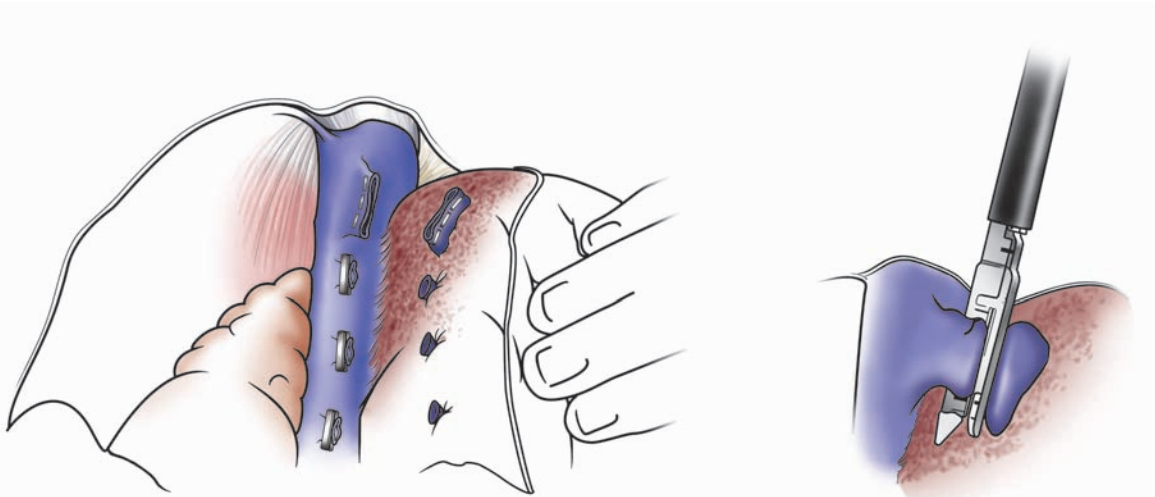
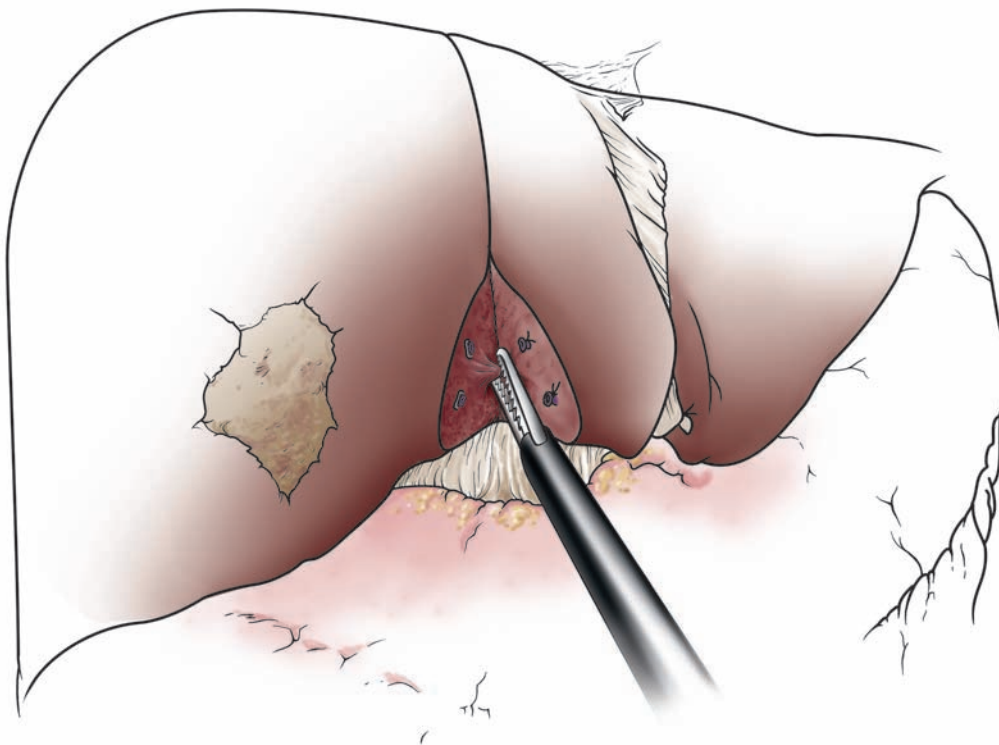


Figure 11.17



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should not be used blindly as accidental injury of the middle hepatic vein could happen with subsequent significant bleeding. Basically, staying slightly to the right of the demarcation line would put the surgeon to the right of the middle hepatic vein and would avoid the main branch, having to deal with its direct branches then, albeit smaller. With the electrocautery on and off, one can achieve significant dissection, and then the ultrasonic shears are used for vessels up to 3 mm in diameter.

For larger vessels, ligatures are used, reserving staples for larger size vessels. Clips are usually placed on the specimen side to avoid the distortional effect on postoperative imaging of the transection line. An advantage of the ultrasonic shears is the double effect of sealing and cutting, enabling the assistant to continue compression and not change positions during the parenchymal transection. The surgeon needs to be cognizant of the location of the tumor or tumors and major structures, especially the contralateral pedicle. The middle hepatic vein is classically preserved unless it is not oncologically sound.

A Pringle maneuver (vascular inflow occlusion or clamping) is not always necessary but could be a good asset to decrease significant bleeding during the operation, especially when arterial, or suspected from portal structures. Although the normal liver will tolerate continuous occlusion for up to 90 min, the authors' routinely occlude the vascular inflow for 15 min followed by a 5-min period of reperfusion. In patients with parenchymal disease (i.e.; cirrhosis, steatosis), vascular isolation is avoided, if possible.

Once the parenchyma transection is near completion, the right hepatic duct is addressed again; by staying to the right of the line of transection and visualizing the common hepatic duct, the right hepatic duct should be taken with confidence. Hemostasis is achieved with electrocautery, TissueLink or fibrin glue. Typically, surgical drains are not left unless there is deep concern for bile leaks.

A new technique worth mentioning is the Liver hanging maneuver. Since the drainage of the caudate lobe consists of small veins on each side of the midline of the IVC, this technique uses that space to slide an aortic clamp just on the midline space, on a cephalad direction to reach the groove between the right and the middle hepatic veins. Classically, the right hepatic artery and portal veins, and a couple of caudate branches are taken. Then, the mentioned clamp is accommodated as described, and on its emergence to the left of the right hepatic vein, an umbilical tape is captured and passed in between the liver and the IVC which will serve to hang the liver. This is tremendously useful for the anterior approach and orientates the plane of parenchymal transection.

Another method to control the right portal pedicle is the Glissonian approach. As the portal pedicle divides inside the liver, it takes the fibrous capsule with each division. The right portal pedicle divides into an anterior branch and a posterior one. The posterior division has a surface representation in the *Incissura Dextrus of Gans*, which is a cleft in the undersurface of the liver in a plane posterior to the hilum. Although mostly unrecognized, once identified, it is very easy to remember its location. By doing longitudinal incisions on the hepatic parenchyma on each side on the *Incissura*, a vascular renal clamp could be used to encircle the posterior pedicle and fire a stapler for vascular inflow control (this maneuver is done also for isolated right posterior sectionectomy). The anterior division runs on the deep portion of the gallbladder fossa and a horizontal incision on the base of segment IV (towards the right) with another longitudinal incision above the *Incissura* serves as points of entrance to encircle the right anterior pedicle (again, this is also used for isolated right anterior sectionectomy). With those two pedicles controlled, this equates to having extrahepatic control of the right hepatic artery and the right portal vein.

Left Hepatic Lobectomy

Left hepatic lobectomy involves the removal of liver segments II, III, and IV, which comprise the left hemiliver. Indications are lesion(s) within the left lobe where (1) resection requires sacrifice of major portal structures, or major portal structures and hepatic veins, or (2) metastases are scattered within the lobe and cannot be fully encompassed with a nonanatomic or segmental resection.

Incision and Exposure

An upper midline incision usually suffices for exposure in this operation. Furthermore, the dissection of the left hepatic vein is facilitated by having this incision over a Chevron or a right subcostal, since the retraction on the midline incision comes closer to the suprahepatic IVC.

Mobilization and Assessment of Resectability

The round ligament is transected usually leaving an extra 4–5 cm of free length to hang from the left lobe. The falciform ligament is divided all the way down until visualization of the suprahepatic IVC. As with right lobectomy, the preference is to control the portal pedicle before mobilization.

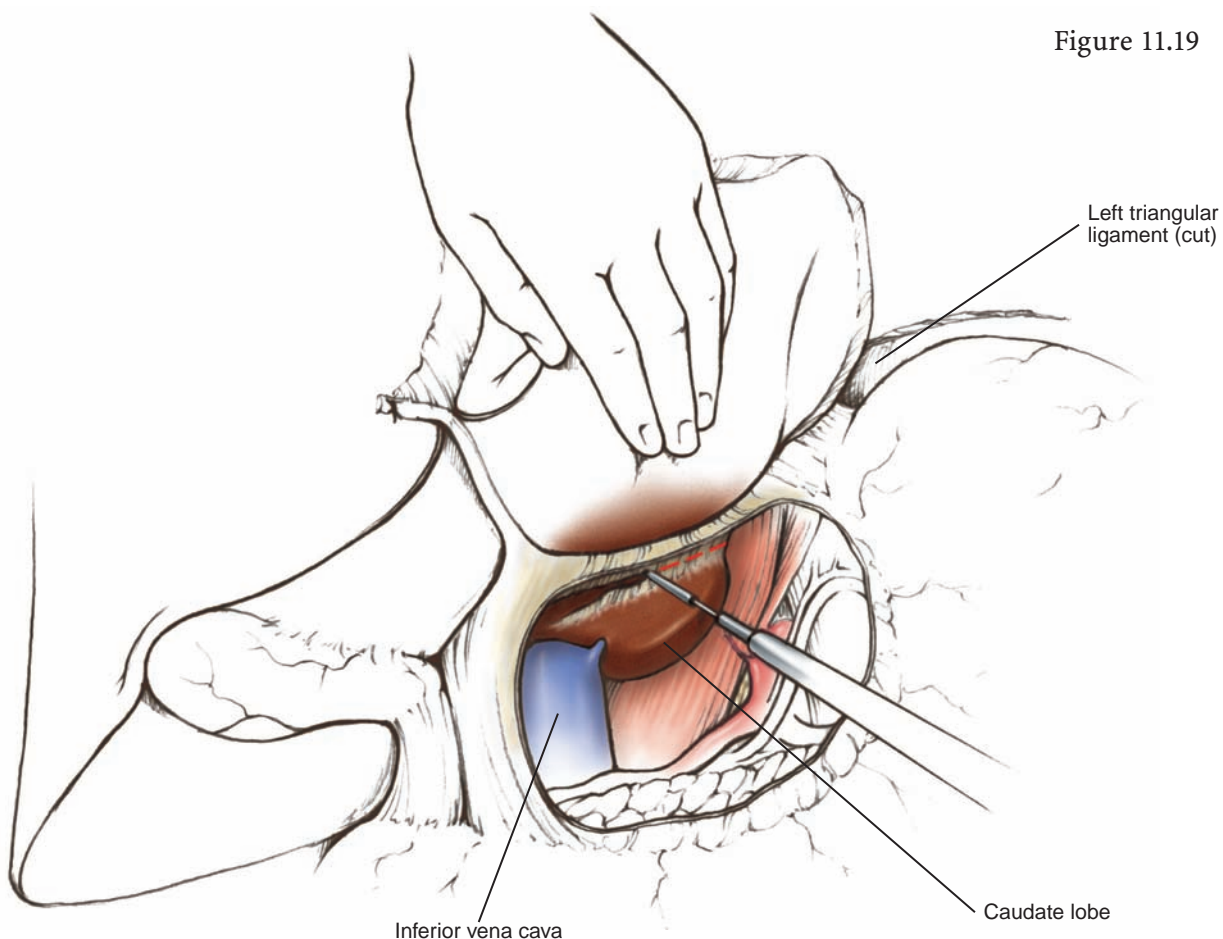


Figure 11.19

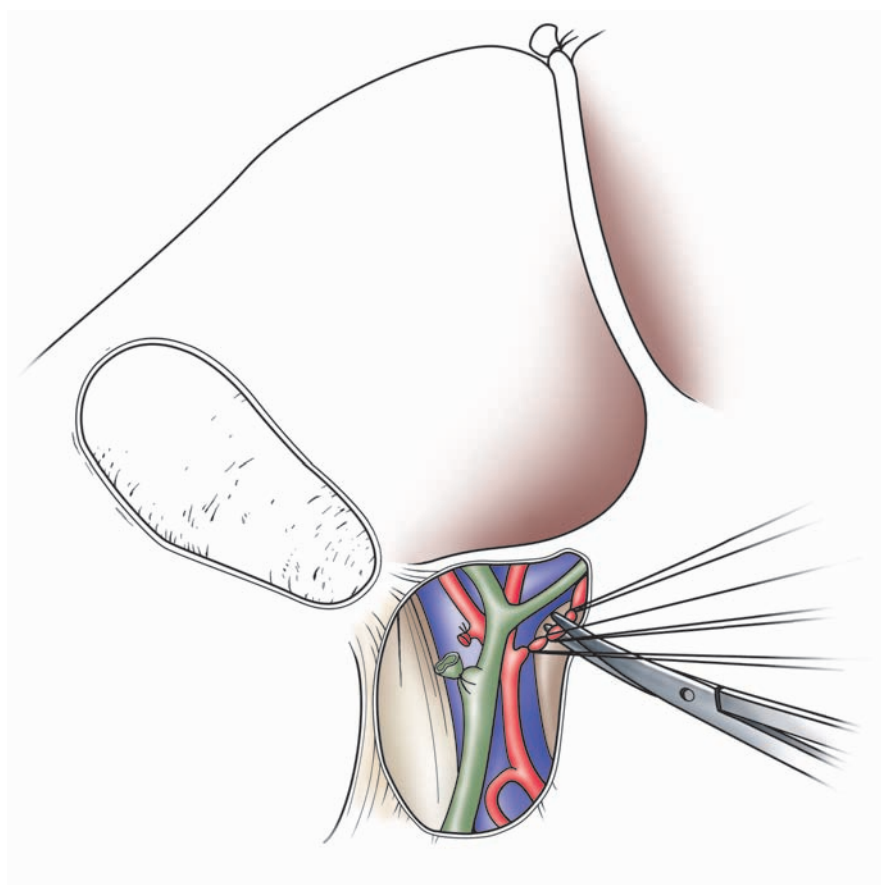
Hilar Dissection

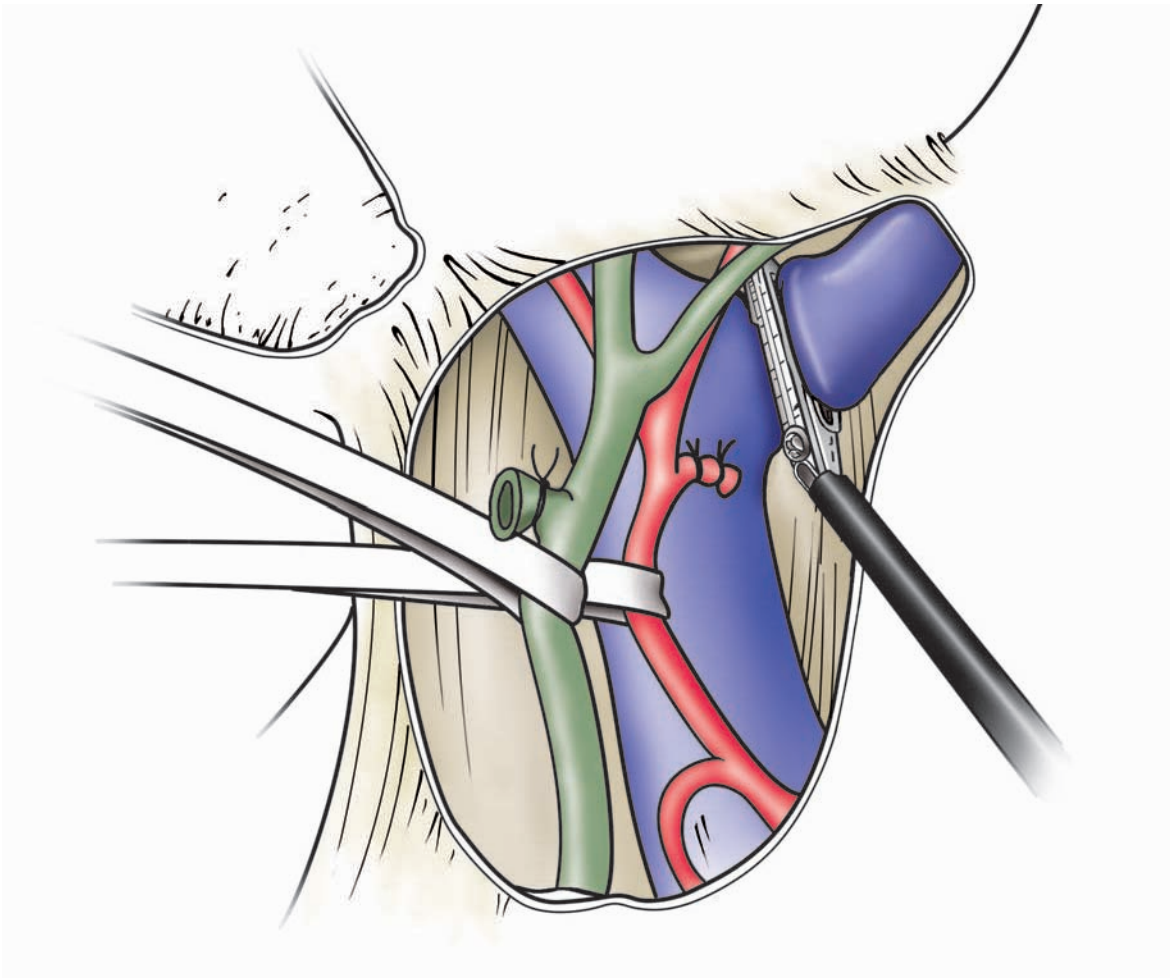
The gallbladder is excised as described above. Usually an additional retraction over the base of segment IV of the liver facilitates the exposure of the left portal pedicle. It is the authors' practice to go to the base of the umbilical fissure to find the hepatic artery; the hepatic duct is partially embedded by the hilar plate and is not readily visible in that area. Once the anterior leaf of the peritoneal covering is opened with electrocautery, the artery is identified and tied off with 2-0 silk and transected. By medially opening some of the hilar plate, and also coming laterally, the left portal vein is identified. From this view, there is a minor doubt that this is indeed the left portal vein as its horizontal course and the anatomical location confirms its presence. Care must be taken to preserve the caudate branch, which is constant from the left portal vein, to assure viability of the caudate lobe. Once encircled, an endovascular stapler is fired across. This could be somewhat tricky as the space does not allow an easy access for the thin jaw of the stapler. The left hepatic duct is controlled within the parenchyma on the latest stages of parenchymal transection. In the presence of a replaced hepatic artery, this is easily visualized in the gastrohepatic ligament and transected.

Venous Dissection

With the operating surgeon exerting gentle posterior and anterior traction on the left lobe, the left triangular and the commonly fused left coronary ligaments are

Figure 11.20





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divided medially to the level of the suprahepatic IVC. If the diaphragm is adherent to the liver in the vicinity of the tumor, it should be resected en bloc with the left lobe. As the dissection approaches the IVC, care should be taken to prevent injury to the phrenic vein, particularly as it empties into the left hepatic vein.

Division of the peritoneum over the suprahepatic IVC is completed and the left and middle hepatic veins are identified. No mobilization of the right lobe is necessary. The groove in between the left and the middle hepatic veins is developed anteriorly and, by elevating the left lateral section, this dissection should be continued posteriorly until complete encirclement; sometimes taking the ligamentum venosum facilitates the posterior dissection.

An endovascular stapler is then fired across the left hepatic vein. As with the left portal pedicle, sometimes it is impossible to negotiate the space to accommodate the stapler and so it is the practice of the authors' to tie off the left hepatic vein with a heavy suture and plan to take it with staplers from the inside of the parenchyma.

Parenchymal Transection

The gastrohepatic ligament is opened in its entirety. After complete control of the left portal pedicle, there will be an ischemic demarcation on the left lobe over Cantlie's

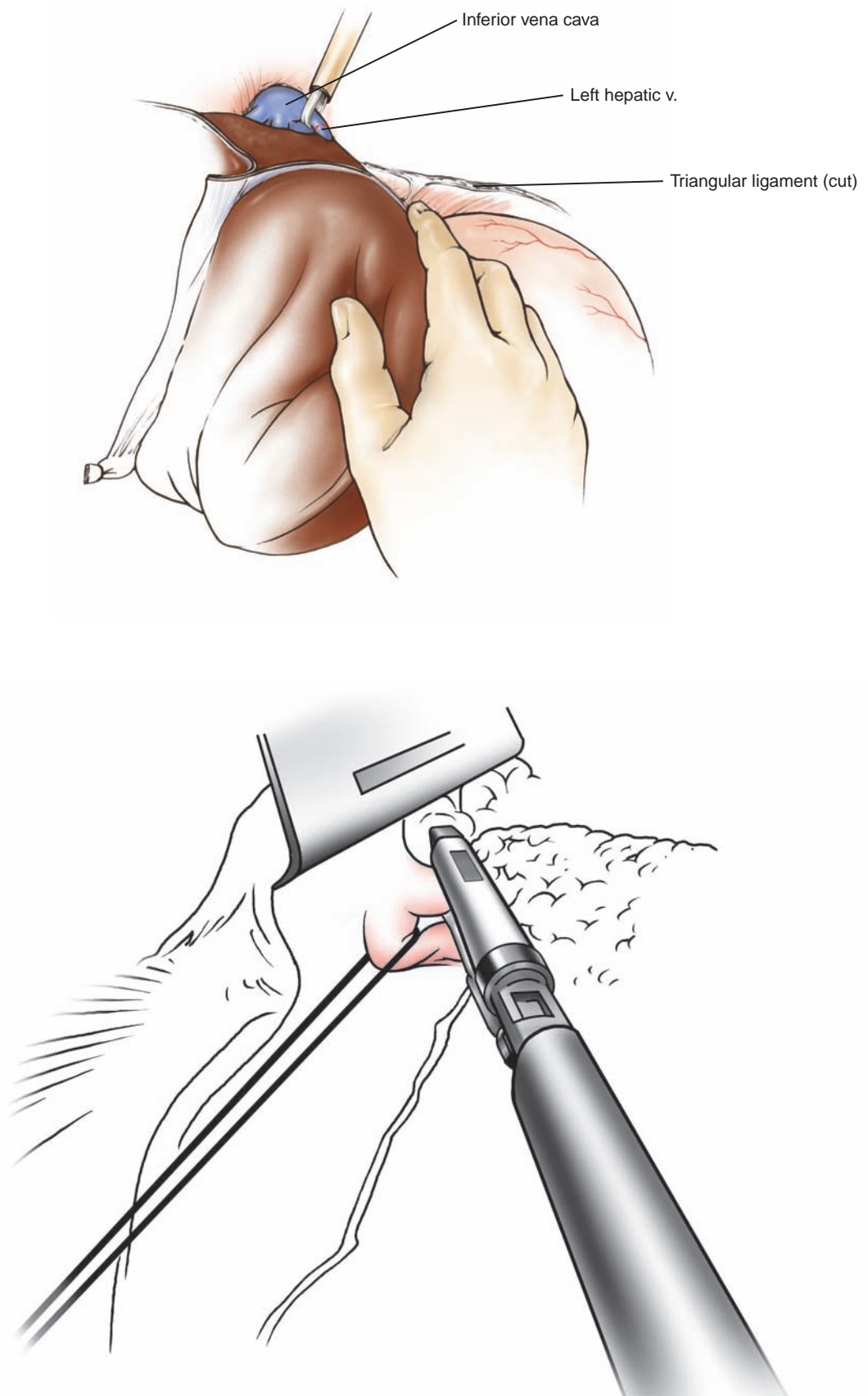


Figure 11.2

line. Preservation of the middle hepatic vein is aimed and this purpose is achieved by staying a centimeter to the left of this line. The parenchymal transection follows the same principles enunciated on the Right Hepatectomy technique, including the use of vascular inflow occlusion when indicated and the use of the same devices. The additional precaution here is to have complete visualization of the middle hepatic vein since it joins the left to form the common trunk. Forceful traction of the left lobe could tear the middle hepatic vein ensuing significant bleeding which is tedious to control. When oncologically indicated, the middle hepatic vein should be resected, since communicating branches with the right hepatic vein will drain the entire right lobe.

Extended Right Hepatectomy involves the removal of liver segments IV, V, VI, VII, and VIII. The major indications are lesion(s) within the right lobe and segment IV where (1) resection requires sacrifice of the major right portal structures, or major portal structures and hepatic veins, or (2) metastases are scattered within the right lobe and segment IV, and cannot be fully encompassed in with a nonanatomic or segmental resection. The Extended Right Hepatectomy (sometimes called Trisegmentectomy) involves removal of about 75% of the liver parenchyma and should be reserved for patients with normal livers and excellent overall liver function. Over time, the parenchymal mass will be reconstituted by hepatocytes in the remaining segments II and III.

Resection of Right Hepatic Lobe Plus Medial Segment (IV) of Left Lobe (Extended Right Hepatectomy)

Incision and Exposure

Incision and exposure are as described for right hepatic lobectomy.

Mobilization and Assessment of Resectability

The liver is mobilized and assessed as described for right hepatic lobectomy.

Hilar Dissection

The portal dissection in extended right hepatectomy is started in the same way as in a right hepatectomy. For these cases, it is usual to keep traction on the round ligament as the plane of dissection/transection lies to the right of the umbilical fissura (meaning into segment IV). With upward traction, the peritoneal covering leaf on the right of the umbilical fissura is opened to find the pedicles entering segment IV. Any tubular structure going into segment IV, especially on the anterior plane needs to be transected (ultrasonic shears, sutures or clips). Care must be taken when coming posteriorly to avoid injury of the left hepatic duct. Lowering the hilar plate over this area aids with the identification of the duct and preservation. The pedicles usually enter the left medial section separately, one for segment IV-B (anterior) and one for segment IVA (posterior); occasionally, they enter together and then divide into the liver substance. The latter distribution facilitates the dissection over the umbilical fissura. At all times, the surgeon needs to be alert that the portal pedicles entering the left lateral section are preserved.

Venous Dissection

Venous dissection in left hepatic lobectomy is similar to that in right hepatic lobectomy, where the right hepatic vein is transected. In this case, the middle hepatic vein should also be transected. However, due to its position in the middle of the liver substance, extrahepatic control is not usually feasible. The authors prefer to use a low CVP and undergo the parenchymal transection to take the middle hepatic vein at the end of the transection within the liver substance. This is a very risky area since inadvertent injury to the left hepatic vein leads to acute liver congestion and death.

Parenchymal Transection

The parenchyma is transected 0.5–1.0 cm to the right of the falciform ligament with the device(s) of choice. Transection is begun by dividing the tissue bridge joining the left lateral section to segment IV at the lower end of the umbilical fissure. With this divided bridge, it is possible to identify and divide the vessels passing to segment IV in the umbilical fissure. Since all the portal pedicles of the liver can be controlled before transection as explained above, vascular inflow occlusion is normally avoided.

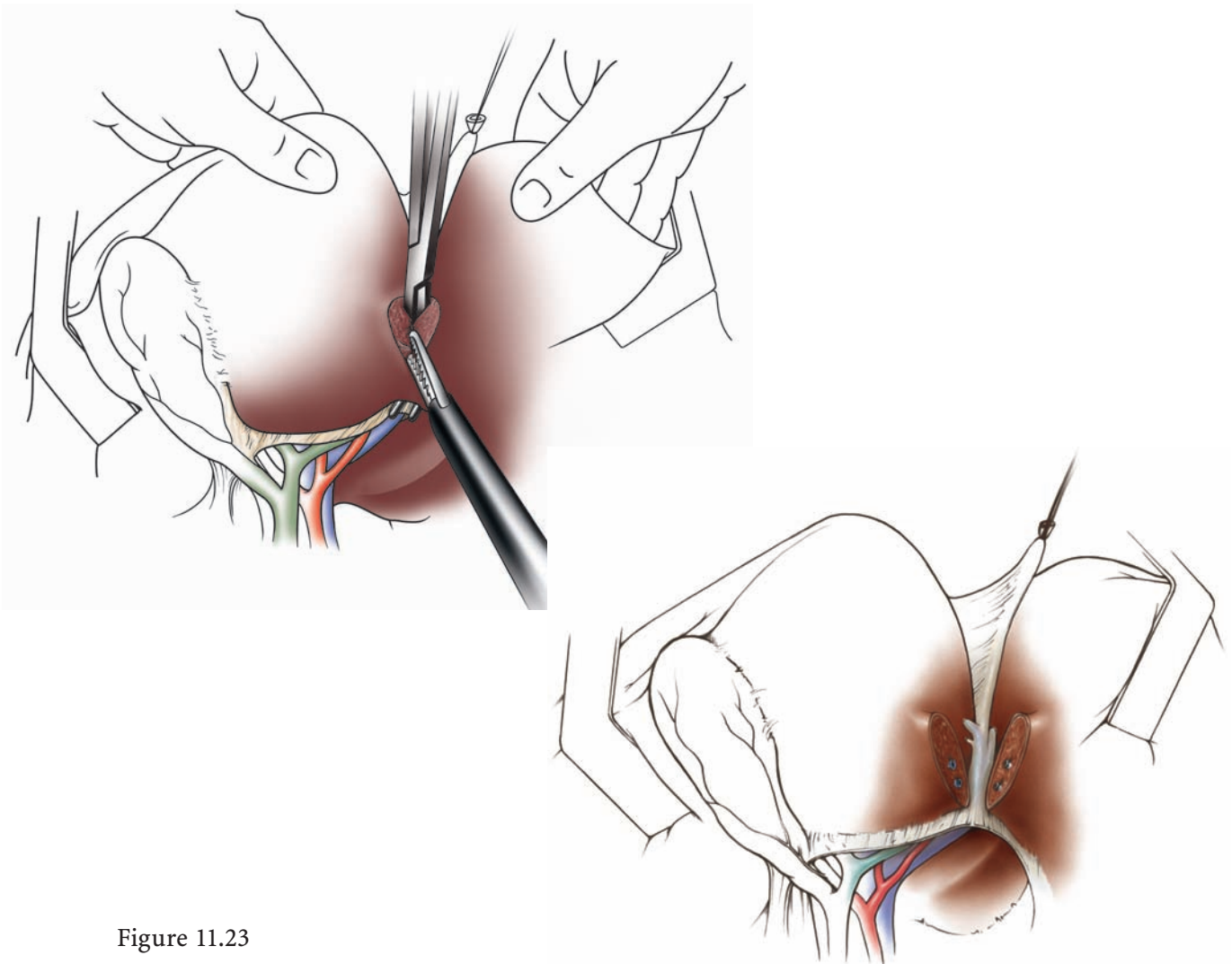


Figure 11.23

This is a mirror image of the extended right hepatectomy; mobilization and exposure, hilar dissection and hepatic vein dissection follow the one described for left hepatectomy. On the same token, the middle hepatic vein is taken with the specimen, but its transection is left for the latest stages of parenchymal transection.

The main difference lies in the dissection of the right anterior pedicle. To get to it, lowering of the hilar plate is very helpful. There are basically three ways of controlling this pedicle:

1. In extrahepatic approach, after the hilar plate dissection, and after taking the cystic artery and duct, the gallbladder is used for anterior traction. On that position, the bifurcation of the right hepatic artery is dissected and after isolation, and clamping of the anterior branch, the pulsation on the *Incissura Dextrus of Gans* is evaluated. If present, the right posterior branch is patent and the anterior branch should be ligated and transected. Throughout the division of the artery, it is possible to see the anterior branch of the right portal vein. After dissection and clamping, ischemic demarcation sparing the surface of the right posterior section is indicative of proceeding with transection of the dissected portal branch. As always, the hepatic duct is left to the late stages of the liver transection to avoid injury of actual right hepatic duct.
2. In Glissonian approach (see above), the liver is incised horizontally immediately above the right side of the hilum, and longitudinally above the *Incissura*. By passing a vascular renal clamp around the right anterior pedicle, the traction is secured for subsequent placement of the stapler.
3. With vascular inflow occlusion on, the parenchymal transection is started to the right of the gallbladder and the right anterior pedicle is found inside the liver and then, it is controlled directly.

Incision and Exposure

For these patients, the incision is generally a right subcostal one. If the patient has a wide costal angle, an upper midline incision could also be used.

Mobilization and Assessment of Resectability

The liver need not be mobilized for this technique. This operation is very useful in patients with large tumors in the middle of the liver (right anterior section and left medial section), in whom the liver function is impaired, or when the surgeon is concerned about postoperative liver insufficiency.

Hilar Dissection

For personal preference, the cystic artery and the duct are transected and the gallbladder is left in situ. Then the stump of the round ligament is tented anteriorly and the dissection is started to the right of the umbilical fissura. After uncovering the

Resection of Left Hepatic Lobe Plus Anterior Segment (V–VIII) of Right Lobe (Extended Left Hepatectomy)

Central Hepatectomy (Excision of Segments IV, V, VIII or Left Medial Plus Right Anterior Sectionectomies)

peritoneal layers, the portal pedicles for segment IV are taken. Then the dissection is continued to the right of the patient by lowering the hilar plate all the way into the medial margin of the gallbladder fossa. By applying anterior traction to the gallbladder, the anterior branches of the right portal pedicle should be isolated and transected separately. After, this, the central portion shows ischemic demarcation.

Venous Dissection

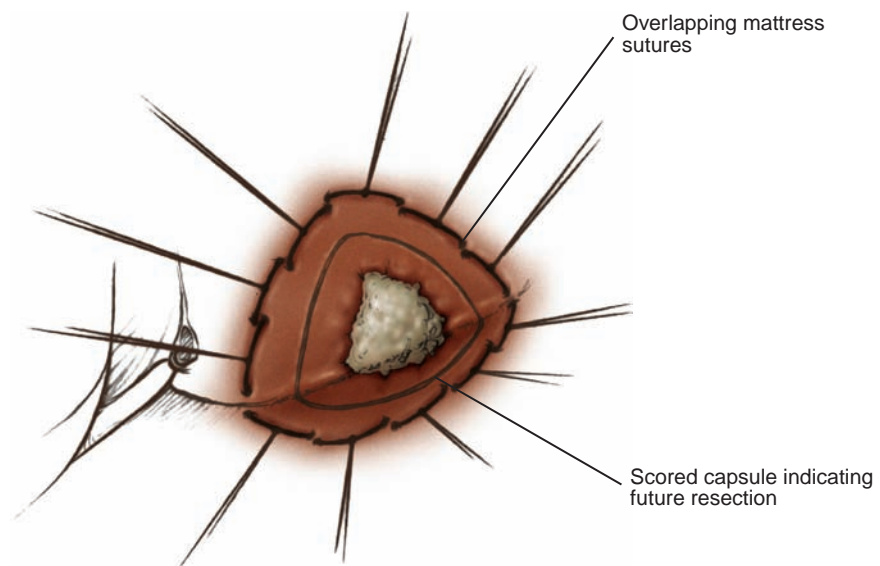
The only vein to be resected is the middle hepatic vein whereas the right and left ones are preserved. Following the same thought process, a low CVP is used for the inability of extrahepatic control of the middle hepatic vein. This is taken after the completion of the first line of transection.

Parenchymal Transection

Usually, it is easy to start the transection on the right of the umbilical fissura since it is more anterior and the amount of liver to transect is thinner and is closer to the midline. The risk here is to control the communicating branches between the left and the middle hepatic vein. The surgeon should use ultrasound liberally to identify the middle hepatic vein and stay away from the common trunk.

Once the middle hepatic vein is identified, a vascular stapler is fired and the area of the first transection is packed with sponges, and then the other line of transection is started according to the ischemic demarcation line. The chances of needing vascular inflow occlusion here are higher, although technically, the bleeding potentially comes from the hepatic veins where the Pringle maneuver has no utility whatsoever.

Figure 11.24



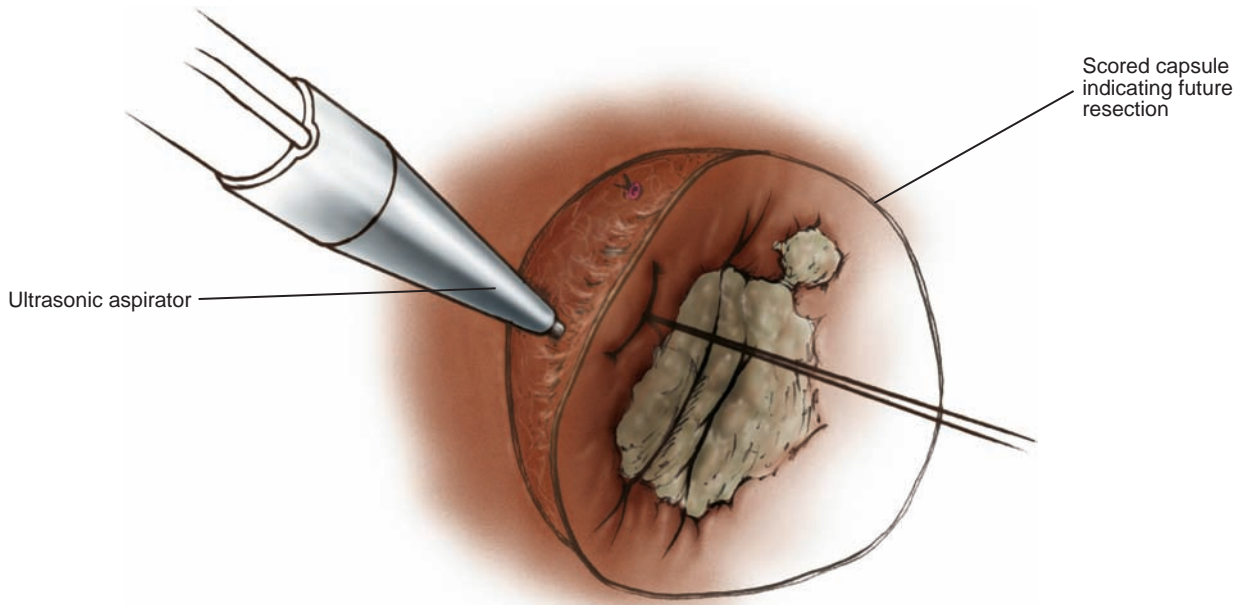


Figure 11.25

1. Left Lateral Sectionectomy (Segments II–III)

An upper midline incision usually suffices for this operation, although this is a perfect indication for a laparoscopic approach (see below). It is important to have an anterior traction from the round ligament because it “shows” the area to the left of the umbilical fissura from where the dissection should start. If there is a bridge of hepatic tissue between the left lateral section and segment IV, this is transected before the vascular dissection. By opening the peritoneal leaf, vasculobiliary structures are seen and then they are individualized and ligated or transected with the ultrasonic shears. Then the mobilization of the left lobe of the liver is continued up to the IVC and usually it is not necessary to control the left hepatic vein. Due to its proximity to the midline and anterior position, the manual control of the bleeding is more feasible and that way, the operative field remains dry. At the end of the liver transection, the left hepatic vein (or its more proximal branch) is taken with staplers.

Isolated Resection of Each Section of the Liver

2. Left Medial Sectionectomy (Segment IV, A–B).

An upper midline incision is used. Again, anterior traction of the round ligament is important to gain access to the portal pedicles to the right of the umbilical fissure. For this operation, two lines of parenchymal transection, one to the right of the falciform ligament and another one just to the right of Cantlie’s line, are needed. Usually no major hepatic vein is taken in this situation but bleeding can come from communicating branches between the left and the middle hepatic vein.

3. Right Anterior Sectionectomy (Segments V, VIII).

A right subcostal incision is used in this operation. The vascular inflow consists of the right anterior portal pedicle whose control was described under Extended Left Hepatectomy. Here also, there are two lines of transection; one just to the right of

Cantlie's line and the other in between the lateral margin of the gallbladder fossa and the *Incissura Dextrus of Gans*, according to the demarcation line. The authors' preference is to start more anteriorly where the surgeon has more control of the situation (Cantlie's line). Usually no major hepatic vein is transected here, but significant bleeding can ensue from the communicating branches between the middle and the right hepatic veins.

4. Right Posterior Sectionectomy (Segments V, VI).

A right subcostal incision is used. The control of the vascular inflow can be achieved by extrahepatic dissection of the right portal vein and further dissection into the bifurcation; the posterior branch is the most lateral. Also, the Glissonian approach is very useful here since the right posterior pedicle could actually be seen in the *Incissura Dextrus of Gans*. Longitudinal parenchymal incisions above and below this cleft and judicious use of a vascular renal clamp to encircle this pedicle greatly facilitates the vascular inflow control. Mobilization of the liver follows the one described for the right hepatectomy; here, IVC branches also need control, especially in the presence of a right inferior hepatic vein. Extrahepatic control of the right hepatic vein is seldom necessary.

Isolated Resection of Each Segment of the Liver

1. Caudate Lobe Excision (Segment I).

This is probably the most difficult hepatic resection because of, the inconsistency of anatomical findings, the difficulty of manipulation, many delicate branches draining directly into the IVC, and the position hidden under the left lobe of the liver. Moreover, there is no anatomical boundary between the caudate process (the most lateral division of the caudate lobe) and segment VII of the liver. An upper midline incision is used. Next, the gastrohepatic ligament is open from the main portal vein to the left hepatic vein; the ligamentum venosum is transected proximally over the left portal vein and distally over the left hepatic vein. By pushing the caudate lobe superiorly and posteriorly, the caudate portal pedicle usually becomes apparent from the left-sided corresponding structures. This is the vascular inflow control of the caudate lobe. Sometimes, a figure-of-eight stitch over the anterior surface of the caudate lobe aids in the anterior traction to gain access to the posterior surface of this lobe. Once two or three veins are controlled (clips, ligatures or ultrasonic shears) and transected, the thumb could be slid underneath the caudate lobe to continue the separation from the IVC. This maneuver is continued along the free border of the caudate lobe and the actual transection from the right lobe is left for last. However, at that point, since the inflow and the outflow are already controlled and the caudate lobe is manipulated by the surgeon's left hand, the transection is relatively bloodless and the hemostasis is readily secured. Some surgeons actually resect the left lobe en bloc with the caudate lobe to gain access to the medial border at the late stage of the liver transection; the latter strategy has no justification.

2. Other Segments

Since each segment of the liver has its own portal irrigation and venous drainage, technically any segment of the liver could be resected in an isolated fashion. In reality, this is not practical (unless we are dealing with peripheral segments) and such

resection involves at least a sectionectomy. Intraoperative ultrasound could be used to determine the intrahepatic portal inflow into each segment; furthermore, ink injection into the vascular inflow of a specific segment will stain the periphery of the corresponding surface of the liver, defining the extent of resection. Although well conceived, this strategy lacks practicality and it is not used often in surgical practice.

The laparoscopic approach has evolved significantly over the latter years. At the beginning, just wedge resections and biopsies of the liver were performed laparoscopically. Then, left lateral sectionectomy was added to the laparoscopic armamentarium; the main advantage was that the anatomical landmarks were clearly delineated and it was still a peripheral resection and the amount of liver parenchyma to be transected was not very thick. By reading the subheading on left lateral sectionectomy, the reader will understand why this operation was the first one to be widely accepted as the ideal for a laparoscopic approach. Within these order of ideas, surgeons considered the possibility of tackling the counterpart of the left lateral sectionectomy in the liver; the right posterior sectionectomy. This accomplished the same criteria of the previous one, but the amount of hepatic parenchyma to be transected was significantly thicker.

We are living in an era where we are basically extending all the applications of the open approach to a laparoscopic one. The authors perform all their right and left hepatectomies laparoscopically, and the sectionectomies mentioned, are basically routine procedures in their practice. The laparoscopic right hepatectomy follows the same principle of the open counterpart. In these cases, the authors' always start with the hilar dissection (same as open), then mobilize the liver and then do venous dissection. The intermediate step is interesting in the sense that once the liver is mobilized, dissection is proceeded to the anterior surface of the IVC, a dissection that is much better visualized in the laparoscopic approach. After that, the IVC ligament is undertaken and finally, the right hepatic vein. Advantages that the authors' have seen are, ease of identification of all the structures, particularly their branching, availability of deep dissection in the hilum, absence of twisting of the liver and decrease in operative bleeding by the increased abdominal pressure of the pneumoperitoneum. As practice evolves, the extended right hepatectomy fits well within the confines of this minimally invasive therapy and also the living donation for right hepatectomy and left lateral sectionectomy.

Contraindications for laparoscopic resection of the liver include increased amount of peritoneal adhesions, tumors located very close to the main hepatic veins/IVC, tumors located very close to the main ductal confluence, especially if considering excision of one of the two lobes of the liver.

Laparoscopic approach

Anatomic Basis of Complications

- The most serious and life-threatening intraoperative complication of liver resection is intraoperative bleeding, especially from previously undissected hepatic veins. These veins can be damaged during their dissection or by excessive

torquing of the liver during mobilization (less common). Inadvertent injury to the hepatic veins can occur during the transection leading to air embolism; this condition is less frequently seen during laparoscopy since the CO₂ used dissolves readily in the bloodstream with less hemodynamic disturbances. Some degree of Trendelenburg position helps to reduce the incidence of embolism; if it happens, rapid insertion of transesophageal echocardiogram and arterial blood gases evaluation help to make the diagnosis.

- Postoperative complications of liver resection can be broken down into the phases of the operation. Diaphragmatic injury and paresis can result during the mobilization of the liver. Budd-Chiari syndrome can result from thrombosis of the hepatic veins secondary to operative injury during venous dissection (on attempts to control bleeding from the only remaining hepatic vein) or postoperatively (torsion of the left lobe in unfixed livers after right hepatectomy). Hepatic ischemia can develop from arterial or portal vein thrombosis due to injury during portal dissection. Biliary fistulas can arise from ductal damage during portal dissection or from inadequate ligation of ducts during parenchymal transection (this one is significantly less frequent and less lasting). Hepatic insufficiency can result from ischemia (inadequately prolonged vascular inflow occlusion) or inadequate hepatic reserve after extended hepatectomies, especially in the presence of diseased livers. Intra-abdominal infection and abscesses can develop like any other clean or clean-contaminated operation.

Biliary Tree and Gallbladder

Cancers arising within the biliary tree and gallbladder are relatively rare, with a yearly incidence in the United States of 3 to 4 per 100,000 persons. Due to differences in their presentation, clinical features, and biologic behavior, these malignancies may be conveniently separated into cholangiocarcinoma (biliary tree) and gallbladder carcinomas.

Cholangiocarcinoma is a disease of older persons (50–70 years), without proclivity for gender. Although cholangiocarcinoma can arise anywhere in the intrahepatic or extrahepatic biliary tree, most tumors arise in the perihilar region, particularly at the hepatic duct bifurcation. Cholangiocarcinomas that arise within the liver are the second most common primary hepatic malignancy after hepatocellular carcinoma. The development of cholangiocarcinoma is associated with preexisting diseases, including biliary cirrhosis, sclerosing cholangitis (often related to coexisting ulcerative colitis), choledochal cysts, and hepatolithiasis. Common features in these diseases include chronic inflammation and chronic exposure of the biliary tree to stagnant or infected bile. A radiologic evaluation for jaundice usually shows a dilated proximal biliary tree, irregularly strictured biliary segment, collapsed distal biliary tree, and normal pancreas. The finding of a mass related to the stricture is an exception rather than the rule.

The discussion of the management is going to focus on the extrahepatic bile duct malignancy limited to the hilar area (sometimes called Klatskin's tumors); distal tumors are treated by pancreaticoduodenectomy which is detailed in the chapter on Pancreas. Management of cholangiocarcinoma follows two principles: curative resection, when possible, and relief of biliary obstruction. At present, surgical intervention is the mainstay treatment for potentially curable disease. The recommended surgical procedure is the resection of the malignant stricture in the bile duct with en bloc excision of one of the lobes of the liver plus the caudate lobe, portal lymphadenectomy and biliary reconstruction. Current 5-year survival rates after curative surgery are 25–30%. The need for surgical palliation is less clear now, especially in the face of advanced percutaneous procedures; however, it should be considered in patients taken for surgical exploration, and those found to have unresectable disease. Lesions determined to be unresectable during the preoperative evaluation are managed with endoluminal stenting and drainage. Stents are placed via a percutaneous transhepatic approach for proximal (intrahepatic) biliary lesions and via endoscopic retrograde cholangiopancreatography (ERCP) for more distal lesions. Median survival after palliative interventions is 5–30 months, with no long-term survivors. The addition of adjuvant therapy to surgery has not resulted in improved survival and is currently not routinely recommended.

One of the most important advantages in the management of hilar cholangiocarcinomas was introduced by the addition of concomitant liver resection and caudate lobectomy. The liver resection is useful for the removal of all the lymphatic soft tissue and obviously, vascular structures corresponding to the side of the lesion. If the surgeon considers that the tumor grows in a radial way, it is also important to remove the hilar vessels involved in the tumor, and also the surrounding soft tissue. And by taking the main vessels, the surgeon is committed to remove the corresponding lobe. While considering that the ductal confluence is located to the right of the hepatic artery, it is intuitive to think that the right hepatic artery needs to be resected in several instances with an associated right hepatectomy. Moreover, by excising the right or the left lobe, the surgeon has intrahepatic access to the contralateral hepatic duct for reconstruction.

The caudate lobe plays a very important role here. If the tumor involves the ductal confluence and is also spreading longitudinally into the bile ducts, it is important to keep in mind that the caudate branch comes from the ductal confluence or from the left hepatic duct around that area and so by leaving the caudate lobe (and its hepatic duct), a resection would be incomplete and could lead to significant local recurrence (the hallmark of this disease); there are a series reporting such recurrence up to 20% when the caudate lobe was not included within the confines of the resection.

Carcinoma of the gallbladder is predominantly a disease of older women, although there are younger patients now. Review of the literature shows that at least 75% of the patients are women, with an average age of 69 years at presentation and a peak disease incidence after the age of 70. A few men who develop the disease are also older, with an average age of 67 years. The most common associated disease, implicated as a risk factor is cholelithiasis. Gallstones are found in 68–98% of the patients, and carcinoma is associated with larger stones. The majority of patients have symptoms,

including abdominal pain, nausea, vomiting, and weight loss. These symptoms can easily be mistaken for the symptoms of benign cholelithiasis. This mistaken identity is further perpetuated by the low diagnostic accuracy of ultrasonography and computed tomography (CT) in the absence of suspicion. These imaging studies enable the identification of cancer in fewer than 50% of the patients.

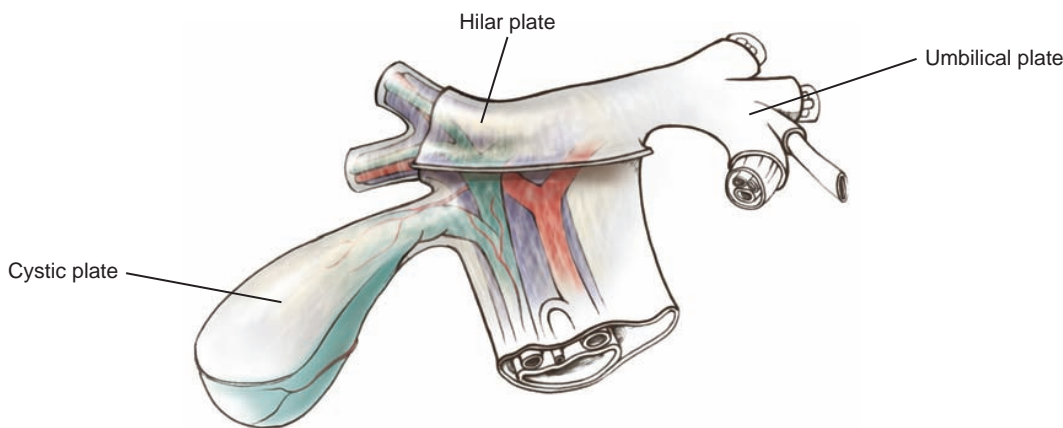
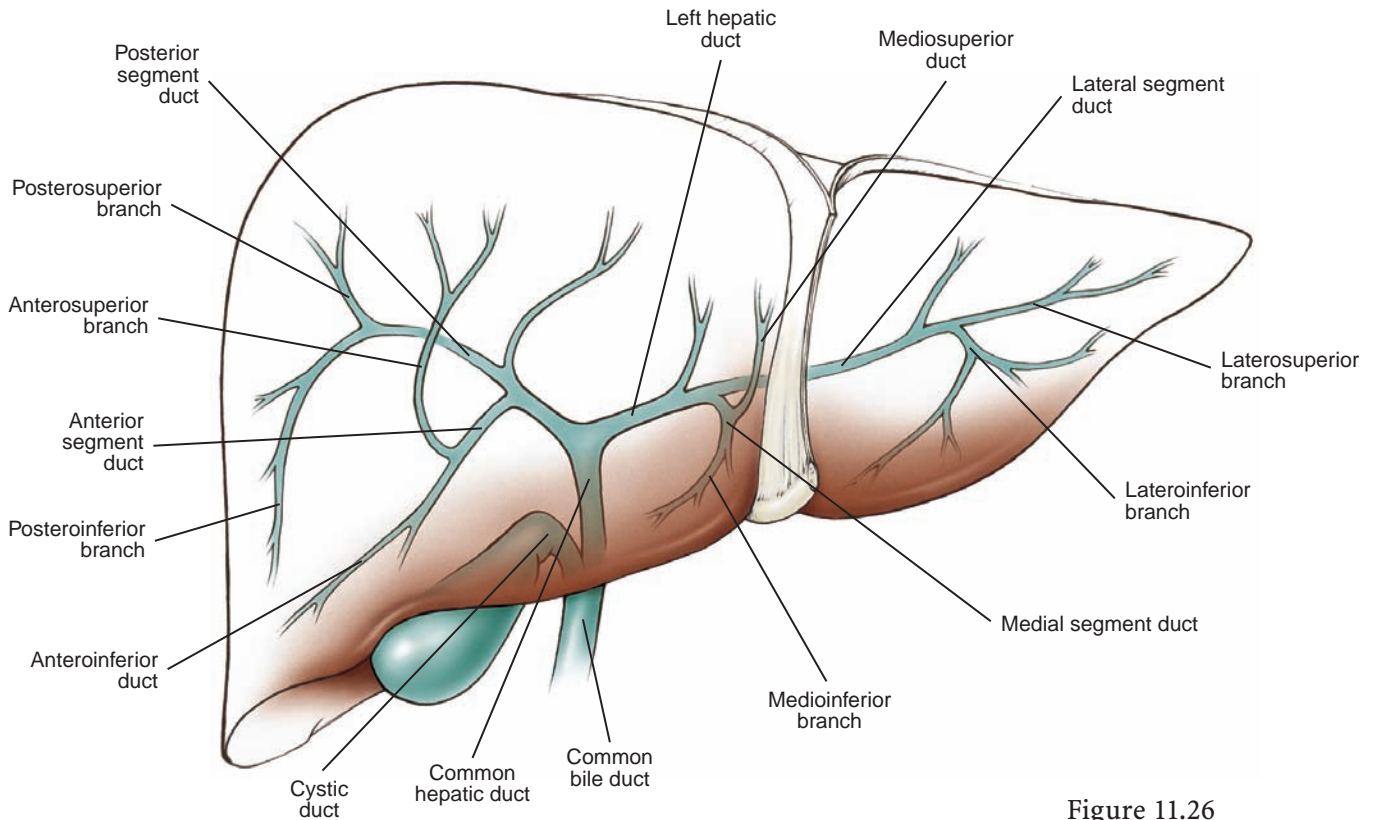
In patients with early disease, whose tumors are confined to the mucosa or invade superficially into the muscularis propria (T1), simple cholecystectomy is an adequate treatment, with a survival rate of 70–90%. Patients with, deep invasion into the muscularis, invasion into the serosa, or invasion breaching the serosa, should undergo resection of the gallbladder bed with a 3–4-cm margin (segments IV-B and V) and complete portal lymphadenectomy (an operation called radical cholecystectomy); 5-year survival rate in this group of patients is 25–40%. Transmural extension of the tumor into the liver calls for a more aggressive resection in good anesthetic candidates. In these cases, following the same principles of the hilar cholangiocarcinoma, an aggressive nodal/soft tissue resection can be achieved with en bloc extended right hepatectomy, sometimes including the extrahepatic bile duct (and obviously subsequent biliary reconstruction). Although an aggressive procedure, the well known lack of response to chemotherapy by these tumors calls for an aggressive locoregional excision. Therefore, the liver resection will address the liver invasion by the tumor and will allow for excision of the main vessels in the hilum of the liver.

Selection of the appropriate therapy in each clinical situation is based on the understanding of the biologic behavior of the primary tumor, familiarity with the indications and limitations of each therapeutic modality, and a thorough knowledge of hepatobiliary anatomy and its variations; obviously major resections should be limited to good performance candidates. This chapter reviews the surgical management of biliary tree and gallbladder malignancies from an anatomic orientation. Topics included, are the clinically relevant anatomy of the liver, biliary tree, and its accessory structures; the preoperative evaluation and patient selection in the management of biliary malignancies; the technical details of bile duct resections and radical cholecystectomy with portal lymphadenectomy; and an overview of potential complications.

Surgical Anatomy

Topography

The main extrahepatic biliary system begins as the right and left lobar ducts, which join to form the common hepatic duct. As the hepatic duct passes through the porta hepatis, it is joined by the cystic duct to form the common bile duct. The common bile duct passes through the lower porta and pancreatic head to empty into the duodenum. The main extrahepatic biliary system is joined by the accessory biliary structures, which consist of the gallbladder and its associated cystic duct.

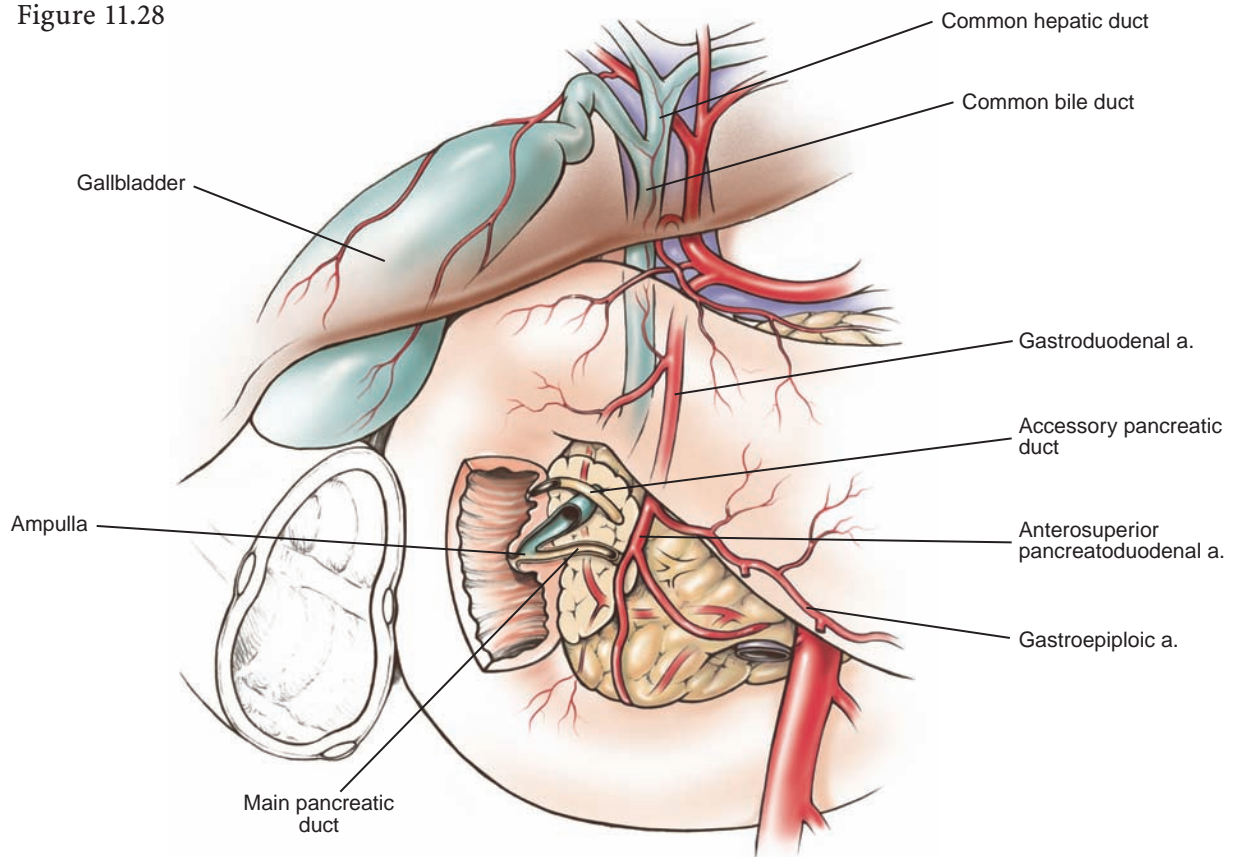


The common hepatic duct arises from the junction of the lobar ducts in the right half of the liver hilum, anterior to the portal venous bifurcation and overlying the right branch of the portal vein. The origin of the common hepatic duct is usually contained within a series of fibrous “plates,” the hepatic plates, which surround the portal structures. The plate system is formed at the level of the liver hilum by coalescence and thickening of the liver capsule and vasculobiliary sheaths. Dissection of the lobar ducts and the proximal common hepatic duct often requires division of these plates. The common hepatic duct runs downward and anterior to the portal

vein for approximately 3–4 cm before it is joined by the cystic duct; in few instances the cystic duct will join the common hepatic duct very distally, in the pancreatic portion of the bile duct. The common hepatic duct is usually in close association with the proper hepatic artery, which lies to its left. The right hepatic branch of the proper hepatic artery crosses either the common hepatic or the common bile duct. This crossing is usually posterior to the biliary structures (a fortunate situation for biliary reconstruction), although crossing of the artery anterior to the ducts occur in rare instances.

The common bile duct, considered to be the union of the cystic and common hepatic ducts, is more conveniently thought of as the continuation of the common hepatic duct. The duct, which is approximately 9 cm long, begins in the porta hepatis and descends in the free margin of the lesser omentum (supraduodenal portion). It continues behind the first portion of the duodenum (retroduodenal portion) and enters a groove in or behind the superior lateral part of the head of the pancreas (pancreatic portion). The duct then descends obliquely and to the right, to enter below the middle of the second portion of the duodenum on its posteromedial surface (intraduodenal portion). The intraduodenal portion of the duct is usually joined on its left side by the main pancreatic duct. Once united, the ducts form a reservoir within the duodenal wall, known as the ampulla of Vater. The distal constricted end of the ampulla opens into the duodenum on the summit of the major duodenal papilla.

Figure 11.28



Relations of major vascular structures to the common bile duct include the following:

1. The infrahepatic supraduodenal portion of the duct usually descends adjacent, and to the right of the hepatic artery. The artery often passes obliquely towards the midline, away from the duct, towards the distal end of this portion. The anterior surface of the portal vein is directly posterior or posteromedial to the supraduodenal portion of the duct.
2. The retroduodenal portion of the duct is situated to the lateral or the right side of the gastroduodenal artery and is anterior to the right edge of the portal vein.
3. The pancreatic portion of the duct is accompanied by the gastroduodenal artery, which at a variable distance along its course gives off superior pancreaticoduodenal branches, crossing the duct anteriorly and posteriorly. In addition, this portion of the duct is contained within a cage of vessels formed by the vasa recti of arcades from superior and inferior pancreaticoduodenal arteries. The significant venous relation of the pancreatic portion is the right edge of IVC, which is separated from the duct by a thin layer of connective tissue or pancreas. The duct has no relationship with the portal vein, which approaches it obliquely from below, and from the left.

The gallbladder is a thin-walled pear-shaped sac approximately 8–10 cm in length capable of holding 50 mL of bile. It lies in a fossa on the inferior surface of the liver along a line (Cantlie's line), dividing the right and left lobes. The gallbladder is usually surrounded on its inferior and lateral surfaces by loose connective tissue and peritoneum. Although the gallbladder is usually suspended from the gallbladder fossa, it may also be enveloped by parenchyma, so that only a portion of the inferior surface is visible. The fundus of the gallbladder is its large bulbous cap, which commonly protrudes, approximately 1 cm, beyond the liver margin. When the gallbladder is full, the fundus comes in contact with the anterior abdominal wall opposite the ninth costal cartilage in an angle formed between the right rectus muscle and the costal margin. The body is the main part of the gallbladder and lies within the gallbladder fossa. The superior surface of the body is usually in direct contact with the liver without intervening peritoneum. Small vessels and bile ducts can pass directly from the liver into the body through the fossa. The lateral and inferior surfaces, which are covered with peritoneum, are in close proximity to the second portion of the duodenum and the transverse colon, although there are no attachments with these structures in a vast majority of cases. The neck of the gallbladder, which results from tapering of the body, is folded into an S curve that terminates in the cystic duct. The neck is contained in the deepest part of the gallbladder fossa and lies in the uppermost free portion of the lesser omentum. The mucosa of the neck is ridged, forming the spiral valve (of Heister). Pathologic dilation of the gallbladder results in the formation of a bulge or pouch in the neck, called the infundibulum. The infundibulum may overhang and obscure the cystic or bile ducts. Division of the right edge of the lesser omentum and mobilization of the infundibulum from the duodenum and biliary structures are necessary to prevent misidentification and accidental injury of the cystic duct.

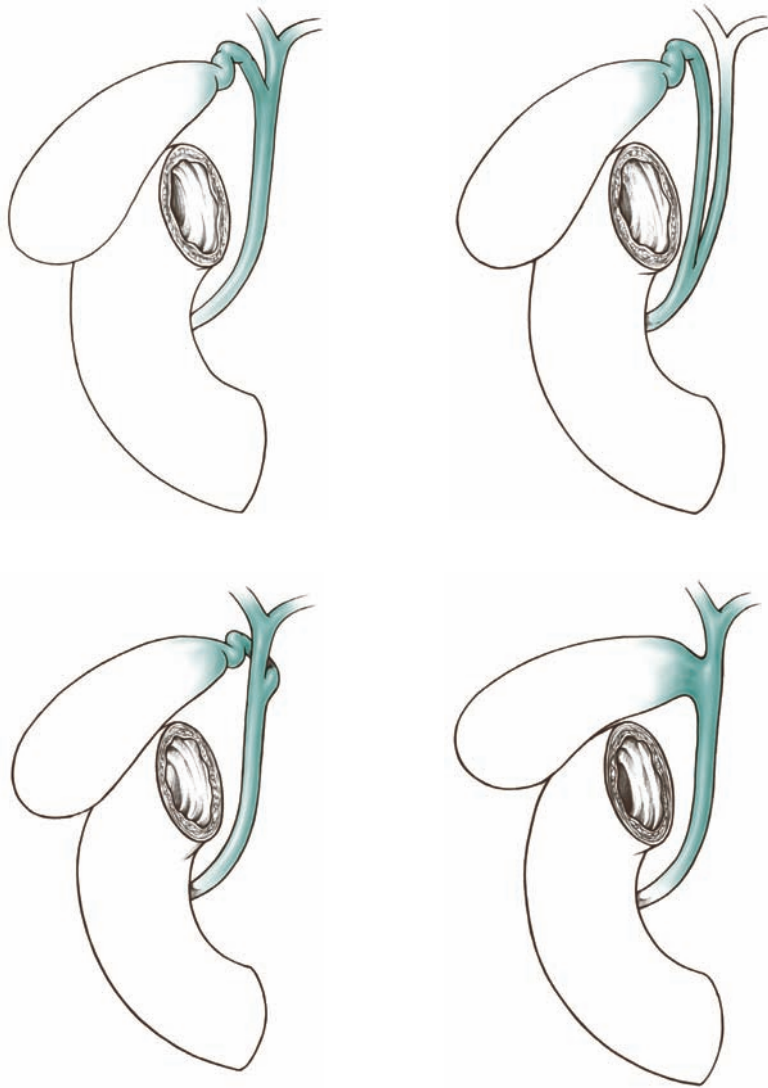


Figure 11.29

The cystic duct is approximately 4 cm long and extends from the gallbladder neck to the porta hepatis, where it runs beside, then joins the common hepatic duct to form the common bile duct. Although the cystic duct is relatively long, it is usually folded on itself so that its union with the common hepatic duct is close to the neck of the gallbladder. The tortuosity of the duct is attributable to the spiral valves, which continue into the cystic duct from the gallbladder neck. The anatomy described is the usual arrangement, but variations of the cystic duct are common and should be kept under consideration.

Blood Supply

Of all the porta hepatis components, the hepatic arterial blood supply is the most variable, with ten different vascular patterns identified. Typically, the proper hepatic artery divides into the main right and left lobar branches within the porta hepatis and outside the liver parenchyma. Usually the proper hepatic artery branches lower in the porta hepatis than does the bile duct or the portal vein. A middle hepatic branch usually arises from the proximal left hepatic artery. (See the Hepatic Artery Variations classification system early in the liver portion of this chapter.)

Figure 11.30

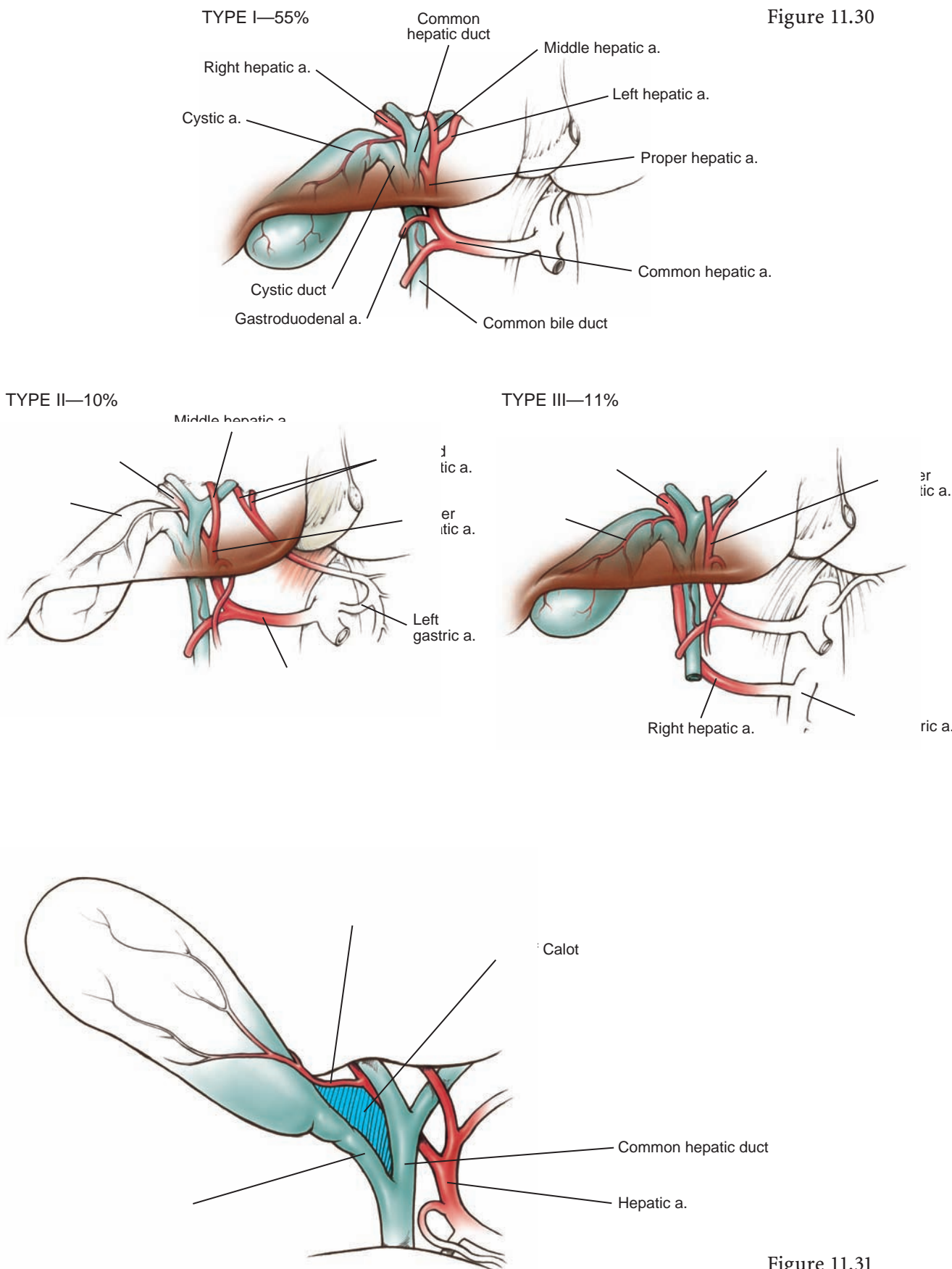
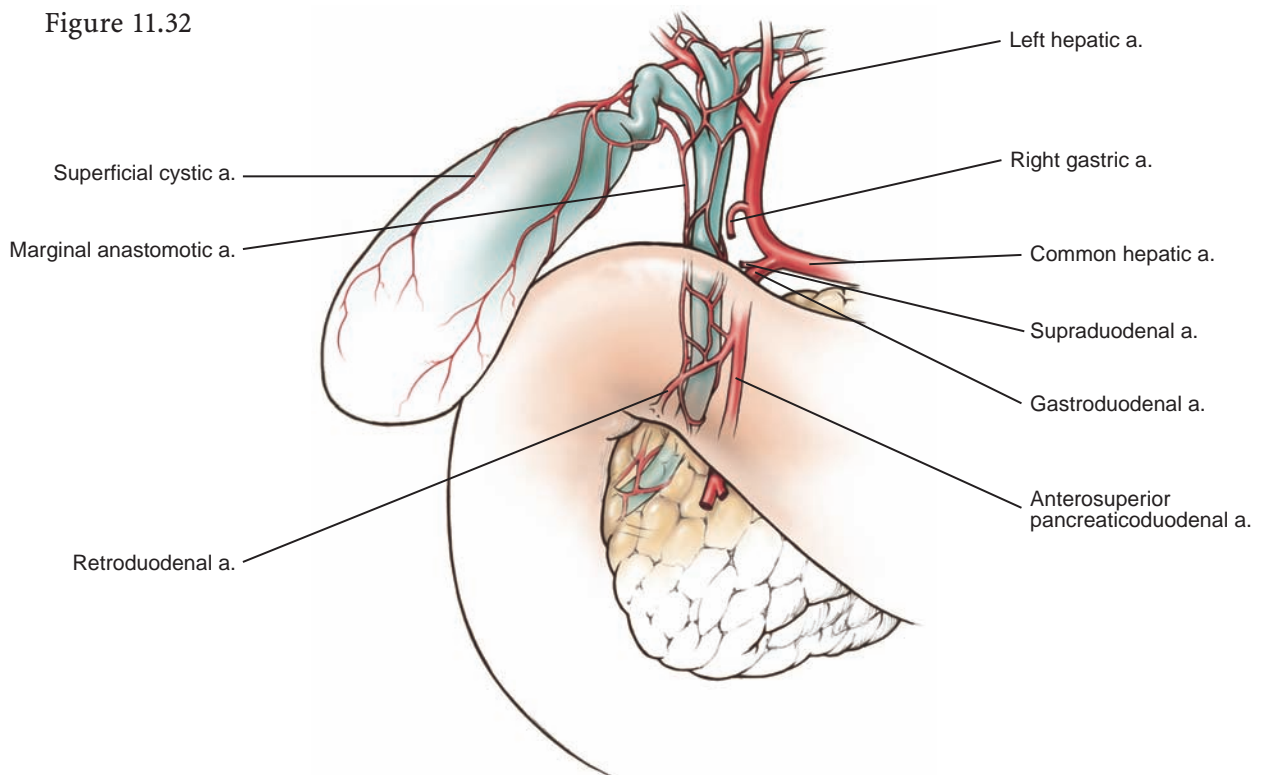


Figure 11.31

The cystic artery supplies the gallbladder and is one of the most anomalous structures in the body. In the most common anatomic variant, found in 60% of the patients, the cystic artery arises as a branch of the right hepatic artery. In this arrangement, the cystic artery runs laterally through the porta hepatis, passing anteriorly to the common hepatic duct to supply the gallbladder. When this anatomic variant is present, the cystic triangle of Calot is formed. The superior base of this triangle is formed by the liver edge, the medial border by the common hepatic duct, and the inferolateral border by the cystic duct, the cystic artery being the dominant structure of this triangle. Important structures contained within Calot's triangle include the right hepatic artery, anomalous hepatic arteries, and bile ducts. Overall, 12 variants of cystic arterial anatomy have been described.

The blood supply of the bile duct deserves special emphasis. Despite an apparently rich arterial supply, segmental devascularization of the duct with resulting ischemia and stricture is a well-recognized and serious complication in hepatobiliary surgery. The blood supply of the bile duct is based on the division of the bile duct into hilar, supraduodenal, and retropancreatic segments. The blood supply to the supraduodenal duct is axial, with most of the vessels arising from the retroduodenal artery, the gastroduodenal artery, the right hepatic artery, the cystic artery, and the retroportal artery. On an average, eight 0.3-mm diameter arteries supply the supraduodenal duct. The most significant of these vessels run along the lateral borders of the duct at the 3- and 9 o'clock positions. Of the blood supply to the supraduodenal duct, 60% ascends



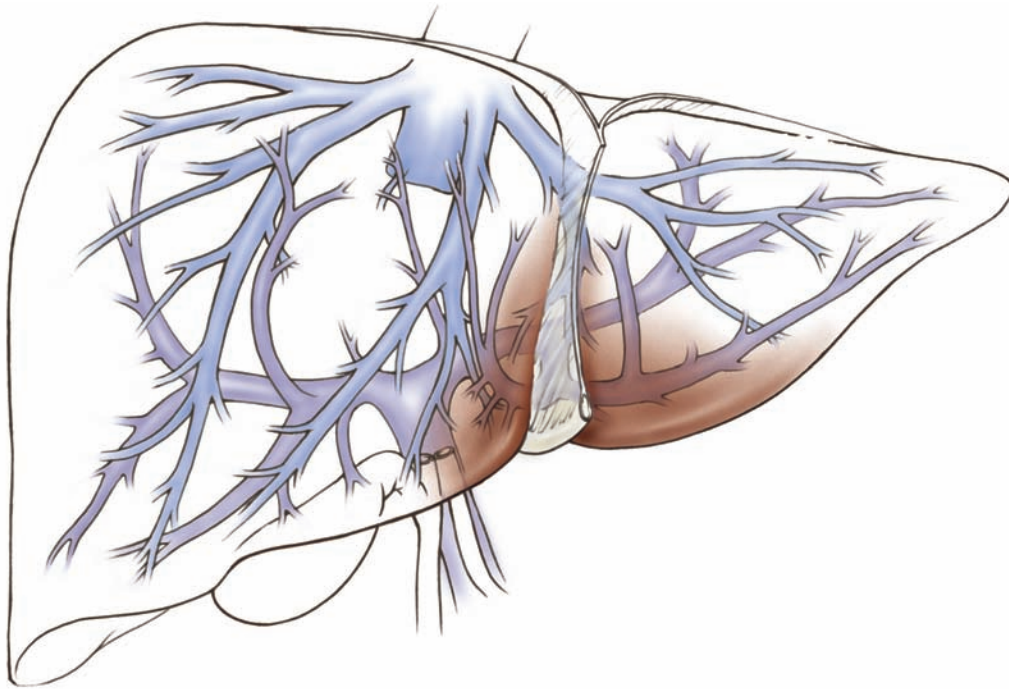


Figure 11.33

from the inferior vessels and 38% descends from the superior vessels; the additional 2% comes from the direct contribution of small proper hepatic artery branches. The hilar ducts receive a rich blood supply from the plexus of vessels in continuity with the plexus surrounding the supraduodenal duct.

The retropancreatic bile duct is supplied by a plexus of vessels derived from the retroduodenal artery.

The portal vein and its branches are the least variable components of the porta hepatis. The portal vein is the most posterior portal structure, situated beneath the bile ducts and the hepatic artery. Like the right hepatic duct, the main right portal vein is short and branches soon after it ascends into the parenchyma. The left main portal branch, like the left hepatic duct, is relatively long with a predictable horizontal course through the liver.

The venous drainage of the bile ducts and gallbladder is in the form of a continuous venous plexus. The veins draining the bile ducts accompany the small axial arteries and empty into larger veins along the lateral borders of the duct at the 3- and 9-o'clock positions. The venous drainage of the lower bile duct eventually enters the portal vein. Veins draining the gallbladder empty into this system, as well as into the liver parenchyma at the gallbladder fossa. The venous drainage of the gallbladder into the liver does not enter the portal circulation.

The lymphatic vessels of the gallbladder and the biliary tree drain medially into the vessels and nodes along the common hepatic and common bile ducts, as well as directly into the liver parenchyma at the gallbladder fossa.

Lymphatic Drainage

Surgical Applications

Preoperative Evaluation of Cholangiocarcinomas and Carcinoma of Gallbladder

Preoperative evaluation of cholangiocarcinoma or carcinoma of the gallbladder is complex, and multiple modalities are used to define tumor anatomy, locoregional vascular involvement, underlying liver function, histologic features (sometimes), and the presence of metastatic disease. While a great deal of nonoperative information can be obtained, many patients with cholangiocarcinoma have obstructive jaundice without a definable associated mass. This makes the successful preoperative histologic diagnosis of cholangiocarcinoma very difficult; moreover, the hilar cholangiocarcinoma creates a significant amount of desmoplasia that makes histologic interpretation very challenging even in the presence of appropriate tumor sampling. Therefore, the preoperative diagnosis of cholangiocarcinoma is made on the basis of clinical and radiographic findings. Liver function is critical in determining whether a patient with cholangiocarcinoma is a suitable candidate for surgical resection. A routine biochemical profile, which includes levels of total bilirubin, the hepatocellular enzymes, aspartate transaminase and alanine transaminase, and the ductal enzymes alkaline phosphatase and gamma-glutamyl transpeptidase, indicates biliary obstruction and identifies underlying hepatocellular damage, which may result from ongoing obstruction of the biliary tree. Serum albumin and prothrombin time are important measures of underlying hepatic function. Studies such as galactose elimination capacity, although not widely available, can serve to quantify hepatocellular reserve and are particularly important in patients who may require liver resection. Finally, marked elevation of the biochemical marker CA 19-9 correlates well with the presence of malignancy, although it can be elevated to a lesser degree in benign biliary obstruction. Probably, of the tests mentioned above, the bilirubin is the one that needs to dictate the timing of the operation. Patients with total bilirubin levels above 5–10 mg/dL have inherent hepatic dysfunction which could be life-threatening if a major hepatic resection is undertaken. For these patients, the protocol is to drain the future remnant of the liver (internal-external drainage) to achieve biliary decompression and improve liver function; therefore, a period of at least 2 weeks is necessary to wait for the return of the liver function. If the future remnant looks small (and that has to be defined by the surgeon based on volumetric and liver function analyses), embolization of the contralateral portal vein is a useful strategy to avoid postoperative liver dysfunction.

Transabdominal ultrasonography is important in the screening of suspected obstructive jaundice, but it is not useful in delineating the level and anatomic features of the obstruction. It can identify the presence of multiple hepatic metastases that would preclude surgical intervention. Endoscopic ultrasound is becoming more widely available and, as further experience is gained with this modality, it will become particularly useful in assessing the size and invasion of distal cholangiocarcinomas. Abdominal and pelvic CT is a good diagnostic method but fails to detail the anatomy of the bile ducts; usually CT is complemented with percutaneous transhepatic

cholangiography (PTC). In this regard, the authors prefer the MRI/MRCP as a study of choice in these patients; its diagnostic accuracy will be greatly enhanced if previous PTC is avoided. Apart from the definition of the anatomy and the vascular structures around the tumor, MRI provides a great deal of information regarding the presence of liver metastases, lymphadenopathy, and remote peritoneal metastases. Significant ascites should be aspirated and subjected to cytology evaluation to rule out malignancy. Malignant extraportal lymphadenopathy and malignant ascites are contraindications to a curative surgical intervention. The MRI scan is also particularly valuable in identifying tumor encasement of the portal vein and hepatic arteries, as well as ruling in the presence of portal hypertension by the demonstration of splenomegaly and significant intra-abdominal collateral venous development. Finally, MRI also identifies the presence of lobar atrophy from long-standing unilateral biliary obstruction or vascular encasement, which is important to define the limits of hepatic resection; obviously an atrophic lobe or a lobar vascular encasement defines the lobe that has to be resected. A routine chest x-ray film is important to rule out the occasional pulmonary metastases. Finally, any patient with significant bone pain should be examined with plain radiography of the painful area and bone scans as indicated. Occasionally, patients with skeletal metastasis from cholangiocarcinomas are seen.

Visualization of the obstructing cancer is within the realm of the endoscopist or interventional radiologist. ERCP can be used to define the level of the lesion, as well as to rule out other potentially obstructing cancers in the upper gastrointestinal tract. Endoscopic biliary stent placement can also be used to palliate obstructive jaundice. It is our experience, however, that ERCP is more valuable for middle to distal common bile duct lesions, and often does not define the level of involvement of proximal bile duct lesions. Endoscopic stenting of a proximal cholangiocarcinoma can also be technically challenging. For these reasons, PTC is the diagnostic study of choice when the obstruction is in the region of the hepatic duct bifurcation or more proximally in either the right or the left hepatic ducts. As mentioned before, the site of the PTC is chosen on the basis of the future remnant lobe of the liver (defined on the MRI evaluation), provided the patient needs biliary decompression. The lobe to be preserved is the lobe to be drained. PTC for diagnostic purposes is less frequently used. Because of the risk of cholangitis from instrumentation, the authors do not recommend pre-operative intubation of the biliary tree, again in the presence of normal or slightly elevated bilirubin.

Another important point about a good MRI is the definition of the arterial and portal anatomy; this has attained a level where visceral angiogram is no longer necessary. Even the presence of replaced right/left hepatic arteries is clearly seen on MRI. Furthermore, in doubtful cases, the surgeon should ask the radiologist for MRA which basically has the imaging quality of a visceral angiogram without being invasive. Minimal arterial encasement could be difficult to visualize on angiogram whereas the MRI gives the combined imaging of the liver, the tumor, the soft tissue and the surrounding vessels.

The role of diagnostic laparoscopy should be mentioned. Unlike the case of pancreatic carcinoma, laparoscopy is not performed prior to formal exploration,

because of the relatively low incidence of metastatic disease, which would preclude exploration. It is not clear whether the cost of routine laparoscopy to those patients with equivocal preoperative radiographic studies for metastatic disease is warranted.

Potential Contraindications to Surgical Resection

The extensive preoperative evaluation should determine those instances in which the tumor is not resectable, and obviate the need for surgical exploration. In the opinion of the authors, the following are the contraindications to surgical resection of suspected cholangiocarcinoma:

1. Significant comorbid medical conditions such as chronic obstructive pulmonary disease (COPD), coronary atherosclerotic heart disease, or morbid obesity.
2. Poor underlying liver function.
3. Malignant ascites.
4. Evidence of diffuse hepatic metastases.
5. Evidence of the bilateral presence of the tumor into the secondary or tertiary bile ducts.
6. Evidence of systemic metastases.
7. Atrophic hepatic lobe with the presence or the invasion of the tumor in the contralateral hepatic duct.
8. Involvement of lobar main vessels with the presence or the invasion of the tumors in the contralateral hepatic duct.
9. Encasement of the main portal vein and/or proper hepatic artery by the tumor.

Resection of Hilar Cholangiocarcinoma With Extended Right Hepatectomy (and Caudate Lobectomy)

Cholangiocarcinomas can develop from the very distal common bile duct as it courses through the head of the pancreas all the way into the hepatic duct bifurcation, with extension into the liver. Very distal cholangiocarcinomas often require pancreaticoduodenectomy (see Chapter 14). The technique for the resection of a lesion in the mid-common bile duct, or a lesion located more proximally at the level of the common hepatic duct bifurcation is described.

Incision and Exposure

The patient is positioned on the operating table supine with the right arm tucked on the side; this allows for placement of the Thompson retractor on the table. This retractor is suspended from a frame anchored to the operating table at the level of the patient's shoulders. It creates upward traction and has the ability of adjusting additional retraction on the base of segment IV of the liver which will be useful on the hilar dissection. Also, an additional extension could be placed inferiorly for the countertraction of the abdominal viscera. Sequential compression stockings are used to decrease the risk of deep venous thrombosis. The full abdomen and the lower chest, including the transhepatic biliary stents if present, are prepared and draped into the field. A right subcostal incision is made one fingerbreadth below the costal margin, and the abdomen is explored to assess for the presence of liver metastases or peritoneal implants.

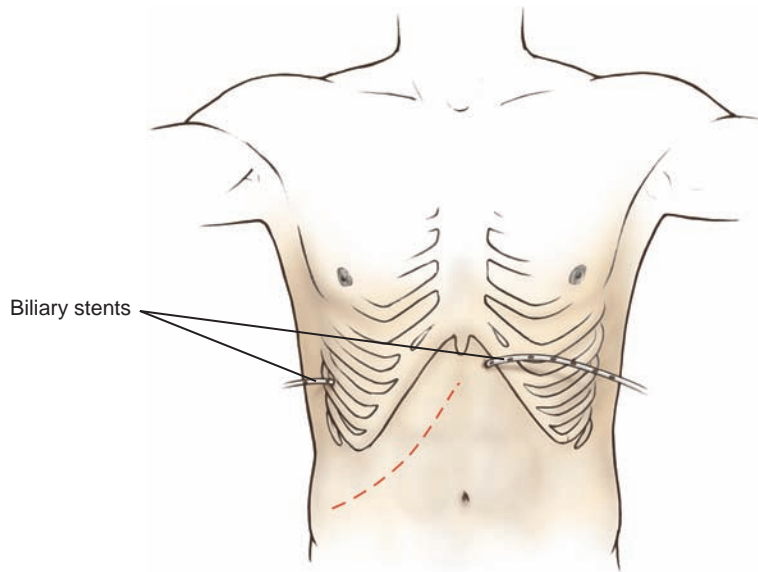


Figure 11.34

Unless the lymph nodes are, extremely enlarged, bulky, present beyond the limits of resection, or encasing major vessels, the resection is continued. The celiac lymph nodes are examined after the gastrohepatic ligament is opened. Care is taken to preserve a replaced left hepatic artery (type III anatomy), which may be encountered within the proximal gastrohepatic ligament. The celiac nodes are often enlarged and are usually negative for tumor. Suspicious nodes are sent for frozen-section analysis, and if they prove to be positive for tumor, the decision to proceed is reevaluated. Regardless of the other intraoperative findings, the presence of tumor within these lymph nodes usually reflects the likelihood of additional distant metastases.

At the initial exploration, the portal structures are carefully examined; however the tumor cannot be visualized frequently. In addition, the gallbladder and extrahepatic biliary tree often appear normal in the case of more proximal tumors. Despite its seemingly occult nature, with palpation up into the hilum of the liver, the tumor and its surrounding inflammatory response are recognized.

If no extrahepatic tumor, vascular invasion, or more extensive intrahepatic tumor is detected, the decision to proceed, is made.

Mobilization and Assessment of Resectability

The ligamentum teres is ligated and divided, and the falciform ligament is taken down with the cautery, halfway between the abdominal wall and the liver. It is the authors' preference to keep the gallbladder in situ since a right hepatectomy in this instance is more like an extended right hepatectomy. The cystic artery needs to be transected and that could be done now or later on the arterial dissection. At this point, it is very critical to rule out the encasement of the left hilar vessels, or the main portal vein, or the proper hepatic artery, since this determines the unresectability of the tumor. Encasement of the right lobar vessels is not a contraindication to proceed since they are going to be anyway resected.

Figure 11.35

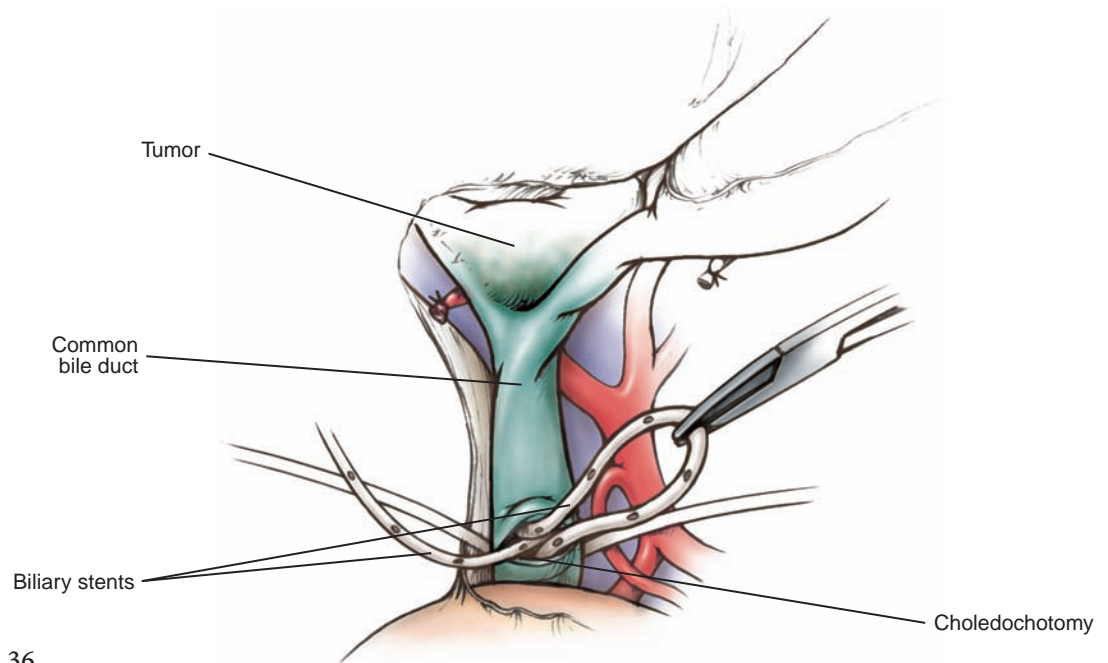
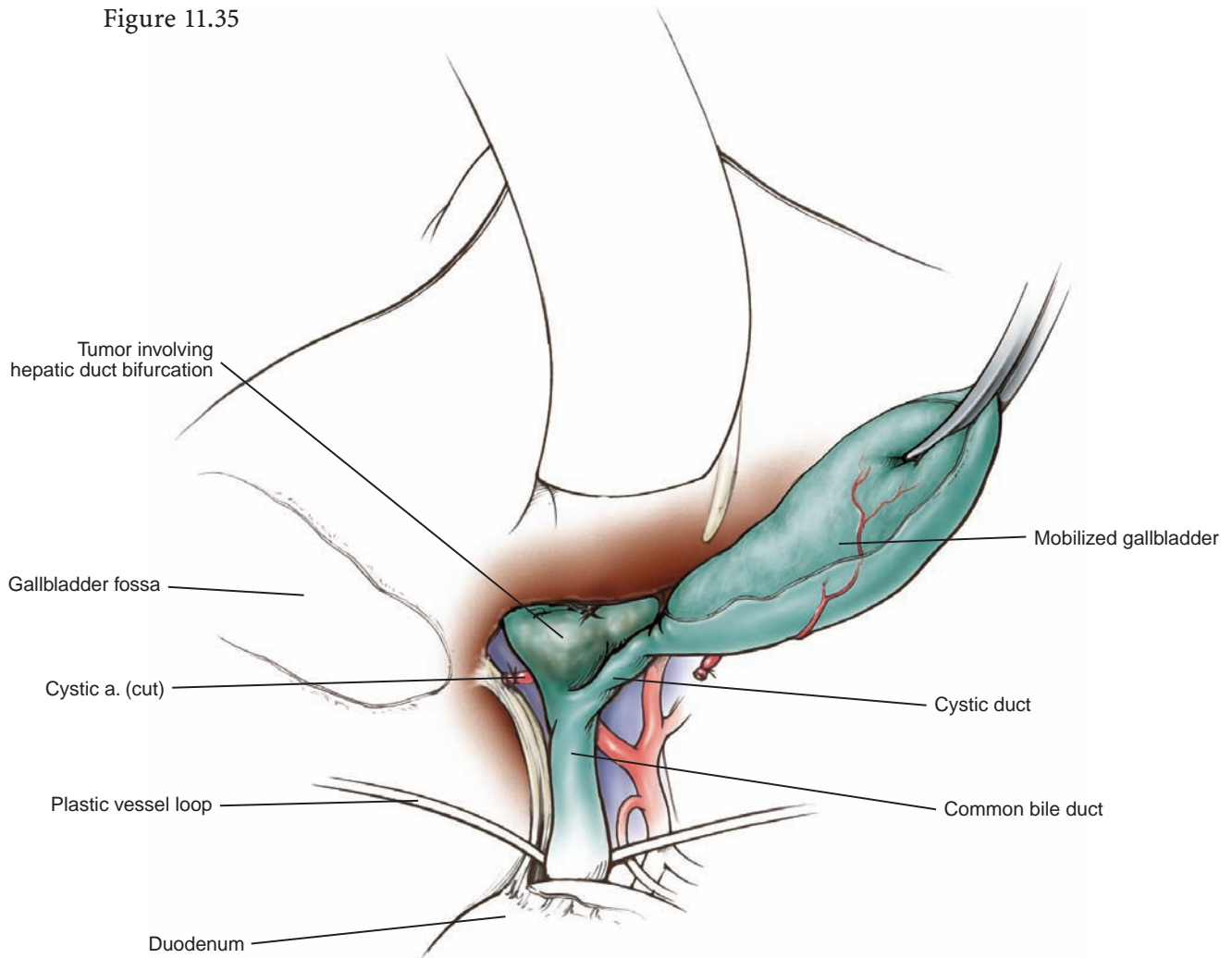


Figure 11.36

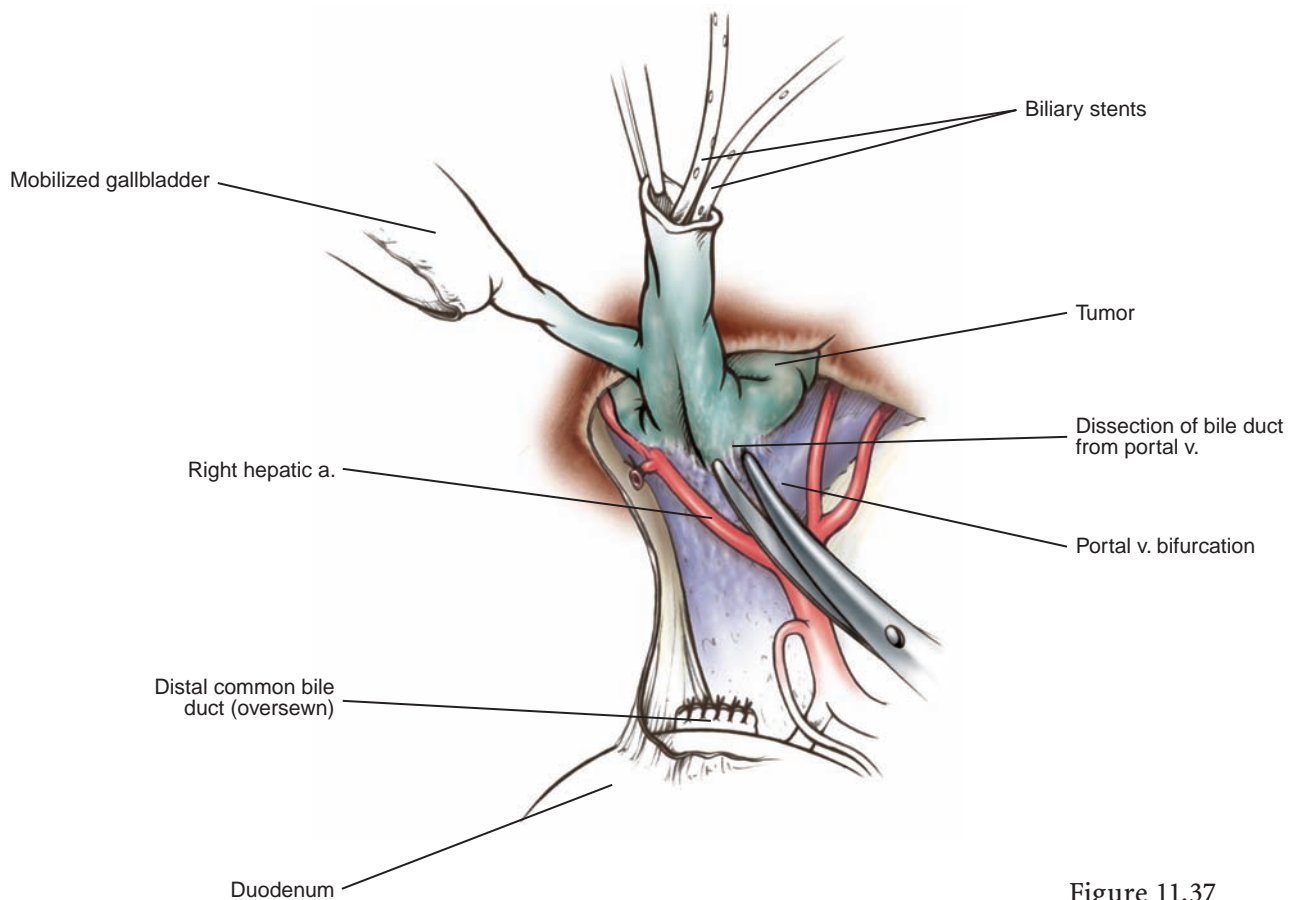


Figure 11.37

The next step is the identification and dissection of the supraduodenal common bile duct. It is transected there, a frozen section is sent, the distal stump is ligated and the proximal one is clamped to serve for traction and further dissection within the porta hepatis. If this ductal margin contains a tumor, a pancreatoduodenectomy will be necessary, and the anticipated additional morbidity and mortality must be assessed before proceeding. Identification and dissection of the common bile duct is facilitated by the preoperative placement of transhepatic biliary stents.

Further dissection should be accomplished by traction on the biliary stents anteriorly and superiorly, exposing the plane between the posterior aspect of the common bile duct and the anterior surface of the portal vein. Dissection is usually proceeded distal to proximal. If at any point, tumor involvement of the anterior surface of the portal vein becomes apparent, it may be necessary to abandon the procedure or consider portal vein resection and reconstruction. In most cases, if the preoperative imaging studies are normal, the dissection is proceeded without incident. Associated nerves and lymphatic channels surrounding the bile duct are dissected away from the hepatic arterial structures medially and are resected en bloc with the specimen.

Further Proximal Portal Dissection

As the dissection is proceeded proximally, the tumor and its associated desmoplastic process are eventually reached. At this point, dissection of the bile duct from the

portal structures, and in particular, the portal vein becomes more difficult. Nevertheless, careful sharp dissection, combined with gentle traction anteriorly and superiorly on the biliary stents, will aid in the elevation of, the posterior surface of the bile duct, tumor, and associated inflammatory reaction off the portal vein. Attempts at this maneuver without early division of the bile duct can result in a poorly accessible injury to the portal vein.

A maneuver that aids tremendously in the portal vein dissection is the identification of the right hepatic artery, at this point of take off. It is not difficult to achieve in this setting, since it is usually to the left of the actual tumor. As soon as the arterial bifurcation is identified, a clamp is placed in the right and pulsation on the left hepatic artery is evaluated. If present, the right hepatic artery is ligated with 2-0 silk proximally and distally, and transected. By doing this, the anterior traction also elevates the artery and this by itself could expose the portal vein bifurcation. On identification, it is preferred to isolate the right portal vein and fire an endovascular stapler. At that point, ischemia is achieved on the right lobe of the liver. If the dissection is continued along the lateral margin of the left hepatic artery, eventually, and with some lowering of the hilar plate over the left side, the left hepatic duct is recognized. Then, the surgeon needs to feel the consistency of this duct; if it is soft and is at a distance of 1 cm or more from the hard area of the tumor, ductal transection is performed.

Once the structures of the right portal pedicle have been controlled, the right lobe is mobilized and the dissection of the right hepatic vein is undertaken (see Right Hepatectomy). Then, the portal pedicles of the caudate lobe are dissected and taken with simple ligatures. This caudate pedicle usually comes off from the initial portions of the left structures (vein, artery and duct), and are generally small.

Figure 11.38

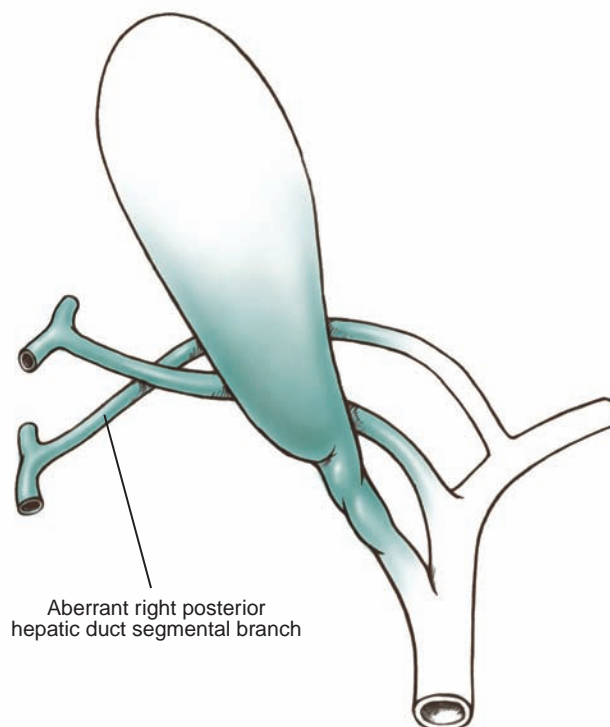


Figure 11.39

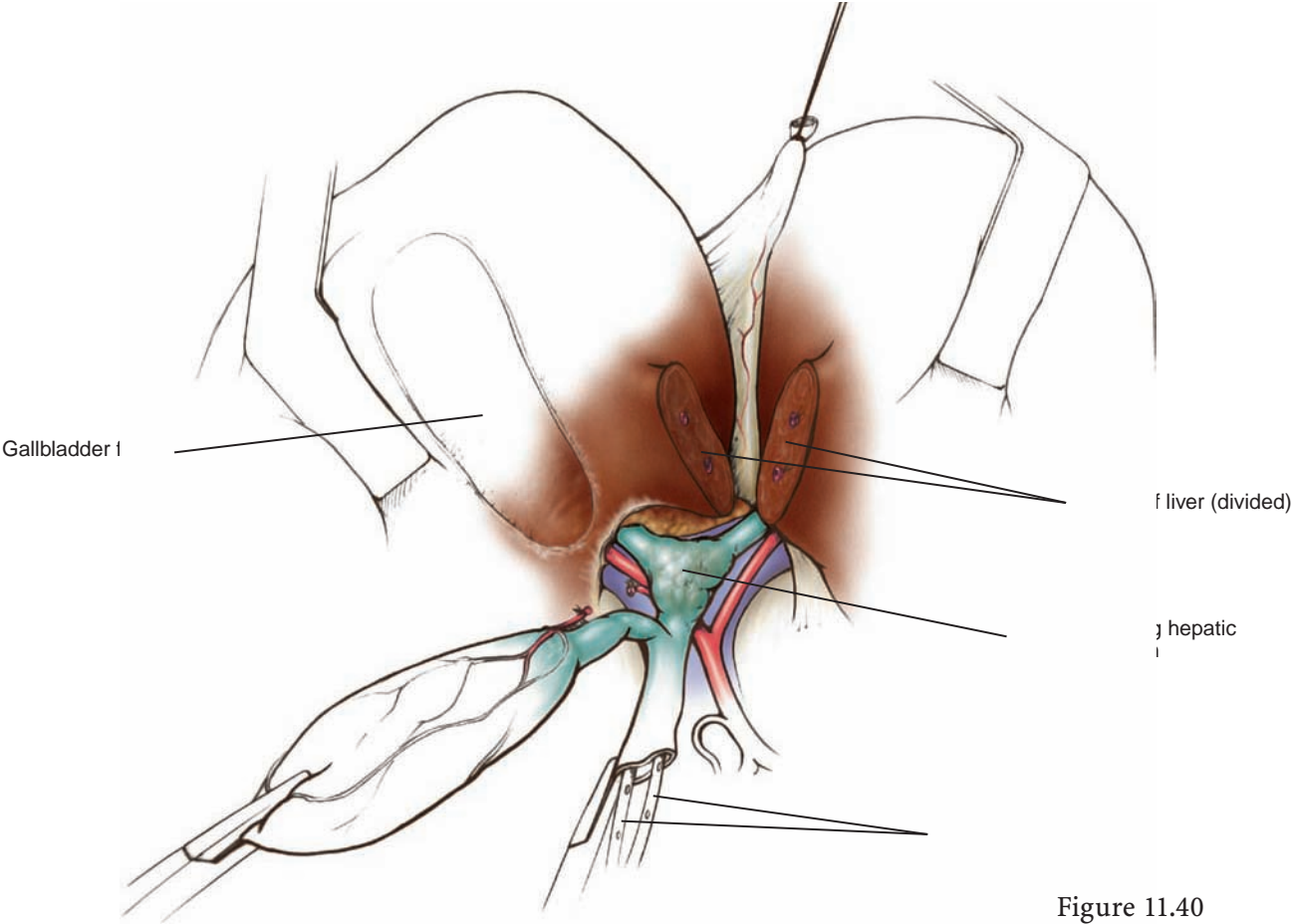
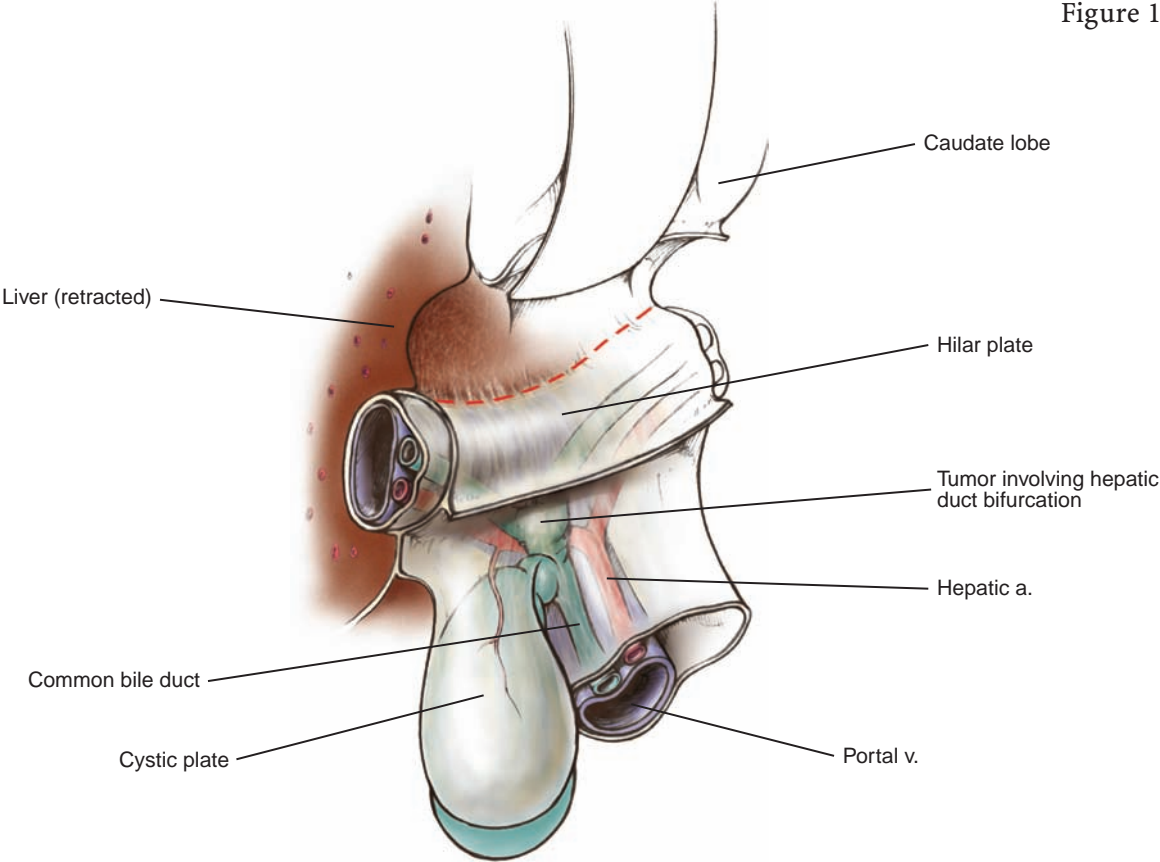


Figure 11.40

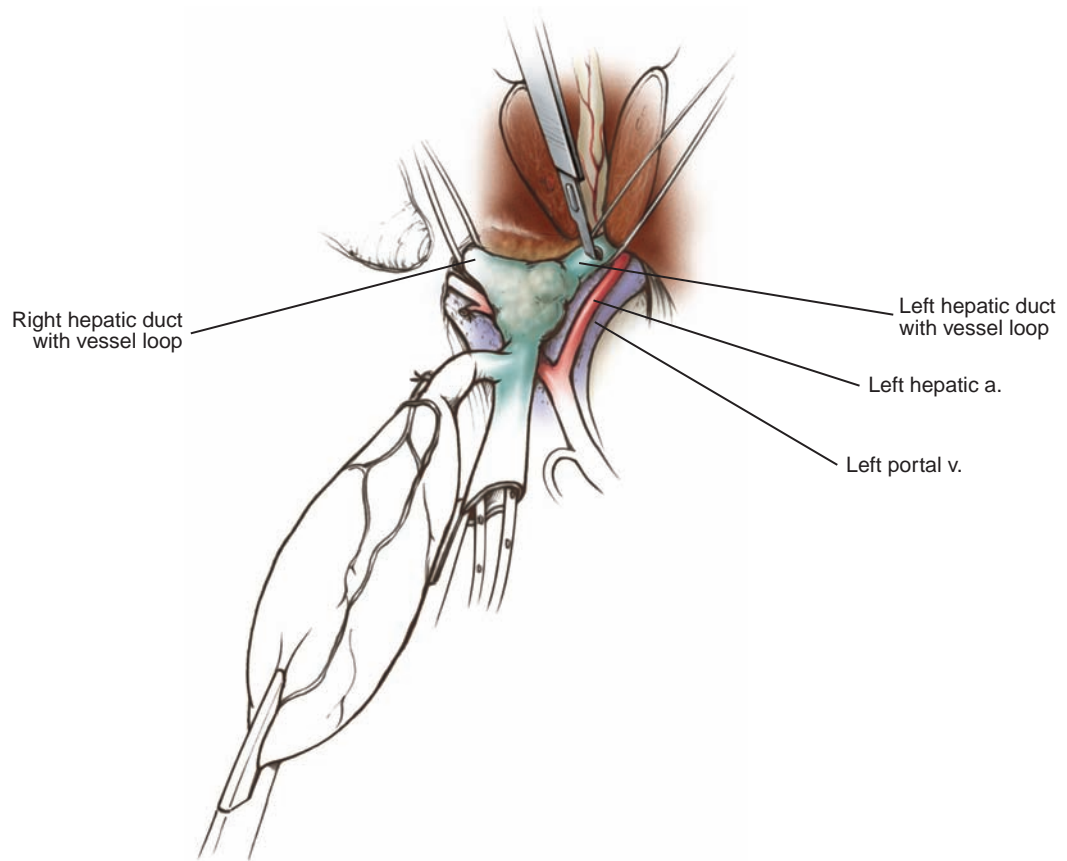


Figure 11.41

The transection is started to the right of the umbilical fissurae; it is not necessary to skeletonize the portal pedicles at that level, but rather, it is better to start transecting the liver in an area corresponding to the level of transection of the left hepatic duct. It should be remembered that any effort to spare parenchyma is worthwhile (providing it does not sacrifice oncologic margins) since the resection amount to 60–70% of the actual liver functioning mass. In some cases, it is very important to embolize the right portal vein to induce hypertrophy of the left lobe and decrease the chances of postoperative liver insufficiency.

The caudate lobe could be taken separately or en bloc with the right lobe. Whereas the vascular inflow of this lobe is relatively easy to control, the outflow is represented by numerous small veins draining directly into the IVC; these are short and fragile (4–12 in number) and care should be exercised to avoid backbleeding from the IVC. A radical portal lymphadenectomy including retropancreatic nodes and hepatic artery nodes complete the extirpative phase of this operation. At the end of this, the surgeon faces the left lateral section of the liver with the portal pedicle and the transected left hepatic duct; the hepatic artery (proper and left) and the portal vein (main and left) are skeletonized.

Biliary Enteric Reconstruction

After reaching the inframesocolic portion of the abdomen and choosing a proximal jejunal loop fitting without tension in the area of the left hepatic duct, the jejunum

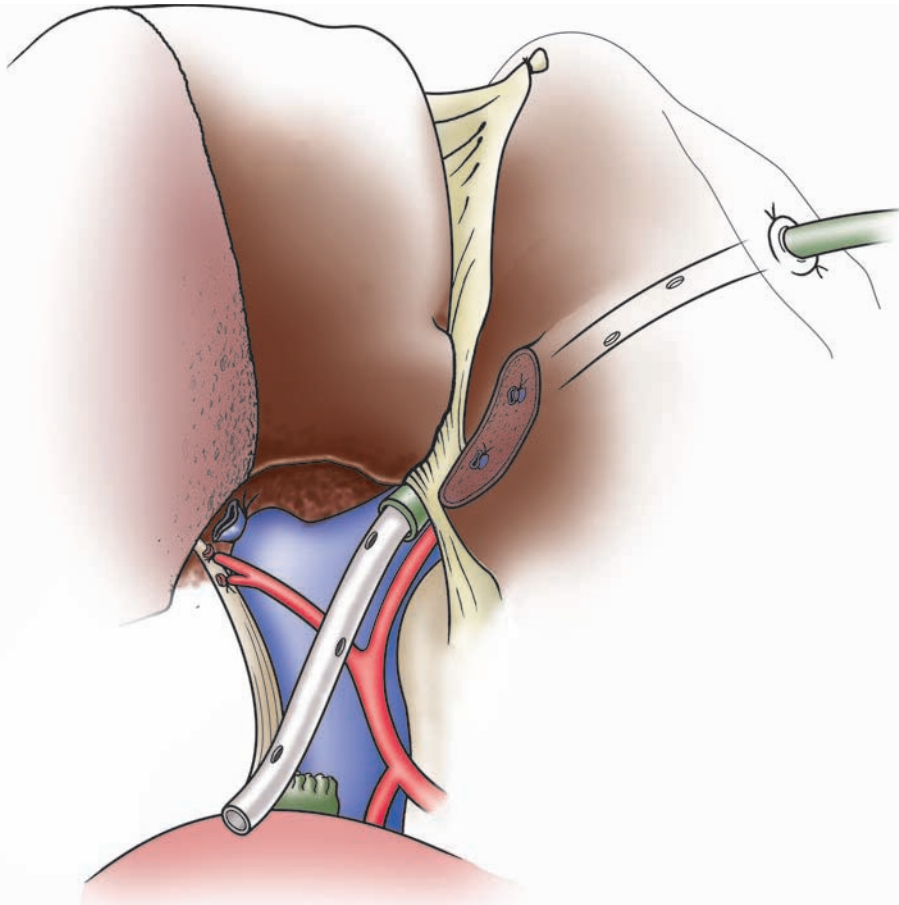


Figure 11.42

is taken with staples, and its mesentery with ultrasonic shears. Then, the base of the transverse mesocolon is examined to find the duodenum on the other side; right above the duodenum, this area of the transverse mesocolon lacks vessels and it is a straight shot to the portal area. The Roux limb is then passed through and then it is positioned for an end-to-side anastomosis.

Stay sutures are placed on each side of the left hepatic duct and the anastomosis is carried away with monofilament absorbable sutures; as long as there is a good apposition of the duct and the mucosa, there is no need for transanastomotic stents. Although there are several techniques to perform this anastomosis, according to the authors, this could be done in separate or continuous fashion (using interlocking stitches).

Generally, the posterior layer is run and then the anterior completes the anastomosis. A jejunojunctionostomy at 50–60 cm distal to the biliary anastomosis completes the reestablishment of the intestinal continuity.

If the patient has a stent placed preoperatively, this should be used mainly for postoperative imaging. Drains are not routinely used but sometimes the bile production from the liver is minimal during the operation and bile leaks could go unrecognized; in these cases, the use of an abdominal drain is favored. With respect to the vascular inflow occlusion (Pringle maneuver), every effort is made to avoid it since there is an urgent need to decrease any potentially damaging effect on the small liver remnant.

Figure 11.43

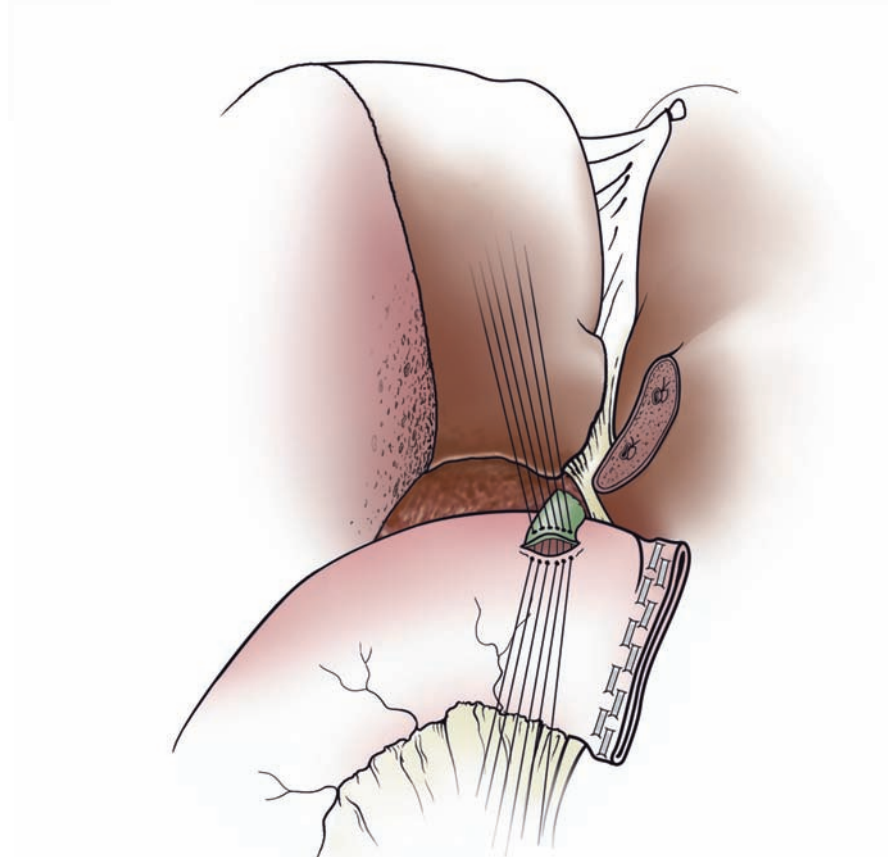
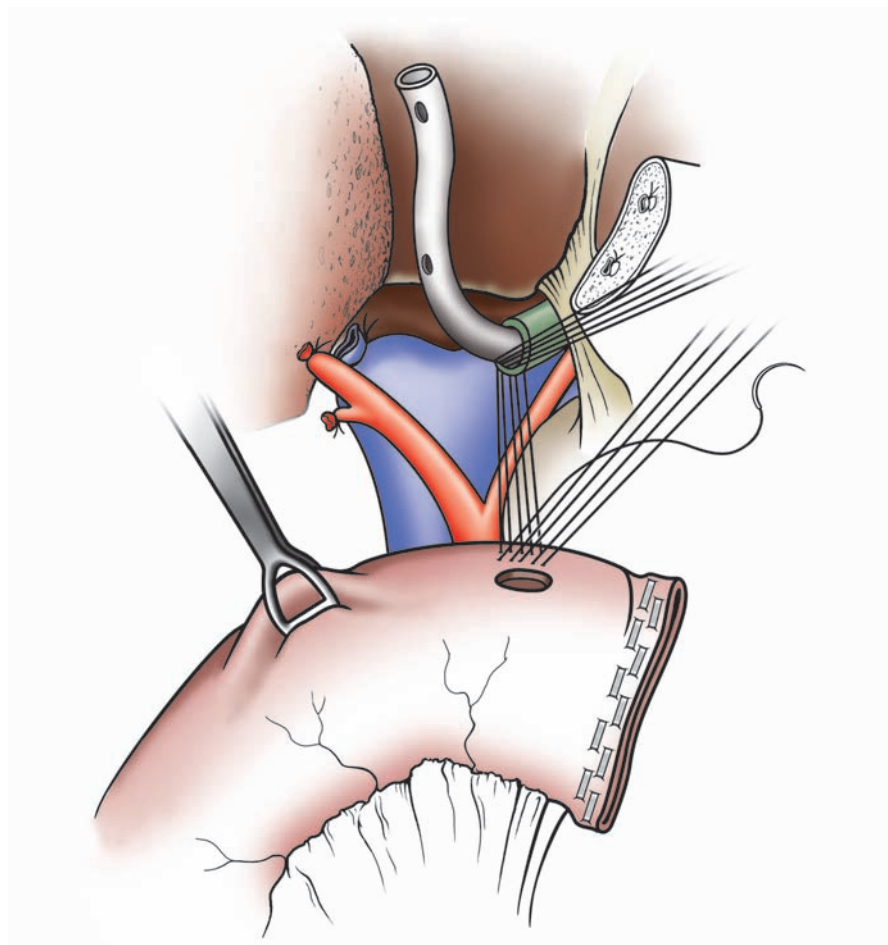


Figure 11.44

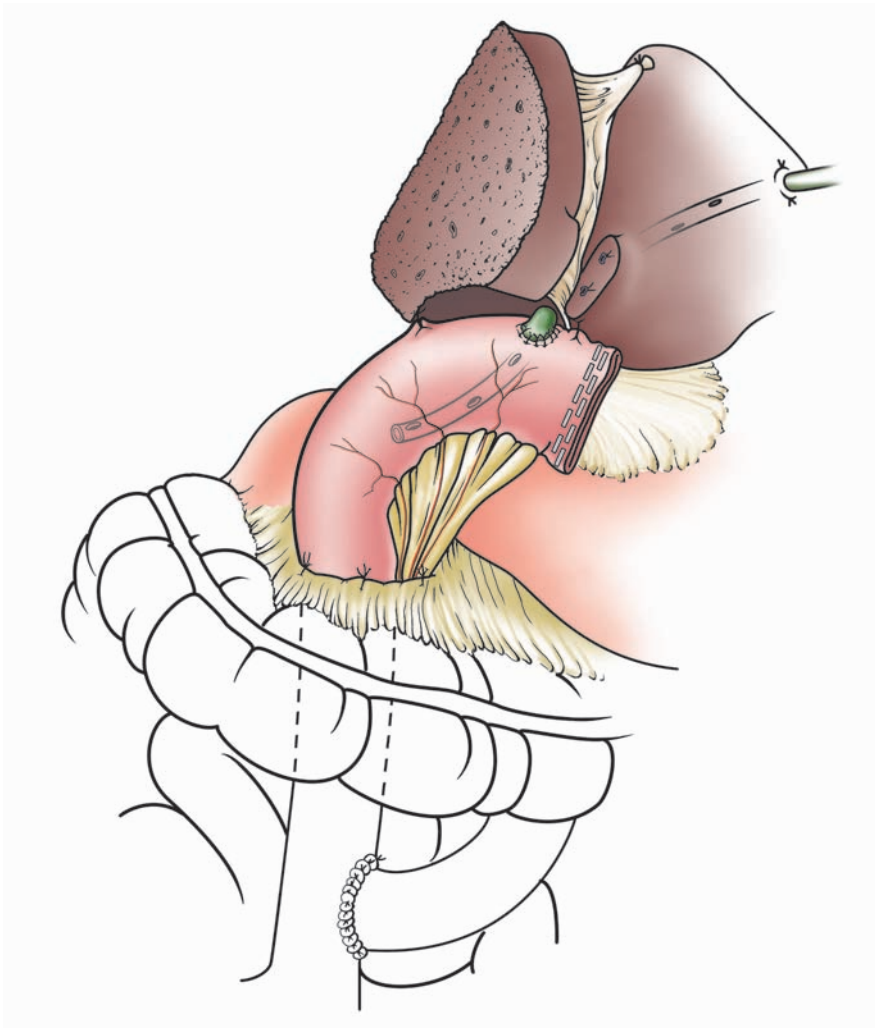


Figure 11.45

Hilar Cholangiocarcinomas located at the common hepatic duct bifurcation extending proximally into the left hepatic duct (Bismuth 3B) require resection of the extrahepatic biliary tree with en bloc resection of the left hepatic lobe and the caudate lobe, followed by bilioenteric anastomosis. Preoperative evaluation, within the limitations previously outlined, is extremely important in determining the extent of proximal and contralateral hepatic duct invasion and the target for hepatic lobectomy. Also, preoperative evaluation of the liver volume and function is important for determining the extent of hepatic resection without producing hepatic insufficiency. Finally, it is not infrequent for one or both lobar branches of the portal vein or hepatic artery to be encased or occluded by tumor extension. These tumors may still be resectable if en bloc hepatic lobectomy is performed along with resection of the bifurcation and extrahepatic biliary tree. The technique for the resection of a cholangiocarcinoma located at or above the hepatic bifurcation, with en bloc resection of the left hepatic lobe is described.

Resection of Hilar Cholangiocarcinoma with Left Hepatectomy (and Caudate Lobectomy)

Incision and Exposure

This resection is performed via an upper midline incision (see Left Hepatectomy). After the assessment of extrahepatic metastases or N2 lymph node involvement, attention is placed on the porta hepatis.

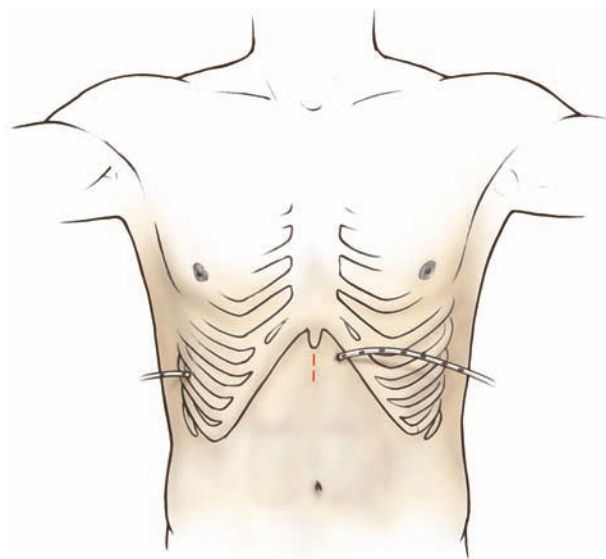


Figure 11.46

Mobilization and Assessment of Resectability

After the abdominal cavity is entered and the retractors are placed, the ligamentum teres is divided and ligated, and the falciform ligament is taken down with electrocautery, halfway between the abdominal wall and the liver. At this point, an additional inferior arm is placed on the Thompson retractor to assist with the inferior traction and thereby exposing the portal structures. The initial operative strategy for this part of the procedure is similar to that described on the resection of hilar cholangiocarcinoma with right hepatectomy.

Further Proximal Portal Dissection and Left Hepatic Lobectomy

The gallbladder is left in situ for anterior traction, although the cystic artery could now be taken to avoid tearing of the right hepatic artery further on. The distal common bile duct is identified, encircled and transected. Frozen section is used for this distal biliary margin. The proximal bile duct is elevated and the surgeons should maintain the present the location of the proper hepatic artery. As the elevation of the common bile duct is continued, the right hepatic artery comes into view; then the surgeon should follow it in a retrograde fashion to find the bifurcation and the left hepatic artery. The latter should be taken there since the caudate branch should also be controlled. By staying in the left margin of the common hepatic duct, the left portal vein will be seen in a deeper plane. This left portal vein should be taken on the bifurcation, again, because the caudate branch coming from it should also be controlled.

For personal preference, the transection of the right hepatic duct is left as the final step of the parenchymal transection.

The left hepatic vein is controlled in the same way as has been described (see Left Hepatectomy). Once ischemia is well demarcated in the left lobe of the liver, the liver transection is started to the right of the gallbladder on a superficial plane.

Figure 11.47

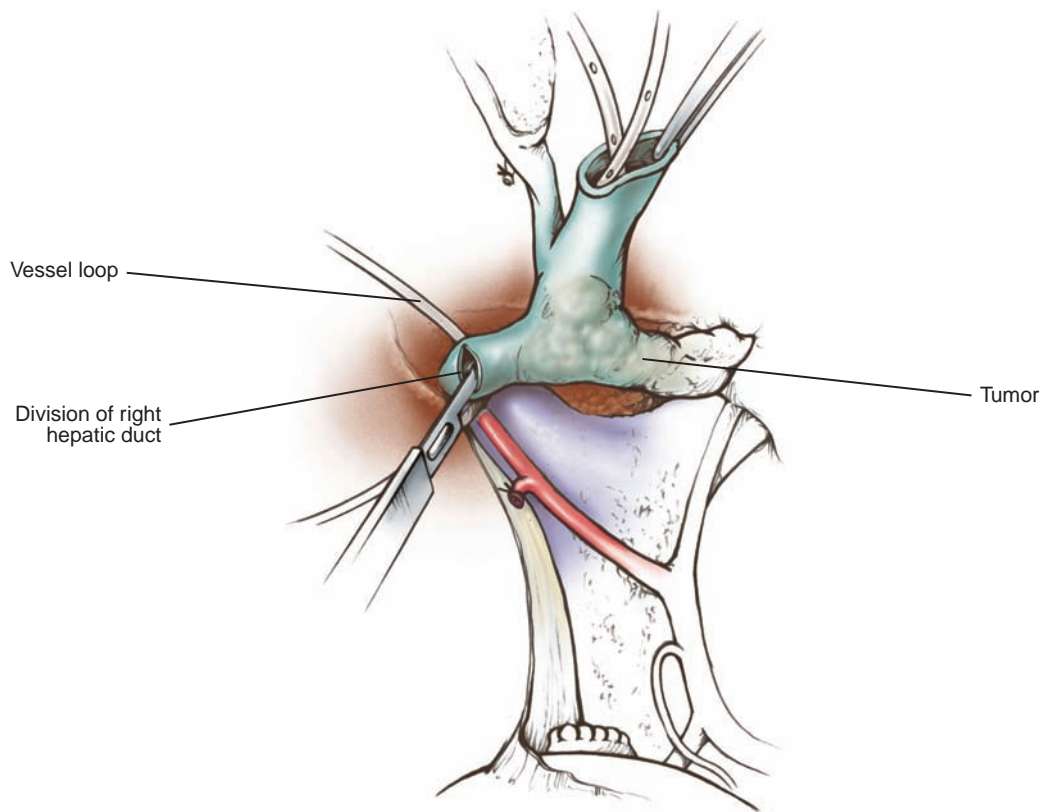
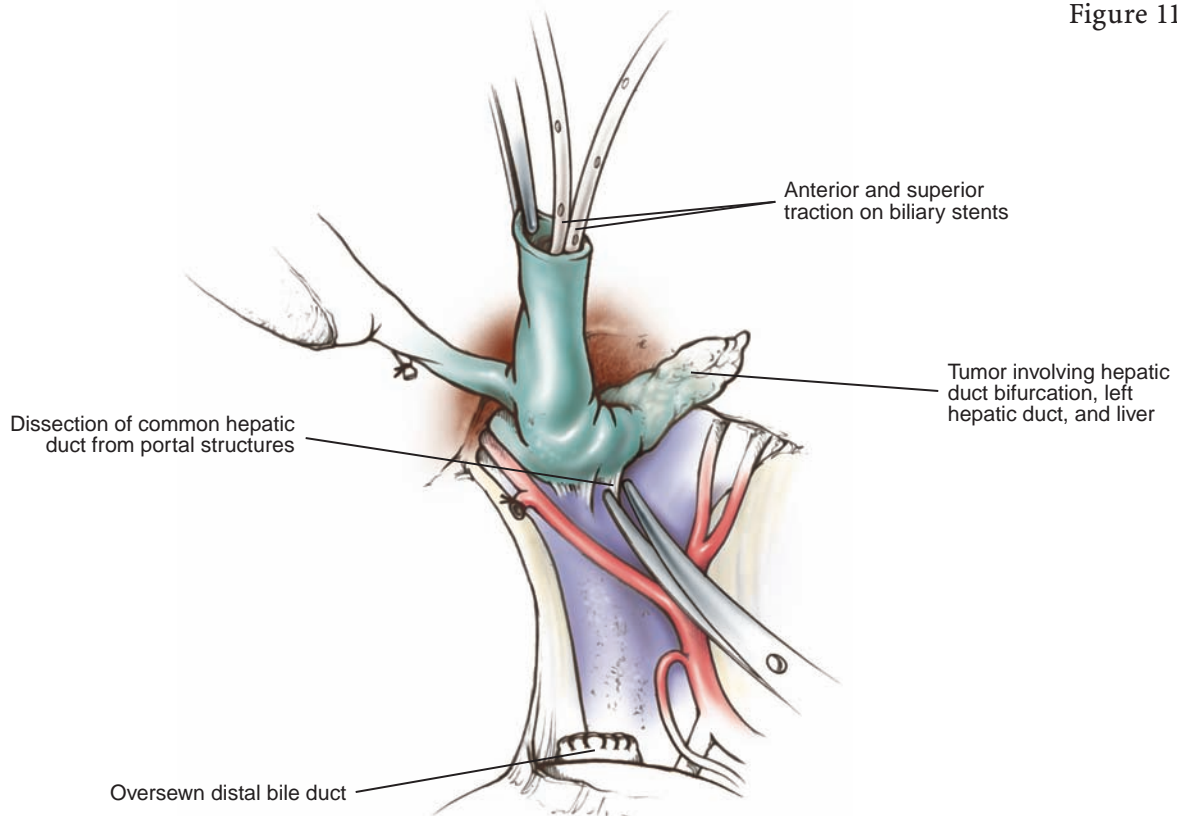


Figure 11.48

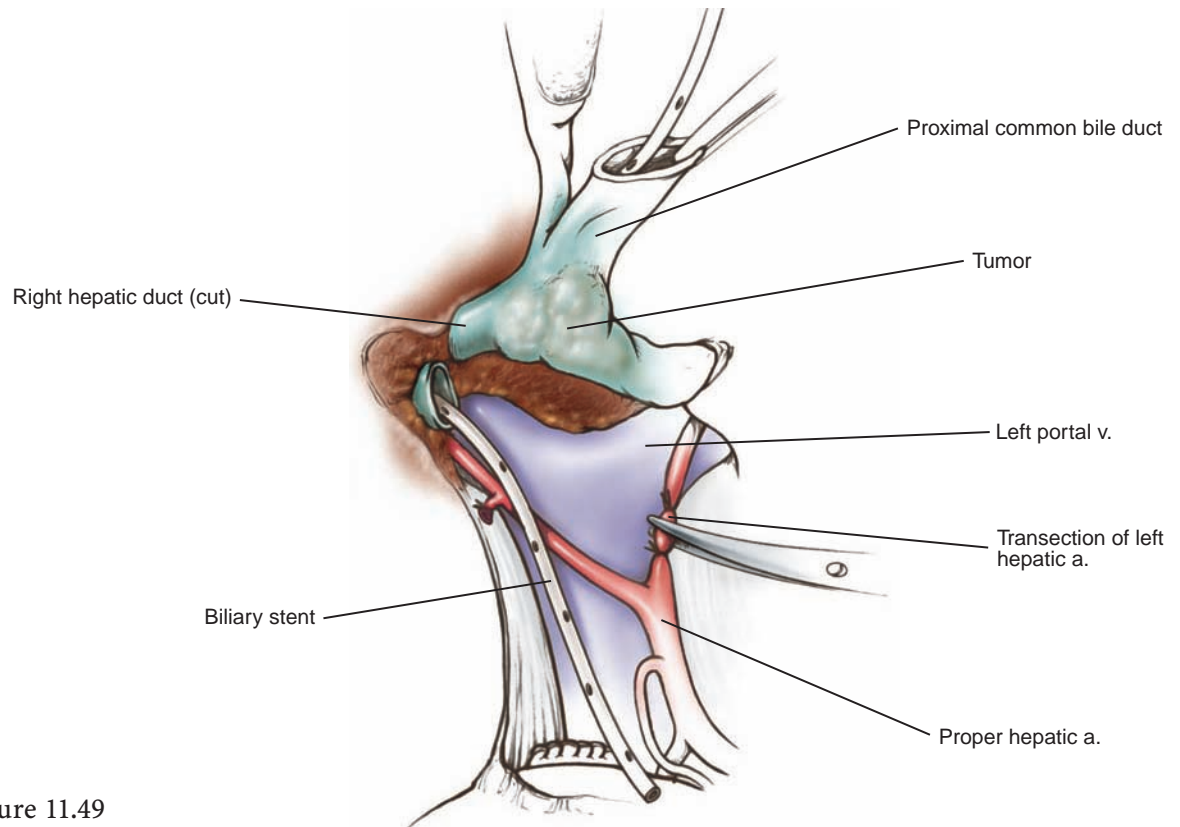


Figure 11.49

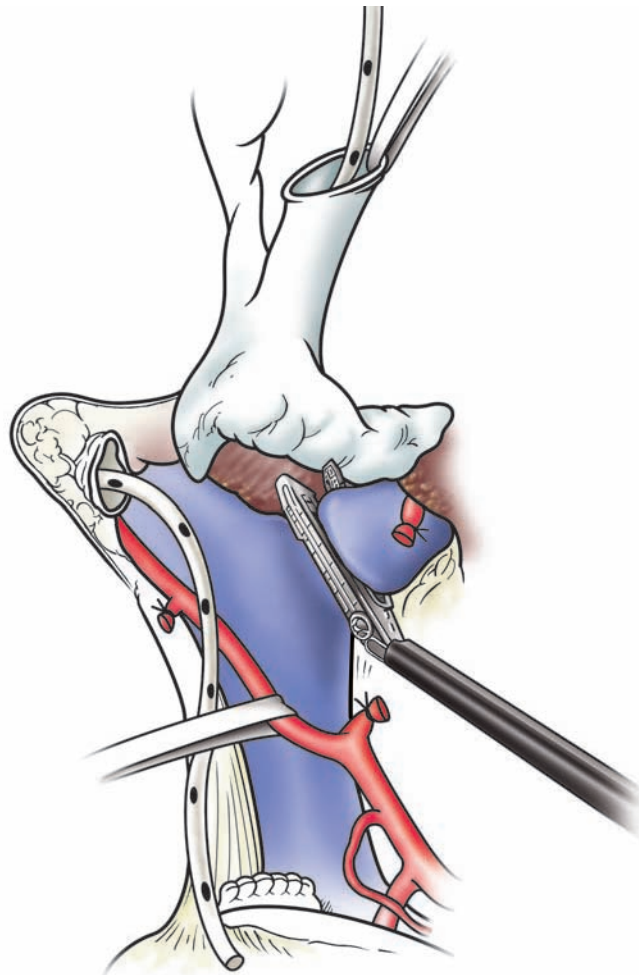


Figure 11.50

As the transection is deepened, the middle hepatic vein will come into view and this should be controlled with staples; this part of the middle hepatic vein is distal and in no way jeopardizes the drainage of the right lobe of the liver. As said before, the transection is continued posteriorly until reaching the left hepatic vein next to the IVC or the common trunk with the middle hepatic vein. In most instances, this hepatic transection could be done without vascular inflow occlusion, since the manual control of the backbleeding from the right lobe is technically more feasible. Once the left lobe is almost completely transected, the caudate process is also transected to remove the caudate lobe en bloc. After this transection and elevation of the caudate lobe from the IVC, the specimen hangs from the hepatic ducts and the surrounding soft tissue. By revisualization of the tumor again, and finding at least 1 cm of soft tissue beyond the hard area of the tumor into the right hepatic duct, the latter is transected and sent for frozen examination. During the right hepatic duct transection, care must be taken not to injure the accompanying hepatic artery and portal vein, since they travel into the liver as a portal unit. They are typically located posterior or inferior to the hepatic ducts. With sharp dissection, the duct is separated from the vascular structures and the specimen is removed from the field.

In some circumstances, during the portal dissection it becomes obvious that the tumor is encroaching the portal bifurcation, and resection of some or all of the portal vein bifurcation en bloc with the tumor, as it extends into the left hepatic lobe may be necessary. Prior to any attempt at resection, proximal venous control of the main portal vein below the bifurcation, and distal venous control of the right branch of the portal vein above the level of the bifurcation must be obtained. After partial excision of the bifurcation, lateral venorrhaphy (in a transverse fashion) using running 5-0 Prolene sutures should be used to repair the vein if the caliber of the remaining portal vein is adequate. If the caliber of the remaining portal vein is too small (<50%), a vein patch, utilizing a piece of harvested internal iliac or saphenous vein sewn into the defect with 5-0 Prolene suture, is usually sufficient. If the entire bifurcation has been excised, an end-to-end anastomosis between the main trunk of the portal vein and the right portal vein is needed. Two 5-0 Prolene corner sutures are placed so that the knots are on the two ends of the portal vein. The first corner suture is brought inside, and the posterior row is sewn in a continuous fashion inside the vein to the opposite corner suture, where it is brought outside and tied. The other half of the first corner suture is used to complete the anterior row of the anastomoses in a continuous fashion on the outside of the vein, to the opposite corner. These two ends of the front suture are then tied, leaving a small "air knot" (called a "growth stitch" by transplant surgeons) to allow for expansion of the anastomosis.

This end-to-end anastomosis can be accomplished without difficulty if less than 2 cm of vein has been resected. However, if more than 2 cm of vein has been removed, a small vein graft is usually necessary. In this case, use of a small section of internal jugular vein is preferred because it is a perfect size match for the portal vein. If the possibility of a venous reconstruction is anticipated based on preoperative MRI, the left side of the patient's neck is prepared and draped in anticipation of harvesting the left internal jugular vein.

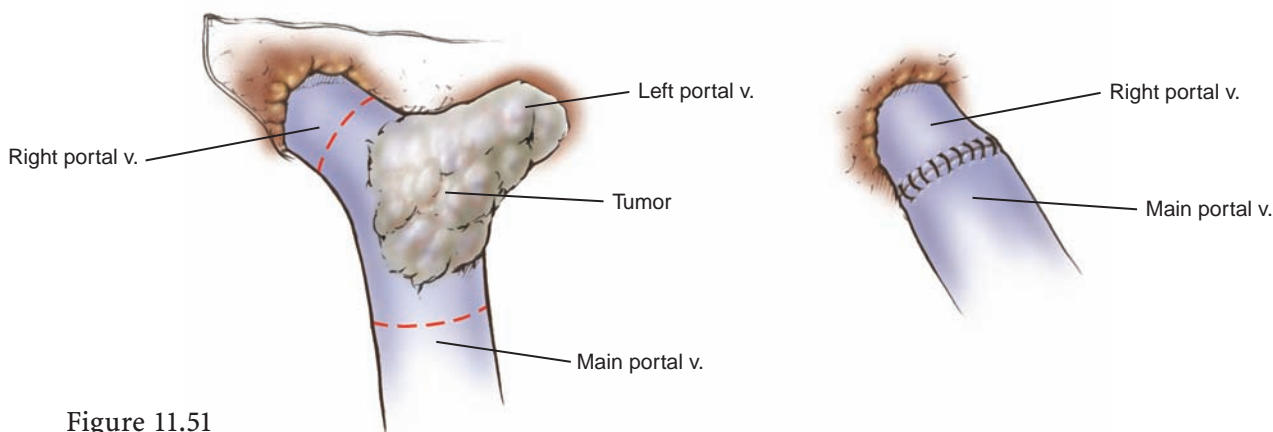


Figure 11.51

Although oncologically more controversial, a similar strategy could be attempted with the hepatic artery. The prognostic implications of such a procedure are beyond the scope of this chapter and this is mentioned because of its technical feasibility.

Biliary Enteric Reconstruction

The biliary enteric reconstruction to the transected right lobe duct is essentially performed as described for resection of hilar cholangiocarcinoma with right hepatectomy. One possible variation is that in many instances, the surgeon has to do the transection above the bifurcation of the right hepatic ducts into the anterior and posterior branches. In fact, that happens more often that the counterpart of ending with the main right duct for anastomosis. In this case, if the separation is not more than 1–2 cm, the two ducts should be sutured together and the surgeon should perform only one anastomosis. The authors' preference is to place separated stitches of 6-0 prolene and leave the superior and inferior sutures as "stay" sutures. If the separation of the anterior and posterior ducts is longer than that, separate hepaticojejunostomies should be done. In these cases, the surgeon should do the deeper anastomosis first and leave the more superficial for last.

Palliation of Proximal Cholangiocarcinoma by Transhepatic Stenting and Hepaticojejunostomy

Proximal cholangiocarcinomas are staged preoperatively and explored when they are thought to be curable based on cholangiographic and angiographic criteria. Palliation should be radiologic in these patients, but a small number of patients will be had in whom unresectable disease is discovered at the time of the operation. In certain patients, palliation could be entertained, given the fact that they are already explored.

Basically there are three options in this setting. Number one entails using the left hepatic duct, where the hilar plate is lowered and the left duct is exposed at the base of segment 4 of the liver. Second scenario occurs when the tumor infiltration takes the entire hilum; then the only resource is to dissect to the left of the umbilical fissure and find the hepatic duct draining the left lateral section; this could be accomplished

by either superficial exploration or by excision of some liver parenchyma. The third option is the so-called Longmire operation which basically describes, that in massively dilated left hepatic ducts, the transection of some parenchyma on the edge of the left lateral section uncovers the dilated bile duct and this is useful for a Roux-en-Y hepaticojejunostomy. These strategies are seldom used these days because radiologically inserted stents work well and provide good short-term palliation in these patients with a limited life span.

In some patients with carcinoma of the gallbladder the tumor extends into the liver, extrahepatic biliary tree, or regional lymph glands, making cure difficult, if not impossible. Occasionally, patients have symptoms of gallstone disease and undergo elective cholecystectomy, only to find at pathologic examination of the gallbladder, that an incidental adenocarcinoma is present. These patients with, incidentally discovered, superficially invasive gallbladder carcinoma have an excellent opportunity for cure by simple cholecystectomy (provided this is a mucosal lesion –T1 stage). In rare patients, the tumor is still confined primarily to the gallbladder and the surrounding liver parenchyma, and subsegmentectomy IV-V of the liver and regional lymphadenectomy will yield at least significant palliative benefit and an occasional cure.

Resection of Gallbladder Fossa with Portal Lymphadenectomy

Incision and Exposure

Many patients are seen after a cholecystectomy via laparoscopic or open technique, during which carcinoma of the gallbladder was discovered. Nevertheless, all patients undergo exploratory surgery through a right subcostal incision. If the gallbladder has already been removed, the adhesions between the omentum, right hepatic flexure of the colon, or duodenum, to the gallbladder bed are gently taken down to expose the gallbladder bed and porta hepatis; any hard adhesion needs to be excised leaving the hepatic side undisturbed. If the gallbladder has not been removed at prior surgery, the gallbladder wall may contain a thickened, whitish mass that is firmer than the typical chronic cholecystitis. In case of previous positive histology or if the surgeon's index of suspicion remains high, the operative procedure is extended to the removal of the liver corresponding to the gallbladder fossa (subsegmentectomy IV–V) for about 3 cm around, coupled with a radical portal lymphadenectomy (see Hilar cholangiocarcinoma).

(Liver) Resection of Gallbladder Fossa

Resection of the gallbladder bed includes resection of a portion of liver segments IV-B, and V. If the tumor is confined to the muscularis of the gallbladder, the line of resection should be approximately 3 cm lateral and medial to the gallbladder fossa and extend at least 3 cm deep into the hepatic parenchyma. If there is invasion through the gallbladder wall into the hepatic parenchyma, the excision should extend at least 2–3 cm beyond the deepest portion of tumor. Preoperative imaging as well as intraoperative assessment is extremely helpful. Intraoperative ultrasonograms are also used liberally.

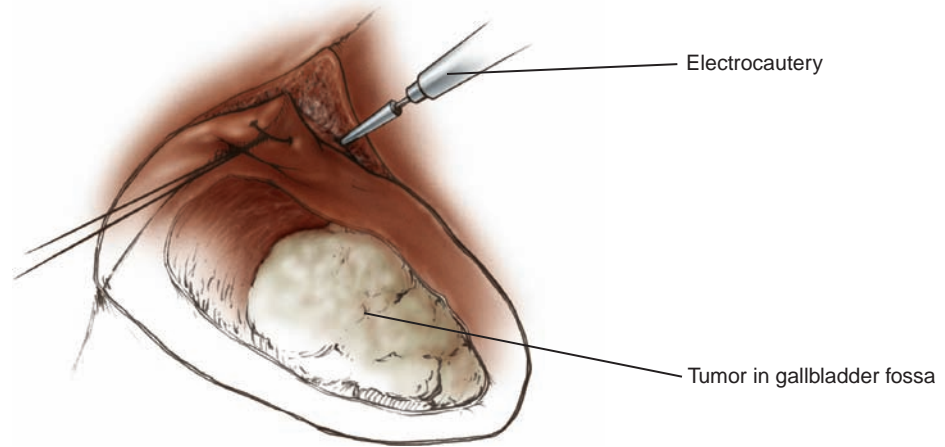
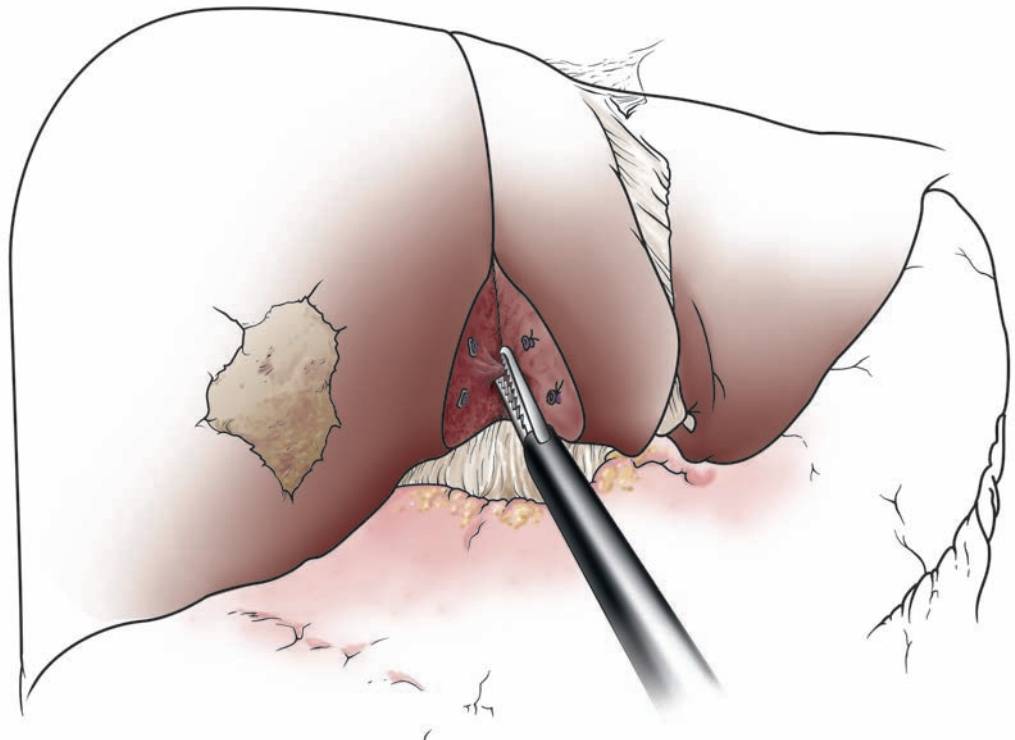


Figure 11.52

The margins of the liver resection are scored on the liver with an electrocautery. In cases where the gallbladder is still attached, this serves as a handle for the resection by the manual grasping of the gallbladder in a supine mode. This also facilitates compression of the liver with the tip of the fingers to decrease bleeding of the hepatic parenchyma.

The harmonic scalpel is used for the superficial planes and the rest of the transection is completed with ligatures, hemoclips or suture. In the deep portion of this transection, either the most distal portion of the middle hepatic vein or one of its main tributaries is always present and efforts should be made to locate it before actual transection and to avoid major bleeding from tears or partial injury.

Figur



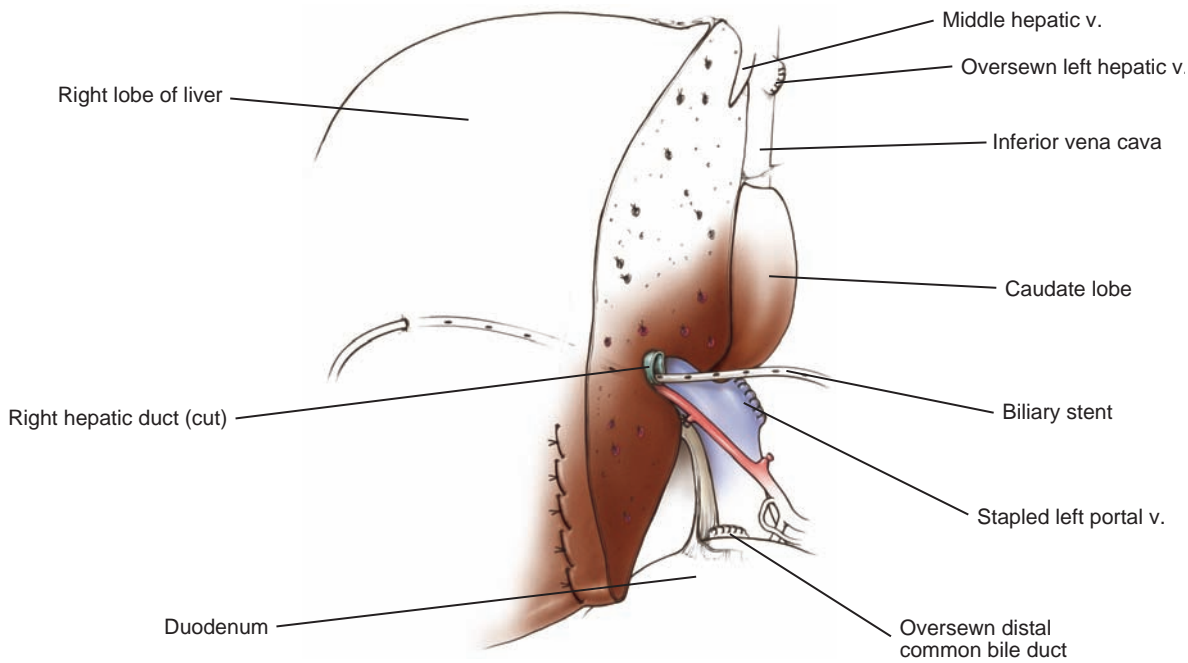


Figure 11.54

Vascular inflow occlusion is used here since nonanatomical resections typically carry more bleeding than the anatomic counterparts; moreover, since located close to the hilum, most of the bleeding comes from inflow branches. Formal portal dissection with the control of specific lobar vessels is not needed for this procedure. Once the specimen has been removed, small bleeding points or small bile ducts are further controlled with suture ligatures. The cystic duct margin is then sent for frozen examination (see below).

Regional Portal Lymphadenectomy

Following the liver resection, regional portal lymph node dissection is performed. All of the tissues surrounding the biliary and major vascular structures, extending from the bifurcation of the common hepatic duct to the distal common bile duct as it enters the pancreas behind the duodenum, are removed en bloc. The majority of the lymph nodes within this tissue are posterior to the common bile duct and adjacent to the portal vein. Care must be taken while removing these nodes to prevent injury to the portal vein or to a replaced right hepatic artery, which originates from the SMA and travels through the lateral posterior aspect of the hepatoduodenal ligament (type III anatomy). Palpation of the posterior lateral aspect of the porta prior to dissection usually identifies the replaced right hepatic artery.

A Kocher maneuver will assist in the removal of the lymph nodes posterior to the common bile duct, which extend behind the C loop of the duodenum. The dissection must also include the nodes extending medially along the common hepatic artery as it arises from the celiac axis. These lymph nodes travel in a groove between the common hepatic artery and the superior border of the pancreas. When the porta hepatis and the hepatic artery down to the celiac axis have been skeletonized, the dissection

is complete. Typically, this operation is not drained, since the amount of parenchyma resected is so limited. All the laparoscopic port sites are then excised to prevent an abdominal wall recurrence. The port sites are closed primarily. The abdomen is then closed with two layers of running nonabsorbable monofilament suture.

Extension of the Resective Procedure

There is a trend to include major resective procedures in cases where there is a locally aggressive disease without metastasis. If the cystic duct margin is positive, an excision of the extrahepatic bile duct is entertained; it not only controls the longitudinal spread of the disease but also greatly facilitates the performance of the regional portal lymphadenectomy. This strategy obviously involves a restoration of the biliary continuity via a hepaticojejunostomy.

Sometimes, on deep invasion of the hepatic parenchyma but no invasion of porta hepatitis, the surgeon can do an extended right hepatectomy instead of the subsegmentectomy IV-V; this radical procedure aims to decrease the local recurrence of the disease and also removes the nodal and soft tissue, right next to the cystic area.

In cases where the involvement of the tumor is close to the hilum (especially to the right portal pedicle) and there is a short cystic duct, or there is induration in the soft tissue around the cystic area, the surgeon can combine an extended right hepatectomy with extrahepatic bile duct excision. This ultimate resection entails the removal of the nodal soft tissue and bile duct, and potentially decreases the chance of local recurrence. By doing this, an increase of the morbidity is definite and the surgeon should balance this with the possibility of complete removal of the disease and its pathways for spread. This is very important while considering the poor effect of the current chemotherapeutic agents against gallbladder cancer.

Anatomic Basis of Complications

- Surgery for biliary tract tumors, particularly those of the hilum, remains difficult and is associated with the potential for significant mortality and high early morbidity. The main complications include bleeding, anastomotic leakage, abscess formation, portal vein or hepatic artery thrombosis, cholangitis, and liver abscess.
- Bleeding usually occurs during the operation, but also can occur in the early postoperative period. Contributing to this problem is coagulopathy, secondary to vitamin K deficiency in patients with prolonged obstructive jaundice. This coagulopathy should be anticipated during the preoperative preparation of the patient and corrected by the administration of vitamin K, fibrinogen, and fresh-frozen plasma.
- Intraoperative bleeding from the portal vein and the hepatic artery tends to occur during dissection of the tumor off these individual structures. Injury to

the portal vein should be prevented by early mobilization, division, and elevation of the distal common bile duct, in an effort to expose the portal vein trunk and bifurcation. Injury to the hepatic artery can occur during the dissection of the tumor mass. Special attention must be paid to prevent injury to the right hepatic artery originating from the SMA (type III anatomy) during lymphatic clearance of the hepatoduodenal ligament. Blind dissection should be avoided at all times. Injury to the common hepatic artery or its branches should be prevented by the identification of the artery in the distal hepatoduodenal ligament early in the dissection, followed by complete mobilization and retraction of the artery and its branches laterally, and away from the bile duct and associated tumor. Again, early division and mobilization of the distal common bile duct tumor lessens the chance of injury to the arterial blood supply to the liver.

- Life-threatening intraoperative bleeding may also occur from the vena cava or the hepatic veins. These veins can be damaged during dissection or by excessive torquing of the liver during mobilization. An adequate incision, with careful dissection under visual control, is mandatory to prevent such injuries. Careful dissection and division of the veins bridging the vena cava and the posterior caudate lobe allow complete elevation of the liver off the vena cava and a more accessible dissection with control of the hepatic veins at their entrance into the IVC.
- Prevention of postoperative bleeding starts at the time of the initial surgery, with meticulous hemostasis and careful inspection of the operative field before closing the abdominal cavity. Bleeding from the hepaticojunostomy or jejunojejunostomy can be difficult to diagnose, but usually occurs later than bleeding into the intra-abdominal cavity. This complication almost always requires repeated exploration and takedown of the anastomosis with the control of specific bleeding points. Visceral angiograms are helpful to determine the exact point of bleeding, and occasionally can treat bleeding from different sources.
- Anastomotic dehiscence with leakage can occur either in the early or late postoperative period. If it occurs in the early postoperative course, it will usually heal spontaneously if the leak is small. A late postoperative leak, however, may be due to bile duct ischemia and may require repeat operation. Abscess formation may also occur secondary to contaminated collections of bile or blood accumulated after the operation. Preventive measures are paramount, including good hemostasis, careful fashioning of the hepaticojunostomies, and adequate drainage of the abdominal cavity in dubious cases. In most cases, CT-directed drainage of the abscess and intravenously administered antibiotics successfully control anastomotic leakage.
- Thrombosis of either the portal vein or the hepatic artery may also occur in the postoperative period. Portal vein thrombosis may be occult and not recognized until symptoms of portal hypertension develop later in the postoperative period. However, acute hepatic artery thrombosis may be recognized by an elevation in hepatocellular enzyme levels, and may be associated with acute liver failure or a late anastomotic leak or stricture.
- Cholangitis is often seen in the early postoperative period, and is usually the result of surgical manipulation of the colonized stented biliary tree. Management

with intravenously administered antibiotics, assurance of the patency of any transhepatic biliary stents, and a search for any remaining obstructed biliary segments are the hallmarks of therapy.

- Liver abscess may develop due to the failure to establish adequate biliary drainage during surgery. Management of liver abscesses, in the majority of the patients, can be achieved by percutaneous drainage under ultrasound or CT guidance. However, occasionally, formal laparotomy with debridement and evacuation of the abscess cavity, followed by drainage is necessary.

Key References

Ahrendt SA, Cameron JL, Pitt HA. Current management of patients with perihilar cholangiocarcinoma. *Adv Surg*. 1996;30:427–52

This is a thorough, detailed, and comprehensive review of all aspects of cholangiocarcinoma management. Included in this chapter, are sections on preoperative evaluation, surgical decision making, surgical technique, palliative therapy, and treatment results. This work is an extremely valuable current review and contains a lengthy list of important references.

Blumgart LH, Hann LE. Surgical and radiologic anatomy of the liver, biliary tract and pancreas. In: Blumgart LH, editor. *Surgery of the liver, biliary tract and pancreas*. Philadelphia: Saunders Elsevier; 2007. pp. 3–36

This chapter puts in perspective, the anatomy of the liver and biliary tract, and correlates elegantly with the radiologic imaging findings. The pictures are clear and sometimes come with illustrative drawings.

Chassin JL. Operations for carcinoma of hepatic duct bifurcation. *Operative strategy in general surgery*. New York: Springer-Verlag; 1994. pp. 585–98

This concise, clearly written chapter contains a detailed sequential step-by-step description of bile duct resection for cholangiocarcinoma. This chapter is structured in such a way that the novice surgeon can be comfortable with the steps involved in curative resection. The illustrations are closely associated with the text and provide important anatomic details.

Georgiev P, Clavien PA. Liver resections. In: PA Clavien, MG Sarr, Y Fong, editors. *Atlas of upper gastrointestinal and hepato-pancreato-biliary surgery*. Berlin: Springer; 2007. pp. 339–91

This is an outstanding review, beautifully illustrating the surgical techniques described above; this work is done by real experts in the area and compiles the joint efforts of HPB Surgeons from US, Europe and Asia.

Liau KH, Blumgart LH, DeMatteo RP. Segment-oriented approach to liver resection. *Surg Clin North Am*. 2004;84:543–61

Excellent review of surgical anatomy for minor hepatic resections. It includes very good drawings and points of interest for HPB Surgeons.

Pitt HA, Dooley WC, Yeo CJ, et al Malignancies of the biliary tree. *Curr Probl Surg*. 1995;32:1–100

Although slightly outdated, this is an excellent overview of biliary tree malignancies, including cholangiocarcinoma and gallbladder cancer. This valuable review article is comprehensive and contains a lengthy list of references.

Sarmiento JM, Bower TC, Cherry KJ, Farnell MB, Nagorney DM. Is combined partial hepatectomy with segmental resection of inferior vena cava justified for malignancy? *Arch Surg*. 2003;138(6):624–30

This article illustrates the anatomic relationship of the liver, the hepatic veins and the IVC. It contains several illustrations with clear explanations of the surgical technique in the text.

Smadja C, Blumgart LH. The biliary tract and the anatomy of biliary exposure. In: Blumgart LH, editor. *Surgery of the liver and biliary tract*. Edinburgh: Churchill Livingstone; 1994. pp. 11–24

This is an excellent in-depth description of biliary tree anatomy from a surgical prospective. All important variations of anatomy have been included in this thorough work, which also includes a section describing the techniques of biliary exposure with emphasis on anatomic details.

Terminology Committee of the International Hepato-Pancreto-Biliary Association: SM Strasberg, J Belghiti, PA Clavien, E Gadzijev, JO Garden, W-Y Lau, M Makuuchi, RW Strong. The Brisbane 2000 terminology of liver and resections. *HPB*. 2000;2:333–9

This article classifies the hepatic resections and standardizes the terminology, thereby ending the different nomenclatures used across the world for similar operations. It is important to keep this work present since this is the current standard for surgical anatomy.

Suggested Readings

Abdalla EK, Vauthey J-N, Couinaud C. The caudate lobe of the liver: implications of embryology and anatomy for surgery. *Surg Clin North Am*. 2002;11:835–48

Abi-Rached B, Neugut AL. Diagnosis and management issues in gallbladder carcinoma. *Oncology*. 1995;9:19–30

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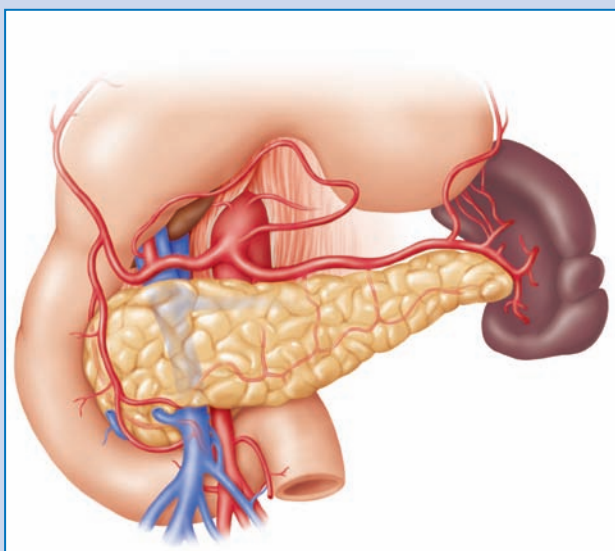
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Pancreas and Duodenum

David A. Kooby,
Gene D. Branum,
Lee J. Skandalakis



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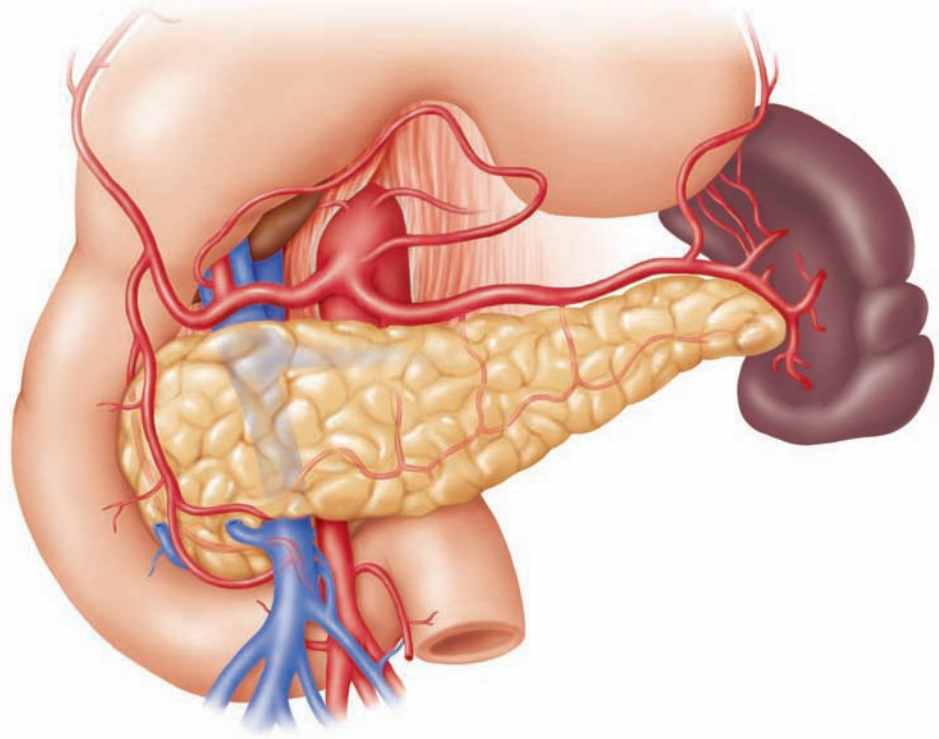


Figure 12.1

Introduction

Primary epithelial neoplasms of the pancreas can be divided into those of exocrine and endocrine origin. Nonepithelial and secondary pancreatic neoplasms are uncommon, and will not be covered in this chapter. Surgical therapy may be appropriate for some of these tumors, depending on the clinical situation, and the principles outlined for primary neoplasms can usually be followed.

Pancreatic exocrine neoplasms are relatively common, with adenocarcinoma accounting for most cases. Early signs and symptoms of pancreatic exocrine tumors vary with tumor location, and are usually vague and nonspecific (e.g., anorexia, malaise, abdominal pain, and weight loss), often resulting in slower diagnosis. Adenocarcinomas of the pancreatic head are more likely to be resectable at diagnosis than body and tail lesions, as they often cause biliary obstruction and jaundice. In general, pancreatic adenocarcinoma is a rapidly progressive and lethal cancer.

Pancreatic endocrine neoplasms (PEN) are encountered less frequently, and vary considerably in presentation and prognosis. Patients with these tumors may be asymptomatic; they may exhibit nonspecific symptoms such as pain or weight loss; or they may manifest recognizable signs and symptoms of clearly defined syndromes. Examples include insulinoma and carcinoid tumors. Malignancy is often

defined by tumor behavior and histology. In general, surgical resection is the mainstay of therapy for PENs. It may be appropriate to surgically remove PENs despite the presence of metastatic disease, given the relative chronic nature of these tumors.

Cystic pancreatic neoplasms are commonly identified on axial imaging performed for vague abdominal pain or unrelated reason. These tumors present a diagnostic dilemma, as some are benign, and do not require surgical resection. On the other hand, a substantial subset of these tumors is premalignant or frankly malignant. Imaging alone may not be sufficient to distinguish the category of lesions, and management options include: interval follow up, cyst aspiration and assessment, or definitive resection.

Primary duodenal tumors are uncommon. When amenable to surgical resection, the operative approach is predicated on tumor histology, stage, and location. In general, duodenal adenocarcinoma is treated similar to adenocarcinoma of the pancreatic head, with pancreaticoduodenectomy. Gastrointestinal stromal tumors (GISTs) and neuroendocrine tumors of the duodenum, on the other hand, may be amenable to local excision or segmental resection depending on tumor size and location. Special consideration is given to tumors of the ampulla or Vater, as local excision with septoplasty or pancreaticoduodenectomy may be appropriate, and surgeons must be comfortable with both approaches before taking patients with these tumors to the operating room. The duodenum is also subject to direct invasion by tumors originating in nearby structures, such as the colon, the right kidney, and the biliary tree. In these cases, operative planning must be individualized by resectability, patient fitness, and tumor biology.

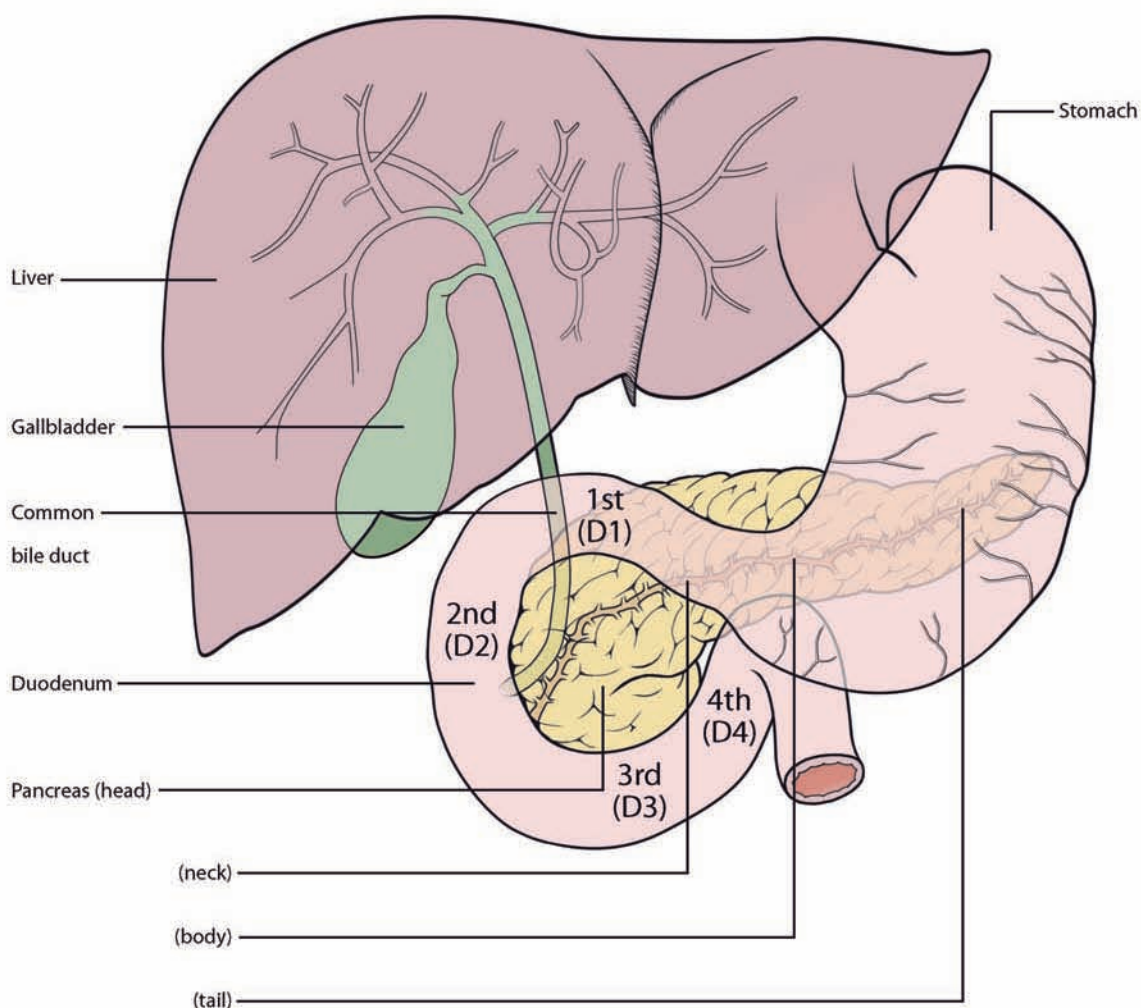
Preoperative evaluation of pancreatic and duodenal tumors has improved with the development of helical computed tomography (CT), magnetic resonance imaging (MRI) with magnetic resonance cholangiopancreatography (MRCP), and ultrasonography (endoscopic and intraoperative). These tools have increased diagnostic accuracy and improved preoperative planning. As a result, fewer patients are found to be unresectable at operation. Additional tools used selectively in the management of pancreatic and duodenal neoplasms include nuclear imaging, such as positron emission tomography (PET) and octreoscans, and staging laparoscopy to assess for metastatic disease. Endoscopic retrograde cholangiopancreatography (ERCP) and percutaneous transhepatic cholangiography (PTC) are more invasive methods of assessing this region, but can also be used to obtain diagnosis and relieve biliary obstruction.

This chapter will cover the anatomy, and the surgical methods applied to the pancreas and the duodenum, with emphasis on neoplastic disease. Laparoscopic approaches are provided for left pancreatectomy and enucleation, as they are being performed more commonly. Pancreaticoduodenectomy is being performed with minimally invasive techniques, but is not routine and will not be covered. Total pancreatectomy is rarely advocated, and will not be discussed. Consideration of preoperative and adjuvant therapies for a pancreatic and duodenal malignancy is beyond the scope of this text; however, increasing data are in support of both of these approaches. Surgeons operating on malignancies of these organs must be familiar with the multidisciplinary approach to their management, in order to provide patients suffering with these cancers the best possible results.

Surgical Anatomy

Topography Duodenum

The first portion of the duodenum (D1) is approximately 5 cm long, and passes upward from the pylorus to the neck of the gallbladder. It is related posteriorly to the common bile duct, portal vein, inferior vena cava, and gastroduodenal artery; anteriorly to the quadrate lobe of the liver; superiorly to the epiploic foramen; and inferiorly to the head of the pancreas. The first 2.5 cm is intraperitoneal and covered by the same two layers of peritoneum that invest the stomach. The hepatoduodenal portion of the lesser omentum attaches to the superior border of the duodenum while the greater omentum attaches to its inferior border. The distal 2.5 cm is retroperitoneal and covered with peritoneum only on the anterior surface; thus, the posterior surface is in intimate contact with the bile duct, portal vein, and gastroduodenal artery. The duodenum is separated from the inferior vena cava by a small amount of connective tissue.



The second (descending) portion (D2) is approximately 7.5 cm long. It extends from the neck of the gallbladder to the upper border of L4. D2 is crossed by the transverse colon and its mesocolon, and can be divided into supramesocolic segment and inframesocolic segment, both of which are entirely retroperitoneal and covered anteriorly by visceral peritoneum. The first and the second portions of the duodenum join behind the costal margin slightly above and medial to the tip of the ninth costal cartilage and on the right side of L1. D2 forms an acute angle with D1 and descends from the neck of the gallbladder anterior to the hilum of the right kidney, the right ureter, the right renal vessels, the psoas major muscle, and the edge of the inferior vena cava. D2 is related anteriorly to the right lobe of the liver, the transverse colon, and the jejunum. At about the midpoint of D2, the pancreaticobiliary tract opens into its concave posteromedial side. The right side is related to the ascending colon and the right colic flexure.

The third portion of the duodenum (D3, horizontal or inferior) is approximately 10 cm long, and extends from the right side of L3 or L4 to the left side of the aorta. D3 begins about 5 cm from the midline, to the right of the lower end of L3 at the level of the subcostal plane. It passes in a transverse pathway to the left, anterior to the ureter, right gonadal vessels, psoas muscle, inferior vena cava, lumbar vertebral column, and aorta, and ends to the left of L3.

The inframesocolic portion of the duodenum is covered anteriorly by the peritoneum. It is crossed anteriorly by the superior mesenteric vessels. Near its termination, it is crossed by the root of the mesentery of the small intestine. D3 is related superiorly to the head and uncinate process of the pancreas. The inferior pancreaticoduodenal artery lies in a groove at the interface of the pancreas and the duodenum. Anteriorly and inferiorly, this part of the duodenum is related to the small bowel, primarily to the jejunum.

D2 and D3 are overlapped by the head of the pancreas, and so there is a pancreatic bare area of the duodenum not covered by peritoneum. A second bare area exists on the anterior surface of D2, where the transverse colon is attached. With pancreatic cancer or pancreatitis, the pancreas and the mesocolon with its middle colic artery may become firmly fixed. The anatomic entities responsible for duodenal fixation are the pylorus, the superior mesenteric vessels, the ligament of Treitz, and the peritoneum.

The fourth portion of the duodenum (D4, ascending) is approximately 2.5 cm long and extends from the left side of the aorta to the left upper border of L2, and is directed obliquely upward, slightly to the left. It ends at the duodenojejunal junction (flexure) at the level of L2, at the root of the transverse mesocolon. This junction occurs approximately 4 cm below and medial to the tip of the ninth costal cartilage. The fourth portion is related posteriorly to the left sympathetic trunk, the psoas muscle, the left renal and gonadal vessels, the inferior mesenteric vein, the left ureter, and the left kidney. The upper end of the root of the mesentery also attaches here. The duodenojejunal junction is suspended by the ligament of Treitz, a remnant of the dorsal mesentery, which extends from the duodenojejunal flexure to the right crus of the diaphragm.

The suspensory ligament usually inserts on the duodenal flexure, and D3 and D4. It may insert on the flexure only, or on D3 or D4. There may also be multiple attachments. In almost one fifth of the cadavers, the ligament is absent.

Pancreas

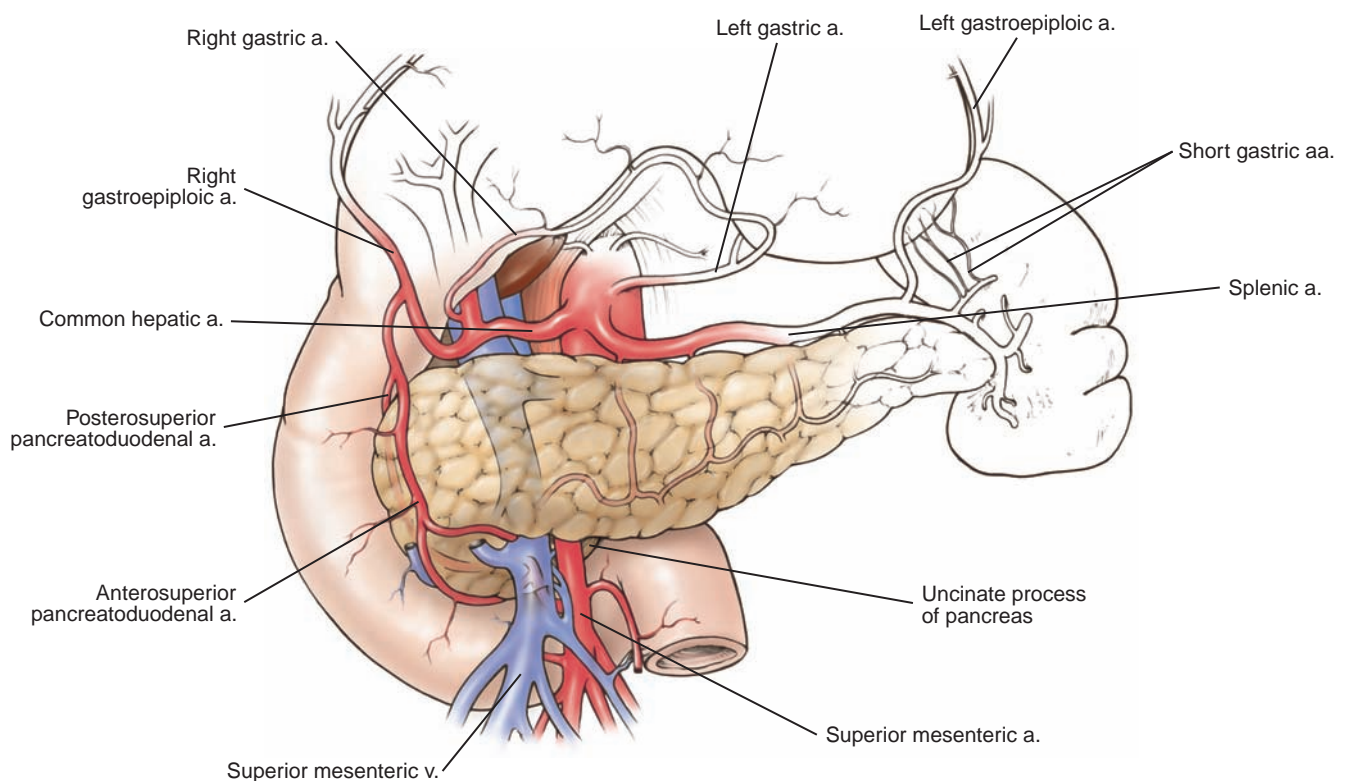
The pancreas is an elongated organ with a lobular surface extending from the C loop of the duodenum to the hilum of the spleen. The gland is retroperitoneal and divided topographically into the uncinata, head, neck, body, and tail. The head lies to the right of the second lumbar vertebra in apposition to the duodenum. The uncinata process lies posterior to the head, extends medially to lie beneath the superior mesenteric vessels, and contacts the vena cava posteriorly.

The neck is a narrowed 2.0–2.5-cm portion of the gland that lies directly over the superior mesenteric vein and beneath the first portion of the duodenum. Rarely are there vascular attachments between the neck and the superior mesenteric vein. Development of the plane between these structures is a critical step in performing pancreatic resection.

The body extends across the second lumbar vertebral body, anterior to the left kidney and tapers slightly cephalad into the tail, terminating in or near the splenic hilum.

The anterior surface of the pancreas is covered by the parietal peritoneum, which separates the gland from the stomach. The inferior surface abuts the transverse

Figure 12.3



mesocolon and is closely associated with the duodenojejunal junction. The splenic vein is imbedded by varying degrees in the posterior surface of the pancreas, and is occasionally completely encased by pancreatic tissue. The splenic artery runs a tortuous course along the superior edge of the gland.

Pancreatic Ducts

The pancreatic ductal system is formed by the fusion of two embryologic ductal systems. The main pancreatic duct originates in the tail and travels longitudinally through the gland to the head, where in most cases, it turns slightly caudally and posteriorly to its termination in the duodenal papilla. At the point of deviation of the duct, an accessory duct travels more directly through the head to the duodenum, terminating in the minor or lesser papilla. In a minority (10%) of patients, the ductal systems fail to fuse, and the accessory duct serves as the major drainage system for the gland. This anatomic variant constitutes the pancreas divisum. Tributaries to the main duct are generally at right angles to it, an arrangement upheld in the secondary and tertiary ducts as well.

Ampulla of Vater

The pancreatic duct and the bile duct terminate in the duodenum at the ampulla (papilla) of Vater. The major papilla is an elevation of the duodenal mucosa at the point where the common bile duct and the pancreatic duct enter the duodenum. It is usually 7–10 cm from the pylorus, but may be as close as 1.5 cm or as distant as 12 cm. The bile duct and the pancreatic duct typically join to form a common channel of varying length (the ampulla) within the papilla. In a minority of cases, the

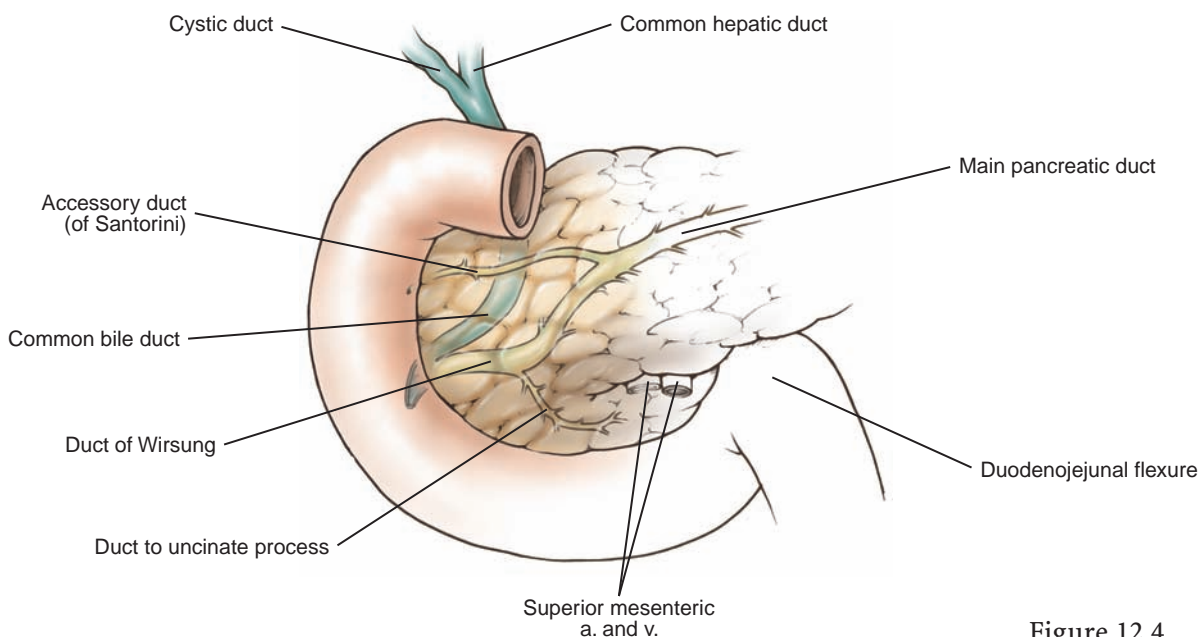
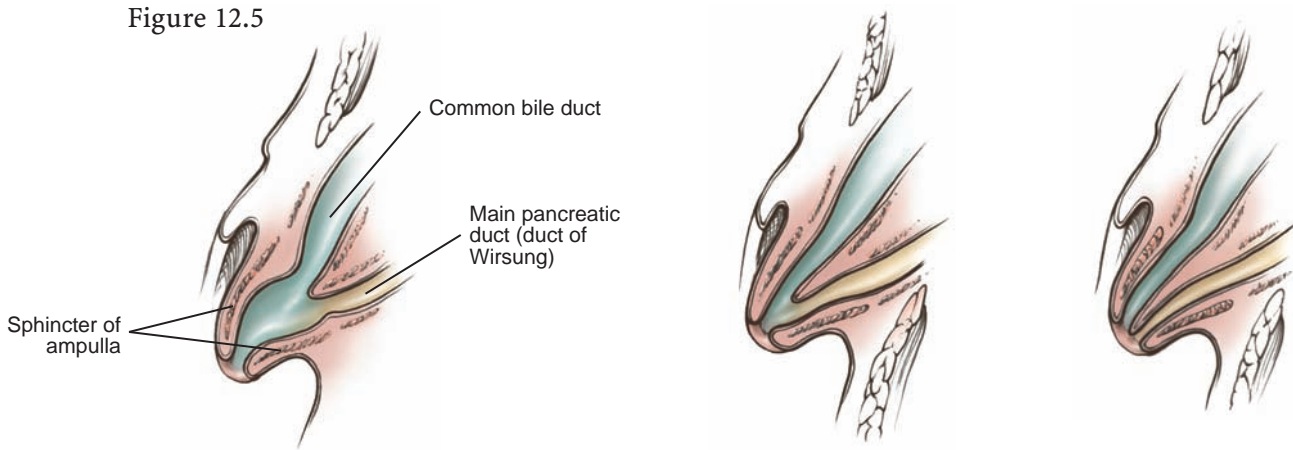


Figure 12.4

Figure 12.5



two ducts enter the duodenum separately through the papilla, in which case, the ampulla is said to be absent. In rare instances, the ducts may enter the duodenum via separate papillae. The minor papilla is present in approximately 70% of patients and lies slightly anterior and cephalad (approximately 2 cm) to the major papilla.

The following classification seems most useful:

Type 1 The pancreatic duct opens into the common bile duct at a variable distance from the opening in the major duodenal papilla. The common channel may or may not be dilated (85%).

Type 2 The pancreatic and bile ducts open close to one another but separately on the major duodenal papilla (5%).

Type 3 The pancreatic and bile ducts open into the duodenum at separate points (9%).

Variable distances between the pancreaticobiliary junction and the duodenal lumen result from developmental processes. In the embryo, the main pancreatic duct arises as a branch of the common bile duct, which in turn arises from the duodenum. Growth of the duodenum absorbs the proximal bile duct up to its junction with the pancreatic duct. When resorption is minimal, there is a long ampulla and the junction of the ducts is high in the duodenal wall (type 1), or even extramural. With increased resorption of the terminal bile duct, the junction lies closer to the duodenal orifice and the ampulla is shortened. Maximum resorption results in separate orifices for the main pancreatic duct and the common bile duct (type 3).

Major Duodenal Papilla

Endoscopically, the major papilla may be recognized at the junction of the transverse and the longitudinal fold of the duodenal mucosa (plica longitudinalis), which forms a T configuration. The orifice of the papilla is often filled with villus-like projections called valvulae.

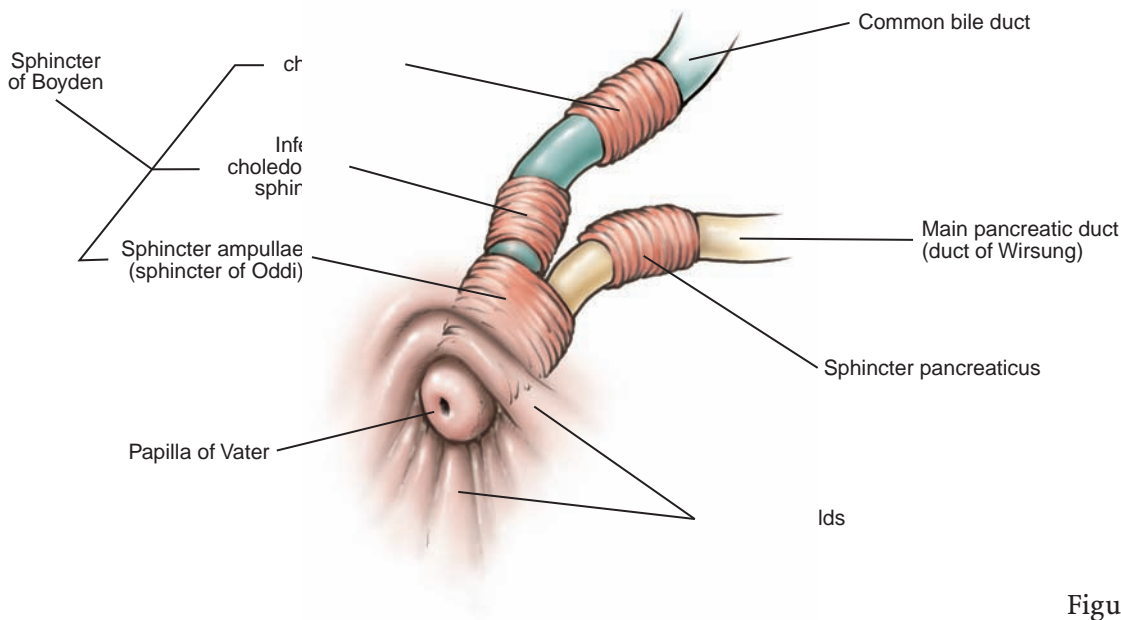


Figure 12.6

Like the papilla of Vater, the sphincter of Oddi at the duodenal end of the pancreatic and common bile ducts is misnamed. By priority of description, it should have been named after Francis Gilsson (1654), who described annular fibers around the entire intramural portion of the bile duct and believed that they guarded the opening against the reflux of duodenal contents.

The sphincter lies within the ampulla and is a complex series of muscular valves that work in conjunction with hormonal and neural signals to control secretion from the pancreatic and bile ducts. This sphincteric mechanism constitutes the narrowest portion of both, the biliary and pancreatic ductal systems and is the most common site of stone-related obstruction.

Minor Duodenal Papilla

The minor papilla is about 2 cm cranial and slightly anterior to the major papilla. The accessory pancreatic duct (of Santorini) opens through the minor papilla, which is smaller and less easily identified than the major papilla. The most useful landmark is the gastroduodenal artery, behind which lie the accessory duct and the minor papilla. Duodenal dissection for gastrectomy should end proximal to the artery.

The minor papilla may contain either no duct at all or only a microscopic, tortuous channel. A true sphincter (of Helly) is rarely present. In about 10% of patients, the duct of Santorini is the only duct draining most of the pancreas. Accidental ligation of this duct, together with the gastroduodenal artery, could result in catastrophic pancreatitis.

Blood Supply Arteries

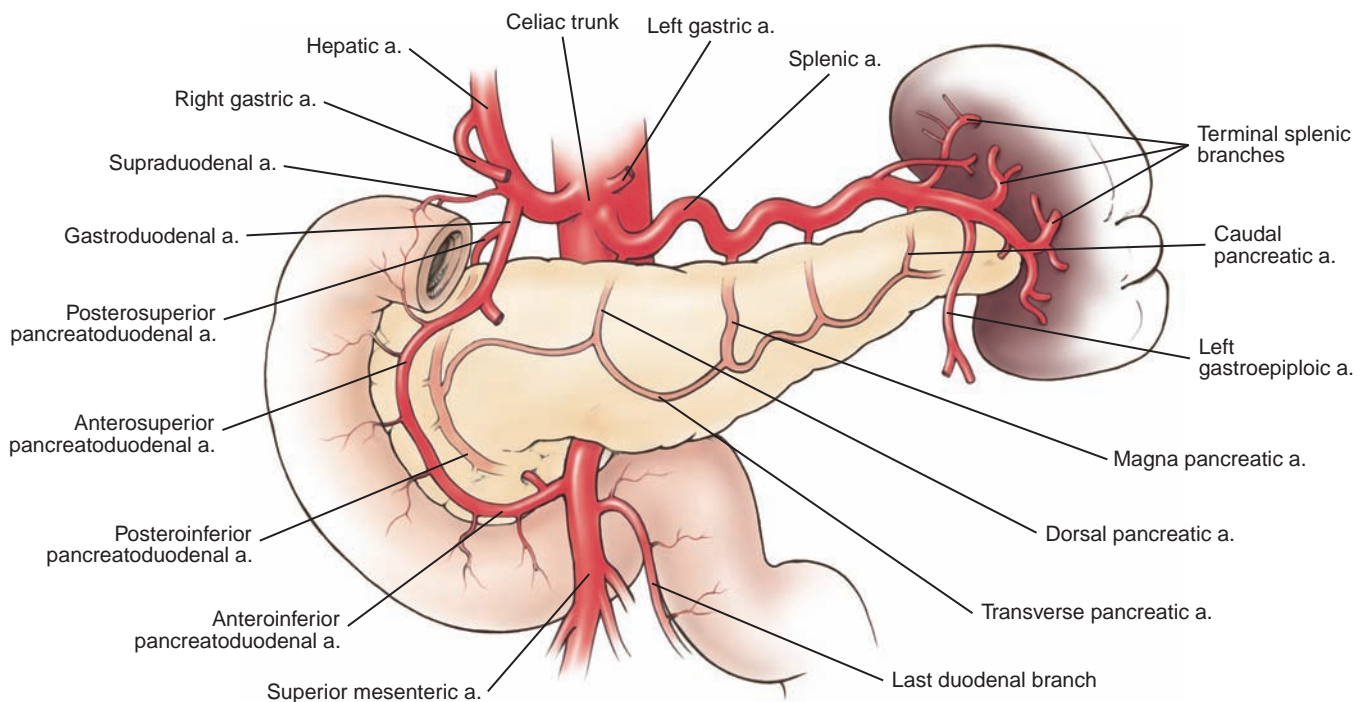
The blood supply of the pancreas and the duodenum is confusing because of the diverse possibilities of origin, distribution, and individual variations. This is especially true in the case of the blood supply of D1.

D1 is supplied by the supraduodenal artery and the posterosuperior pancreaticoduodenal branch of the gastroduodenal artery (retroduodenal artery of Edwards, Michel, and Wilkie), which is a branch of the common hepatic artery. In many patients, the upper part of the first 1 cm is also supplied by branches of the right gastric artery. In some patients, there may be separate small branches to the superior and posterior aspects of D1. These can be properly called the supraduodenal and the retroduodenal, respectively. Each may arise separately or in various combinations. It is preferred, therefore, that the term retroduodenal not be used as a synonym for the posterosuperior pancreaticoduodenal artery, the principal role of which is to supply the second part of the duodenum and the pancreatic head.

After giving rise to the supraduodenal, retroduodenal, and posterosuperior pancreaticoduodenal branches, the gastroduodenal artery descends between the first part of the duodenum and the head of the pancreas. It terminates by dividing into the right gastroepiploic and anterosuperior pancreaticoduodenal arteries, both supplying twigs to this part of the duodenum.

The remaining three parts of the duodenum are supplied by an anterior and a posterior arcade. Pancreatic and duodenal branches emanate from these arcades. Those supplying the duodenum are called arteriae rectae, and they may be embedded in the substance of the pancreas.

Figure 12.7



The pancreas has an extremely rich blood supply from varied sources, the most major of which comes from the branches of the gastroduodenal, superior mesenteric, and splenic or celiac arteries. Numerous smaller tributaries arise from the splenic, hepatic, and gastroduodenal arteries.

The gastroduodenal artery is critical to any discussion of pancreatic arterial anatomy. It arises from the hepatic artery approximately 2 cm from its origin and passes medially and inferiorly to the common bile duct, where it slips beneath the first portion of the duodenum and across the anterior surface of the pancreatic head. The anterosuperior pancreatoduodenal artery is a continuation of the gastroduodenal artery and passes downward and through the sulcus between the duodenum and the pancreas. It continues and anastomoses with the inferior pancreatoduodenal artery along the medial surface of the duodenum. The posterosuperior pancreatoduodenal artery branches from the gastroduodenal artery at the superior border of the pancreas and traverses posteriorly behind the pancreas, crossing medially to anastomose with the posteroinferior pancreatoduodenal artery.

Two other major arterial branches supplying the body and the tail of the pancreas are the inferoanterior and the inferoposterior pancreatoduodenal arteries. These two arteries arise from the superior mesenteric artery, or one of its primary branches, and form an arcade that supplies the duodenojejunal junction and portions of the pancreatic neck.

The superior dorsal pancreatic artery is somewhat inconsistent, but when present, arises from either the celiac or the splenic artery, and courses along the superior border of the body and the tail of the pancreas. The inferior transverse pancreatic artery is fairly constant and arises from either the superior mesenteric artery, the superoanterior pancreatoduodenal artery, or the superior dorsal pancreatic artery, and passes through the body of the pancreas along the inferior margin of the gland.

The body and the tail of the gland receive numerous branches from the splenic artery as it courses along the superior border of the gland.

There are surgically significant arterial anomalies. The most common major anomaly is the origin of the right hepatic artery from the superior mesenteric artery. When this occurs, the artery passes through, or posterior to, the pancreatic head and enters the porta hepatic, posterior and lateral to the common bile duct. More rarely, the common hepatic artery may arise from the superior mesenteric artery and travel anteriorly, posteriorly, or through the pancreatic substance to the porta hepatis. Recognition of these anomalies is critical during pancreaticoduodenal resection and certain hepatobiliary procedures. When either artery travels posterior to the head of the gland, it can usually be dissected free and preserved. When an anomalous artery passes through the substance of the gland, it will be sacrificed and may need to be reconstructed via reimplantation in the common hepatic artery or the gastroduodenal artery, or grafted into the aorta. A sound principle is to test clamp these vessels with noncrushing vascular clamps, prior to ligation.

Veins

The subpyloric veins, which are the veins of the lower first part of the duodenum and the pylorus, usually open into the right gastroepiploic veins. The upper first part of

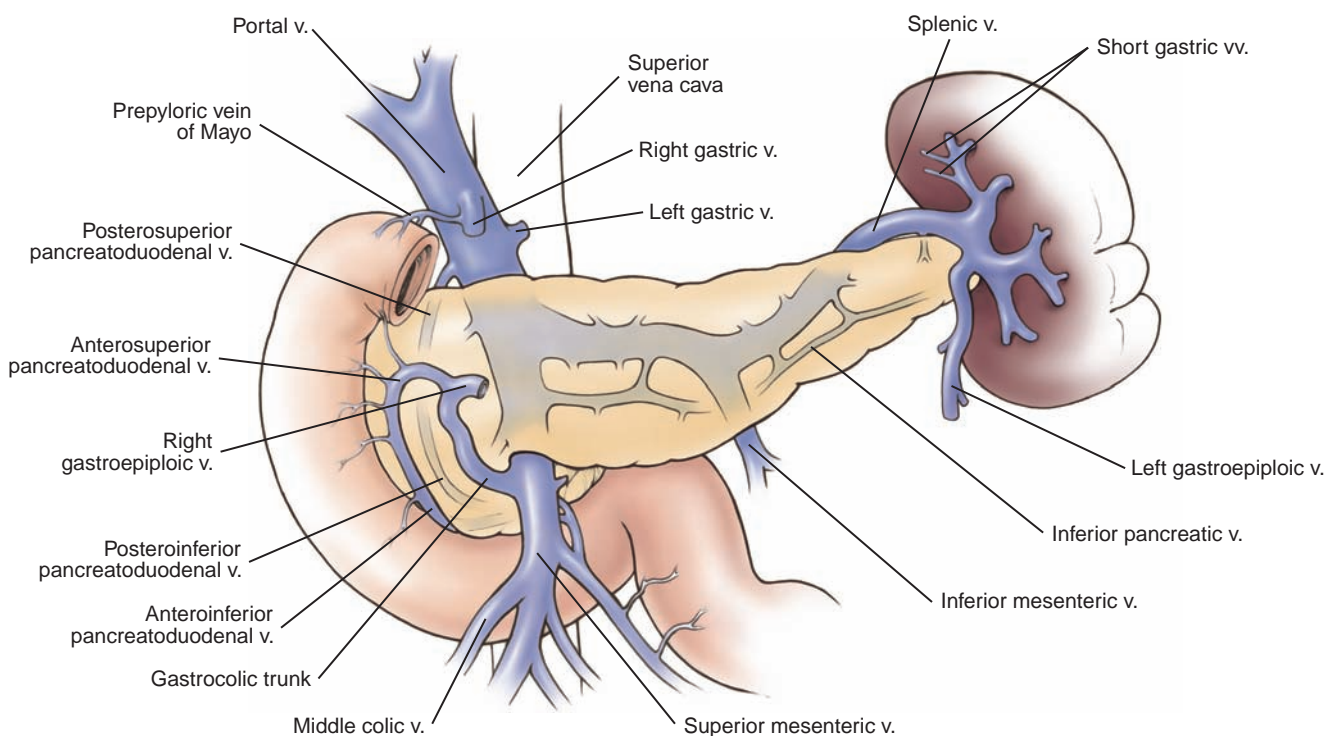


Figure 12.8

the duodenum is drained by suprapyloric veins, which open into the portal vein or the posterosuperior pancreaticoduodenal vein. Anastomoses between subpyloric and suprapyloric veins pass around the duodenum. One of these has been said to mark the site of the pylorus (prepyloric vein of Mayo). However, it is not a consistent indicator of the location of the pylorus.

The venous arcades draining the duodenum follow the arterial arcades and tend to lie superficial to them. The anterosuperior vein drains into the right gastroepiploic vein. The posterosuperior vein usually passes behind the common bile duct to enter the portal vein. The inferior veins can enter the superior or the inferior mesenteric vein, the splenic vein, or the first jejunal branch of the superior mesenteric vein. The veins may terminate separately or by a common stem.

The superior mesenteric vein, the splenic vein, and the portal vein are intimately associated with the pancreas. The anterior surface of the superior mesenteric vein passes directly beneath the neck of the gland and receives branches only rarely. The splenic vein receives numerous branches from the body and the tail of the pancreas along its course to its junction with the superior mesenteric vein, beneath the neck of the gland. The inferior mesenteric vein is constant in its course, but variable in its drainage into either the splenic vein or the superior mesenteric vein. The left gastric (coronary) vein is constant in its course along the lesser curve of the stomach, but terminates at the splenoportal junction or along the portal vein some distance from the splenoportal junction. This trunk is ligated for exposure of the anterior surface of the pancreas.

The head of the gland is drained via an arcade of venous structures forming the anterosuperior pancreaticoduodenal vein and the anteroinferior pancreaticoduodenal

veins. The former receives numerous duodenal tributaries and passes upward and medially from the duodenojejunal junction to enter the gastroduodenal trunk. The latter passes medially through the substance of the pancreas, joining a jejunal tributary of the superior mesenteric vein. The posterior aspect of the head is drained by two significant veins, the posterosuperior and posteroinferior pancreaticoduodenal veins. The superior vein courses behind the bile duct and wraps medially to drain directly into the portal vein, and the inferior vein passes around the superior mesenteric vein and drains into its first duodenojejunal tributary.

The right gastroepiploic vein courses along the greater curvature of the stomach between the two leaves of the gastroduodenal ligament and curves downward where it joins the superior mesenteric vein, just below the neck of the pancreas. The right gastroepiploic vein is significant because it is joined, near its insertion into the superior mesenteric vein, by the inferosuperior duodenal vein and one or more colic veins. This short but relatively broad attachment is called the gastroduodenal trunk.

The superior portion of the neck and body of the pancreas is drained through multiple short tributaries into the splenic vein. The inferior portions are drained by a relatively constant inferior pancreatic vein, which courses along the inferior border of the body of the gland, and commonly empties into either side of the superior mesenteric vein.

Major anomalies of the pancreaticoduodenal venous drainage are unusual. However, particular care must be paid to rare but anomalous connections of the neck of the pancreas to the portal vein, via short tributaries. In addition, when mobilizing the pancreas from the anterior surface of the superior mesenteric vein, short but relatively wide tributaries directly into the vein from the uncinate process are often encountered and must be evaluated and ligated with care to avoid avulsing them from the superior mesenteric and/or portal veins.

The duodenum is richly supplied with lymphatic vessels. They originate as blind-ending vessels (lacteals) in each villus of the mucosa. These vessels form a plexus in the lamina propria and pierce the muscularis mucosae to form a second submucosal plexus. Yet another lymphatic plexus lies between the circular and longitudinal layers of the muscularis. Collecting trunks pass over the anterior and the posterior duodenal wall toward the lesser curvature to enter the anterior and posterior pancreaticoduodenal lymph nodes.

The anterior extramural collecting ducts drain into the nodes anterior to the pancreas. The posterior ducts pass to the nodes posterior to the head of the pancreas. The ducts follow the veins and the arteries to the nodes related to the superior mesenteric artery.

Within the duodenal wall are the two well-known neural plexuses of the gastrointestinal tract, each of which is composed of groups of neurons interconnected by networks of fibers. One plexus (of Meissner) is in the submucosa; another plexus (of Auerbach) is in the connective tissue between the circular and longitudinal layers of muscularis externa. Some of the neuronal cells bodies and processes in the plexuses

Lymphatic Drainage

Nerve Supply

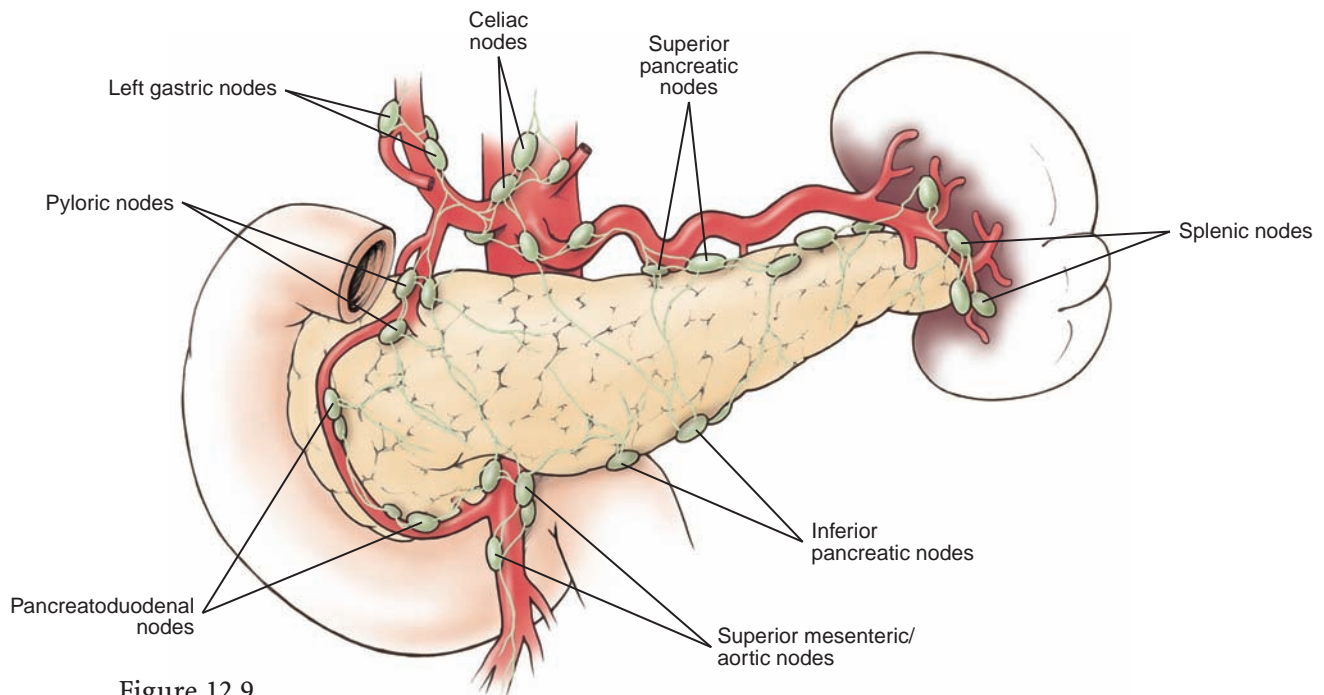


Figure 12.9

are assumed to be postganglionic parasympathetic fibers; however, recent studies indicate that many are related to the circuitry for processing information received from various types of sensory receptors, synaptic complexes for directing neural outflow, and interconnecting neurons.

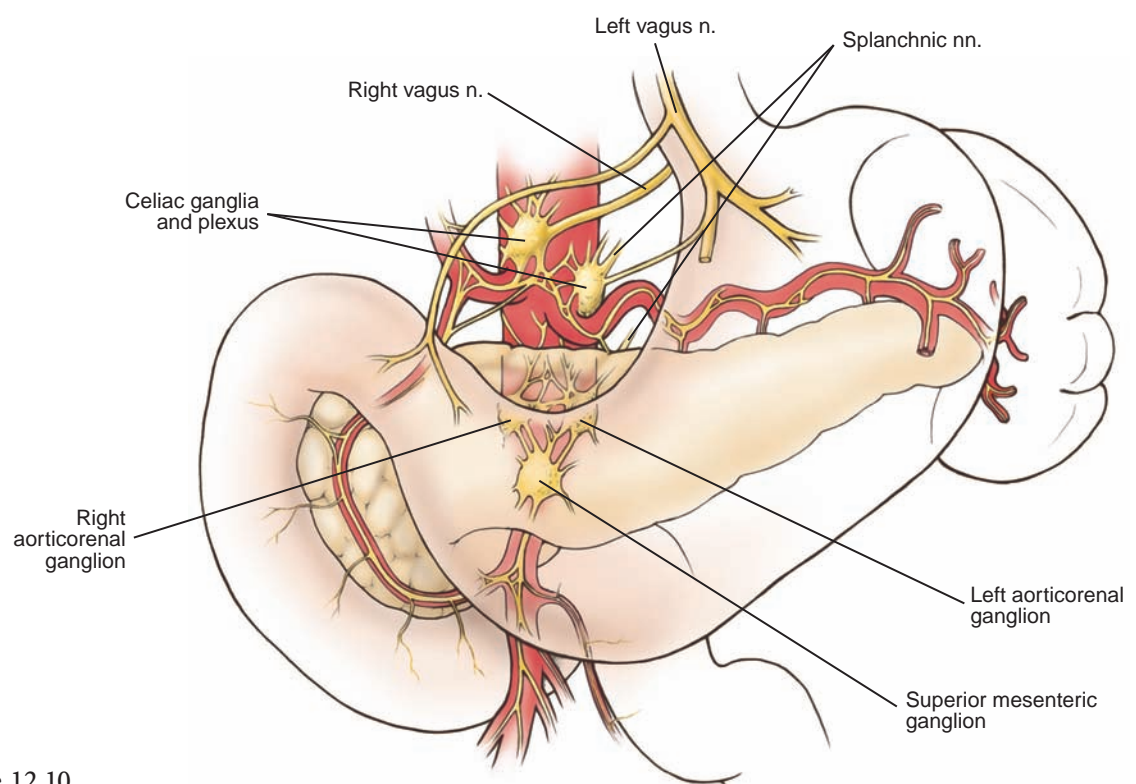


Figure 12.10

The preganglionic parasympathetic fibers in the plexuses are carried initially by the vagus nerves. The postganglionic sympathetic fibers arise from cell bodies located in the celiac and superior mesenteric plexuses, and perhaps, the upper thoracic sympathetic chain ganglia also. The extrinsic nerve supply to the duodenum probably includes contributions that leave the anterior hepatic plexus close to the origin of the right gastric artery. In unusual cases, nerves from the hepatic division of the anterior vagal trunk give rise to one or more branches that innervate the first part of the duodenum. In most specimens, some branches can be traced upward to the gastric incisura.

Innervation of the pancreas largely accompanies the vascular structures. Sympathetic fibers travel via the celiac ganglion, where preganglionic efferent fibers pass before reaching the pancreas. The sympathetic efferent fibers are located in the dorsal root ganglia T10 through T12 which is an important concept in consideration of operations to relieve pain from chronic pancreatitis or pancreas exocrine cancer. The parasympathetic fibers invade the pancreas via the vagus nerve and have their cell bodies in the brain.

Surgical Applications

Several incisions provide adequate access to the pancreas and the duodenum including the vertical midline, right or left subcostal, bilateral subcostal, and a vertical midline with a low transverse extension to the left or right (a.k.a. *hockey stick*). Most procedures can be performed via a vertical midline, which helps to avoid cutting through the abdominal wall musculature. Bulky tumors of the pancreatic head may be better served by a right subcostal or bilateral subcostal approach, while large tumors of the tail may require a left subcostal approach. The low transverse extension off the midline offers the possibility of starting with a vertical midline, and extending the incision to the left or right, if more exposure is necessary.

The laparoscopic approach for focal tumor enucleation and left pancreatectomy, with or without splenectomy, offers patients superior cosmetic results with possible shorter hospital stay and faster recovery. Enucleations are best performed with the patient supine, on a split table or in lithotomy (French position). Ports are placed adhering to the principles of triangulation according to tumor location. Examples are provided for lesions in the head and the tail. Laparoscopic left pancreatectomy can be performed with the patient in supine or in “lazy” right-lateral decubitus position on a bean-bag with axillary roll and arm support. Port placement can be arranged with or without a hand access port. Hand ports are placed in the midline, above or at the umbilicus. Two 12-mm ports are placed in the left subcostal region. This is ideal to switch transection device and camera with ease. An additional 5-mm port can be placed in the lateral position to aid in splenic retraction during division of the short gastric vessels, if necessary.

Incisions

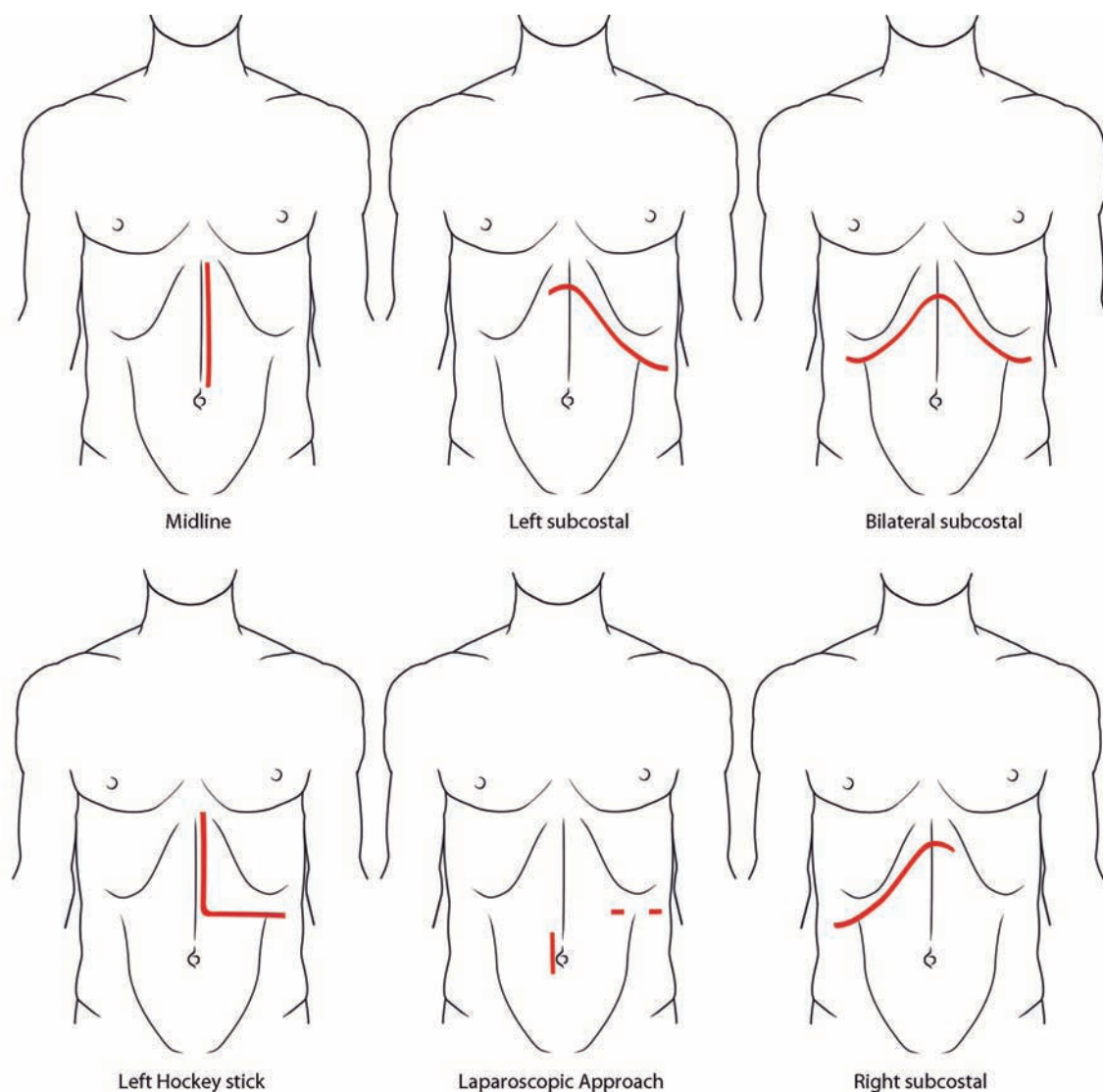


Figure 12.11

Exposure of the Pancreas

The majority of the pancreas can be accessed by entering the lesser sac. This can be accomplished by traversing the anterior leaf of the greater omentum along the greater curvature of the stomach, or by dissecting the omentum off its attachments to the transverse colon, and coming through the posterior leaf. When possible, the gastro-epiploic vessels should be preserved. Tissue transection proceeds between clamps and ties, or with newer devices such as ultrasonic dissectors (e.g., harmonic scalpel) or thermal shears (e.g., Ligasure device). Upon opening the lesser sac, it is often necessary to dissect through the natural adhesions between the posterior wall of the stomach and the anterior surface of the pancreas to expose the gland adequately.

Cattell-Brasch Maneuver

Use of the Cattell-Brasch maneuver may provide improved exposure of the superior mesenteric vein, the vena cava, and the pancreatic head. The lateral reflection of the right colon (white line of Toldt) and the hepatic flexure are mobilized, and the entire

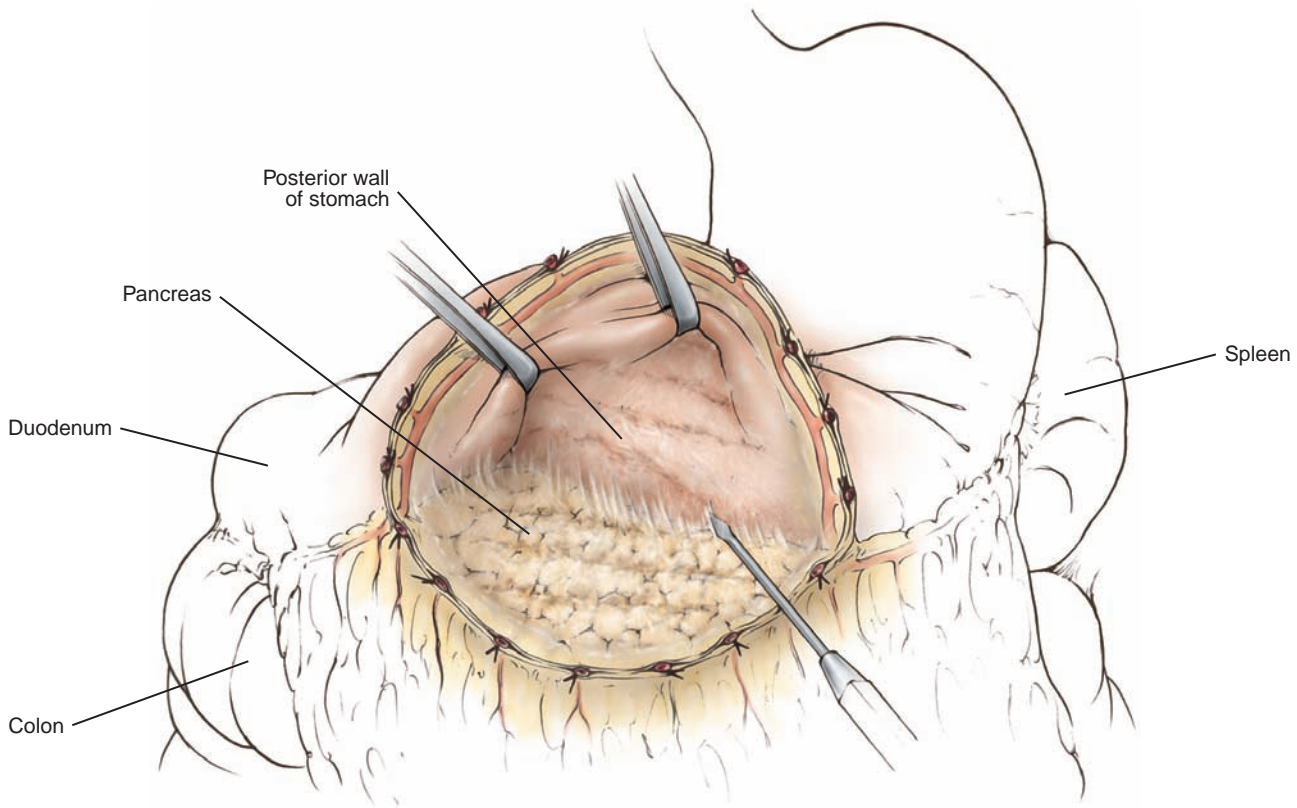


Figure 12.12

right colon is retracted inferomedially. Dropping the splenic flexure of the colon is usually necessary for procedures involving the pancreatic body and tail. Transection of the short gastric vessels must be performed if splenectomy is intended. It is wise to keep the majority of these vessels intact, to optimize splenic blood supply, if splenic preservation is preferred. If the splenic artery and vein must be divided, it is still possible to salvage the spleen on the short gastric vessels alone, if they are preserved (Warshaw technique).

The Kocher maneuver provides exposure of the posterior pancreatic head and lateral and posterior duodenal walls. It also allows access to the retropancreatic lymph nodes and to the inferior vena cava. To perform this maneuver, the hepatic flexure of the colon must be dropped, and the peritoneal reflection of the duodenum incised lateral to the common bile duct, and along the second and third portions of the duodenum. Gentle medial retraction of the duodenum and the pancreatic head exposes the inferior vena cava. This maneuver can be extended to expose the aorta, left renal vein and right gonadal vein. The surgeon should be able to palpate the strong pulse of the superior mesenteric artery on the posterior surface of the pancreatic neck.

Kocher Maneuver

Exposure of the third portion of the duodenum, proximal to the superior mesenteric vessels can be obtained by an incision through the transverse mesocolon (being cautious not to injure the right and middle colic vessels), an incision through the gastrocolic omentum, or reflection of the right half of the colon.

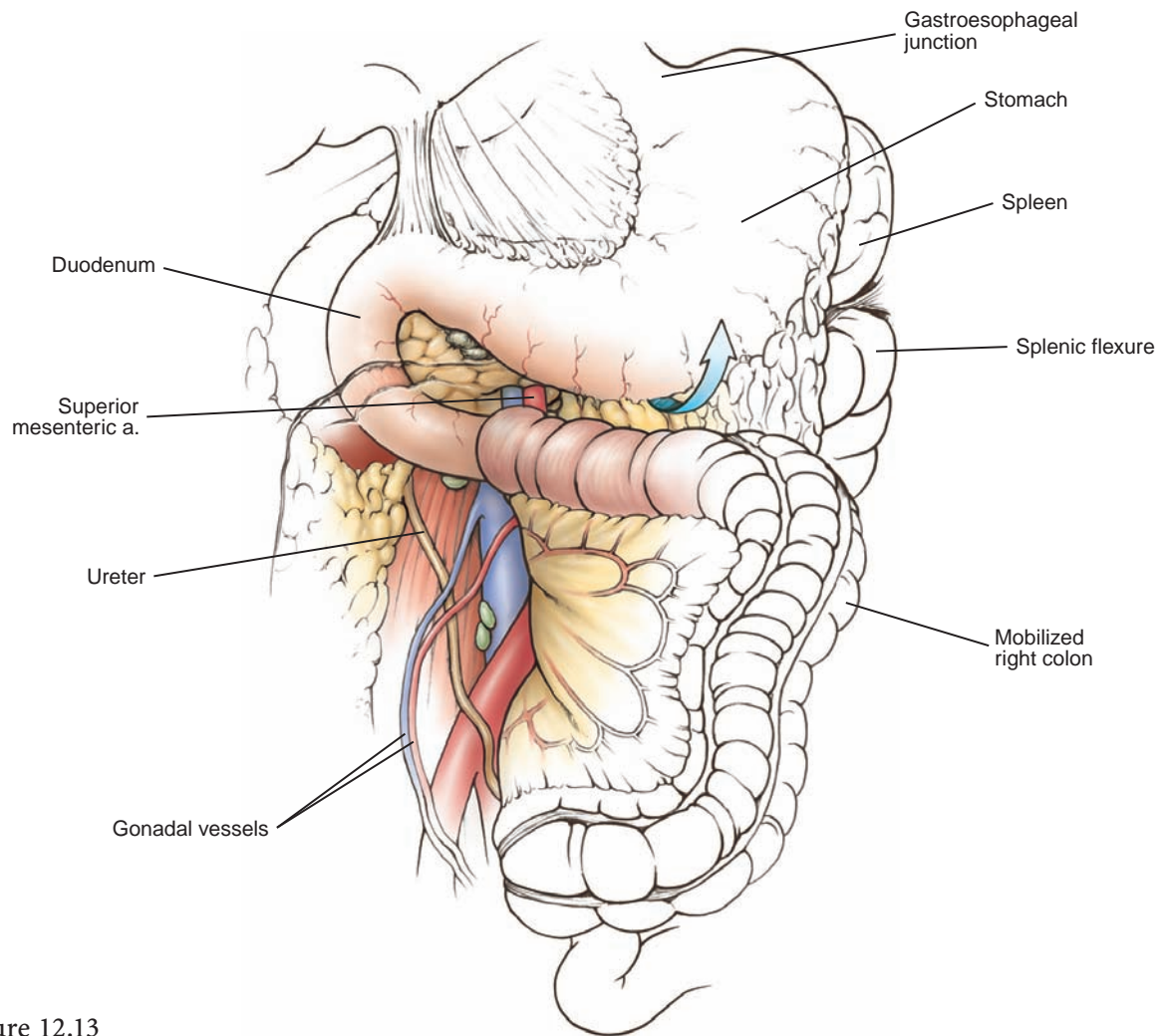


Figure 12.13

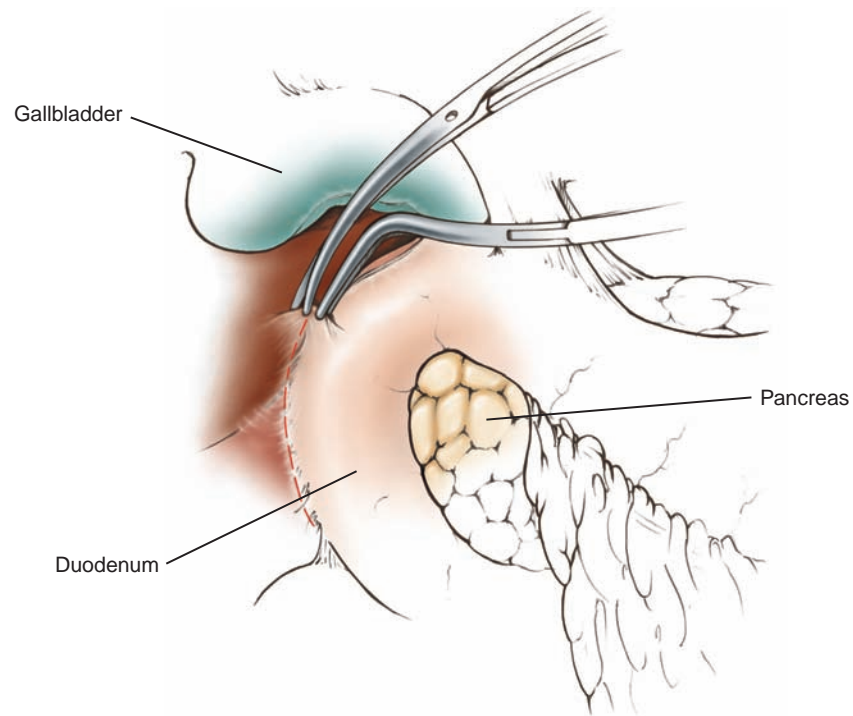


Figure 12.14

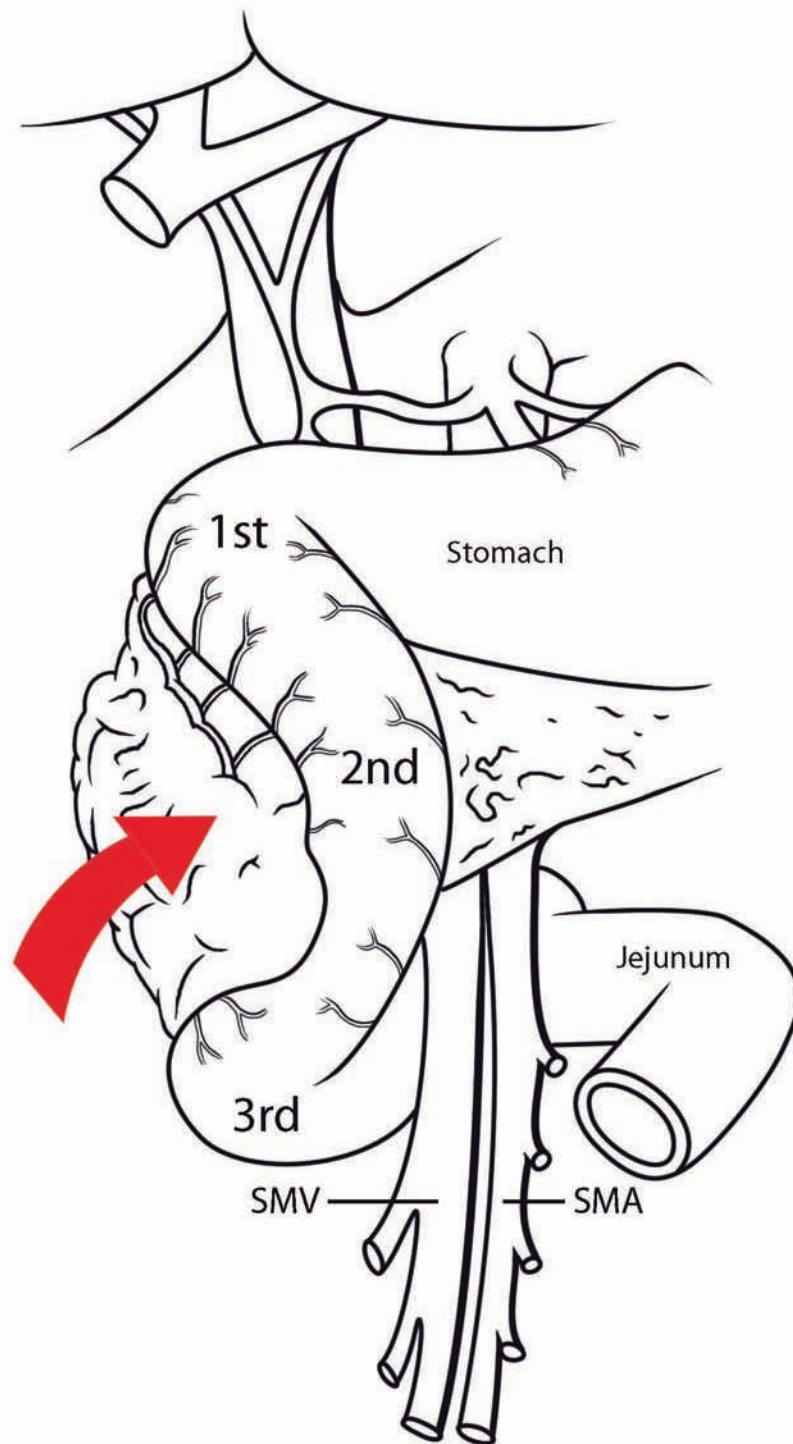


Figure 12.14

Exposure of the duodenum distal to the superior mesenteric vessels can be accomplished by incising through the gastrocolic omentum and dropping the transverse colon, or by lifting the transverse colon and identifying the ligament of Treitz. Careful dissection through the suspensory ligament exposes the inferior mesenteric vein to the left of the distal duodenum and allows safe mobilization of this portion of the duodenum and proximal jejunum.

Transduodenal Biopsy of the Pancreas

Technique: Transduodenal biopsy of the pancreas is accomplished through either a midline or a right subcostal incision; usually at the time of exploration for intended resection. The hepatic flexure of the colon is mobilized as described earlier, and the Kocher maneuver performed, allowing the surgeon to rotate the C loop of the duodenum anteromedially. In doing so, the posterior aspect of the pancreas can be palpated. The lesion in question may be imaged ultrasonographically, or simply palpated. When identified by either of the approaches, a Tru-cut or fine needle is introduced through a very small incision made with a small blade in the lateral duodenal wall and into the lesion, from where samples are taken as desired. Care should be taken to avoid introducing the needle into the main mesenteric vessels and the needle should not be allowed to penetrate the anterior or posterior surfaces of the gland. For fine-needle aspiration, the needle is directed into the area in question, and multiple passes are made through the tumor under negative pressure. The plunger is allowed to return to resting position and the needle is withdrawn. The contents of the needle are deposited on a glass slide, fixed, stained, and evaluated. This technique may have little value in a scirrhous lesion or in a gland that has had recurrent bouts of pancreatitis. If additional passes are desired, the same small lateral duodenotomy is used, but the trajectory of the biopsy needle is changed slightly. Finally, the incision site along the duodenal wall is over sewn with a Lembert suture to prevent leakage of the duodenal contents. Tru-cut biopsy permits better assessment of tissue architecture, but is associated with slightly more hemorrhagic complications.

Indication: As in all cases, biopsies should be performed only when the results will impact patient management, including the necessity for enrollment on clinical trials. The pancreatic head can often be accessed percutaneously or via endoscopic

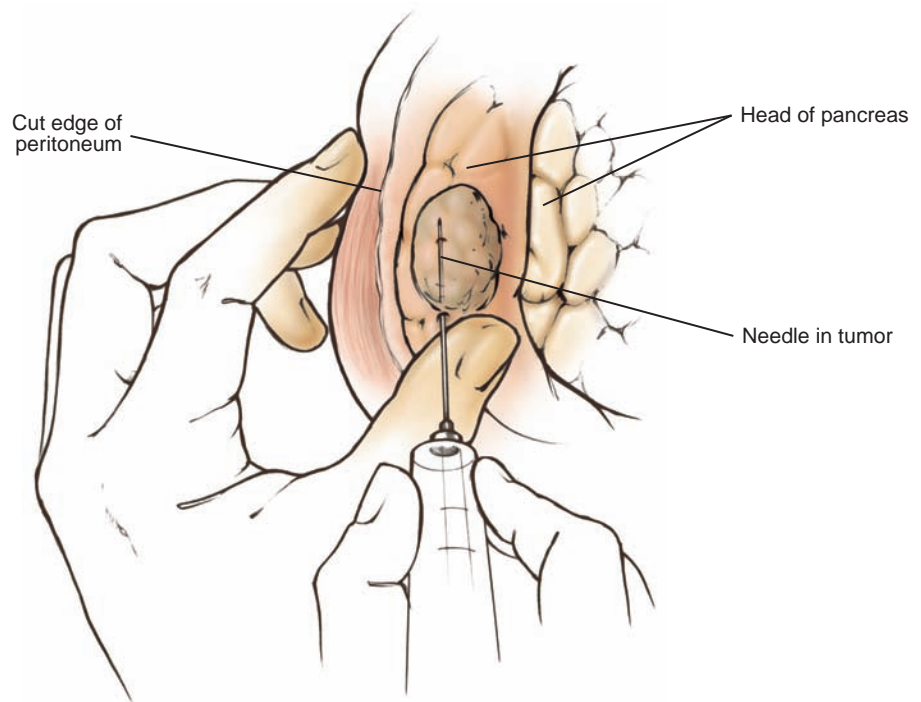


Figure 12.15

evaluation with concomitant ultrasonography and biopsy; therefore, transduodenal biopsy is not commonly performed. Furthermore, resection without tissue diagnosis is often appropriate for masses in the pancreatic head. Reasonable indications for transduodenal biopsy include: incidental findings of a pancreatic head mass during laparotomy, or for definitive histologic diagnosis, when locally advanced, unresectable disease is encountered at operation. It is also important to remember that no biopsy method is 100% accurate.

The pain associated with pancreatic cancer can be daunting and disabling. Theories behind the pathogenesis of this pain include, direct nerve infiltration by tumor cells, pancreatic duct distention secondary to obstruction, development of peripancreatic neuritis, and sensory neural stretch secondary to bulky retroperitoneal tumor burden. The celiac plexus comprises the neural ganglia surrounding the regions of the celiac axis and the superior mesenteric artery together with their pre- and post-

Intraoperative Celiac Plexus Block

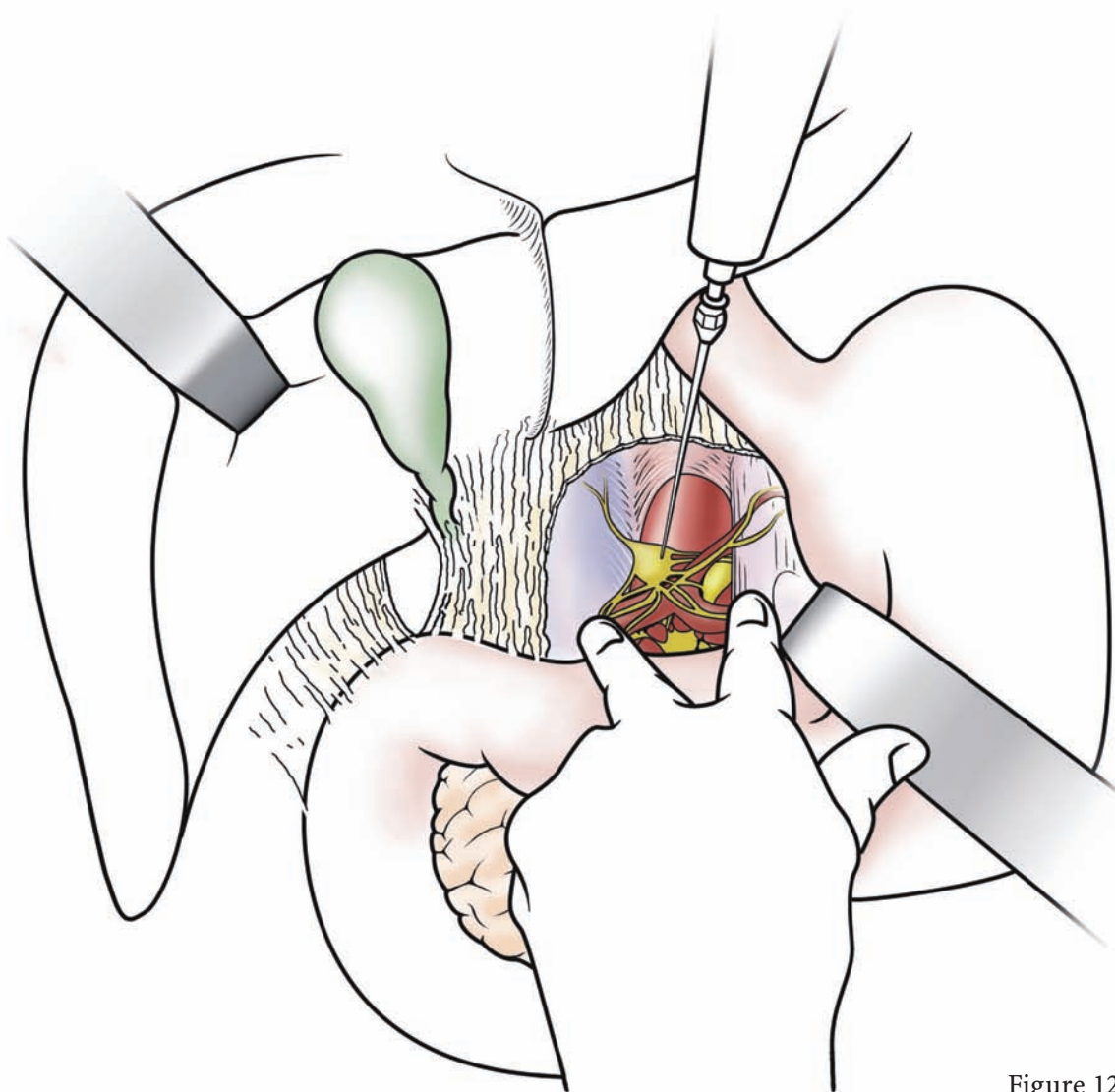


Figure 12.16

ganglionic fibres. Blockade of this neural network can provide substantial relief for patients suffering from advanced pancreatic cancer. While percutaneous approaches to celiac plexus blockade are the most common, the surgeon should be comfortable with the intraoperative technique in symptomatic patients where resection proves impossible or inappropriate.

Approach: A description of celiac plexus anatomy is provided earlier in this chapter. Important anatomic landmarks for this procedure include the common hepatic artery and the splenic artery, to either side of the aorta. The surgeon places the index and the middle finger of his/her left hand on the splenic and hepatic arteries respectively. Ten milliliter of 50% ethanol are injected into the para-aortic tissue above and below these vessels. Importantly, the peritoneal covering over these areas should be left intact to contain the neurolytic solution. One approach is to prepare four 10-mL syringes with the neurolytic solution and administer each dose with a 20-gauge spinal needle to optimize delivery in even the deepest patients. Aspiration prior to injection is important to minimize the risk of inadvertent intravenous delivery.

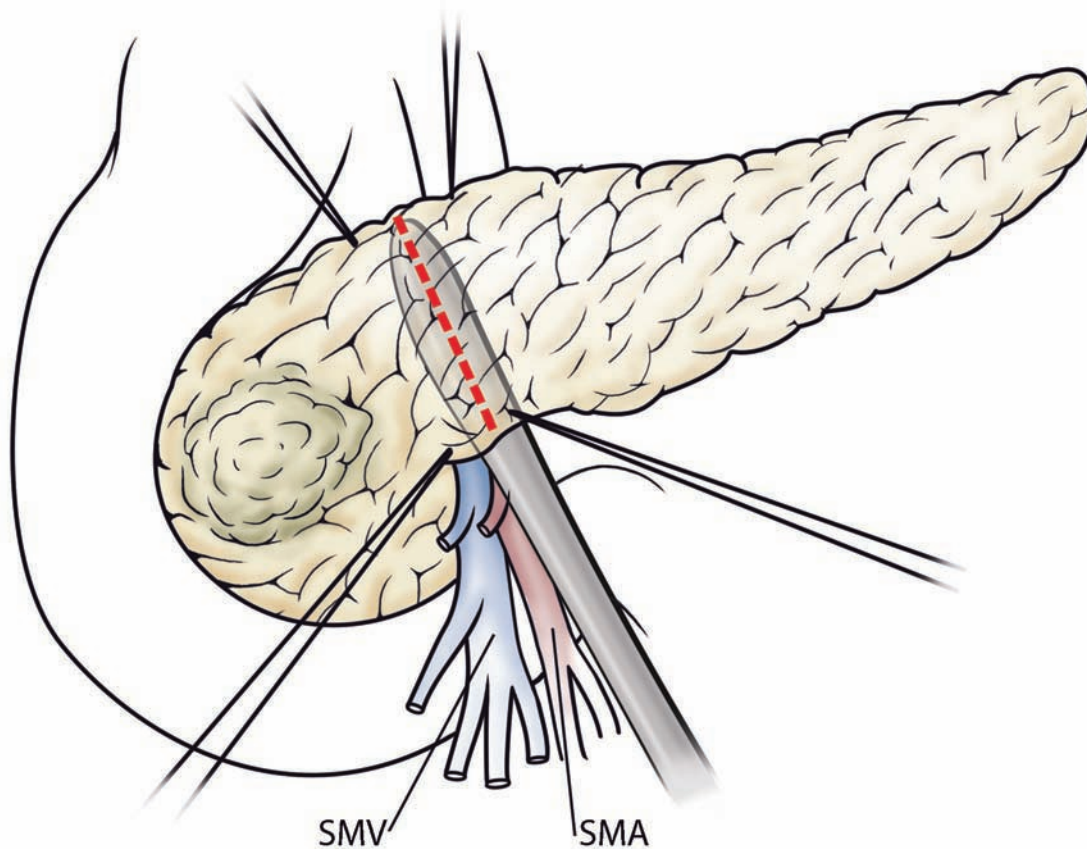
Pancreaticoduodenectomy with Hemigastrectomy (Whipple Procedure)

As with many complex oncologic procedures, pancreaticoduodenectomy can be broken down into three steps: assessment, resection, and reconstruction. The following notes represent the basic steps of this operation, but an experienced pancreatic surgeon may vary the order to suit a particular clinical situation.

Assessment: Diagnostic laparoscopy may precede formal laparotomy in patients with questionable findings on preoperative imaging. At laparoscopy, the peritoneal cavity is examined for suspicious lesions on all accessible surfaces. Biopsies are sent for frozen section; if metastatic deposits are found in this manner, laparotomy can be avoided and the patient can go home the same day. If no evidence of metastatic disease is encountered, the laparoscopic equipment is handed off, and the abdomen is opened.

Following midline or bilateral subcostal incision, four quadrant exploration of the abdomen is performed to rule out metastatic disease from the peritoneal surfaces, the liver, the omentum, and direct extension into the transverse mesocolon. Biopsies are sent if suspicious lesions are found. If biopsies confirm metastatic disease, then a biliary and/or gastrointestinal bypass is/are performed.

Once distant metastases are ruled out, the surgeon assesses for locoregional invasion. The gastrohepatic ligament is divided, and the Kocher maneuver performed. The goal is to identify the plane between the superior mesenteric vein and the pancreatic neck. This is usually best approached along the inferior border of the pancreas, by following the middle colic vein away from the transverse colon, or by continuing the Kocher maneuver over to the third portion of the duodenum. The vein is covered by a thin layer of adventitial tissue, which is incised down to the plane of Leriche on the venous wall. Division of the venous branches from the uncinate process of the pancreas facilitates exposure, and reduces the chance of accidentally tearing these veins. Once the plane is started, upward retraction of the pancreatic neck with a vein retractor allows the surgeon to dissect this space further with a blunt Kelly clamp or suction tip.



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The hepatic artery lymph node is removed, giving exposure to the common hepatic artery. The right gastric artery is transected, providing access to the gastroduodenal artery. It is crucial to test clamp this vessel prior to ligation, and confirm the flow in the left and right hepatic arteries. Anomalous celiac arterial anatomy is present in 40–50% of cases, and occasionally, the common hepatic artery originates off the superior mesenteric artery. Accidental ligation of a completely replaced common hepatic artery may result in catastrophic hepatic necrosis and patient death. More commonly, an accessory or replaced right hepatic artery will run along the retroperitoneal margin and the right posterior aspect of the bile duct. Once confirmed, ligation of the gastroduodenal artery is best performed with permanent suture to limit the likelihood of a gastroduodenal artery stump rupture. Once the gastroduodenal artery is divided, dissection is continued down to the main portal vein. Now the plane under the pancreatic neck can be completed from above and below, indicating clearance off the SMV-portal vein confluence. If the pancreas is inseparable from the portal vein secondary to tumor invasion, the surgeon must decide if en bloc venous resection is appropriate for the patient (discussed below). Up to this point the surgeon has not committed to performing the pancreaticoduodenectomy, but having confirmed resectability, he can now proceed.

Resection: Attention is now turned to the common bile duct. The adventitial tissue overlying the porta hepatis is incised and the duct identified by palpation of an

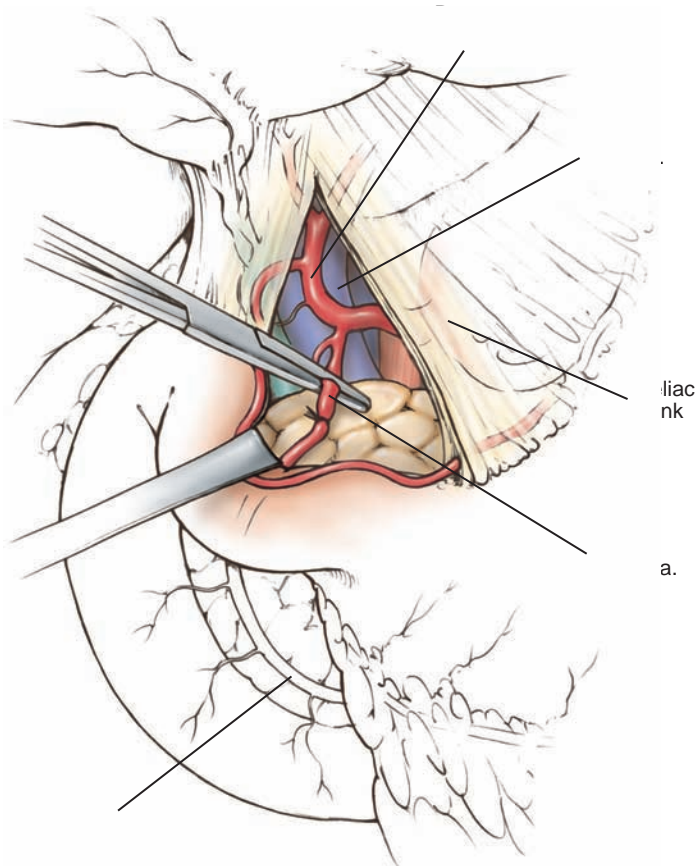


Figure 12.18

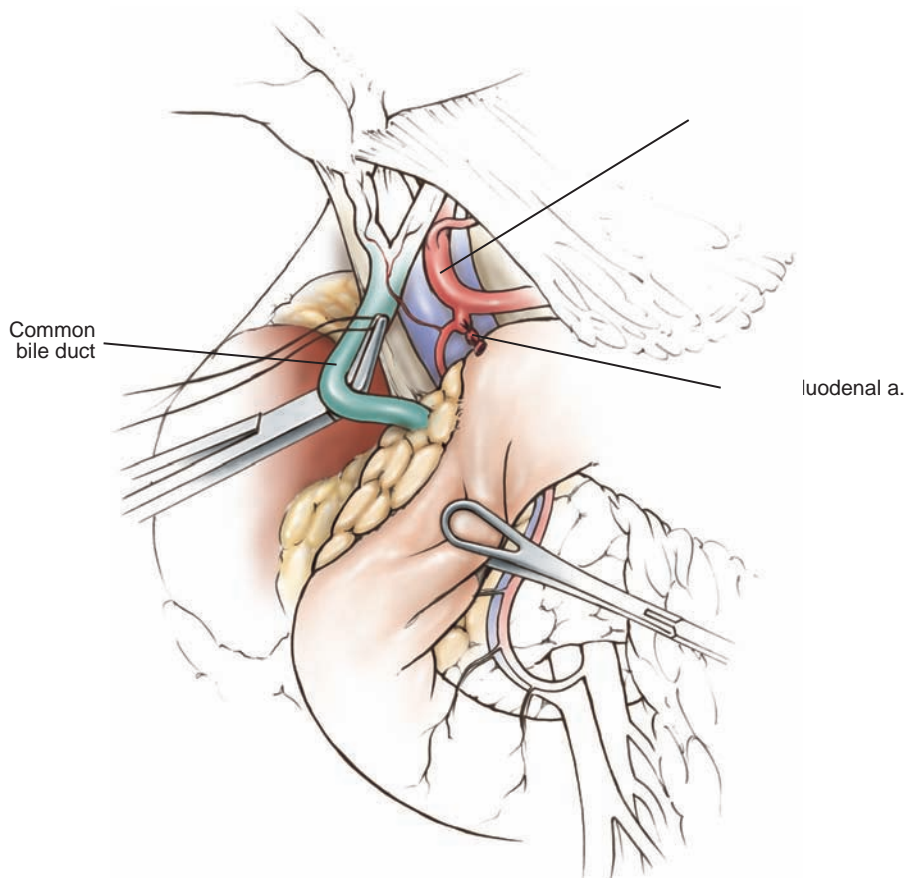


Figure 12.19

indwelling stent, by aspiration of bile with a skinny needle, or by appearance and location. Periportal tissues are divided between clamps and tied to limit lymphatic leaks, and any nodal tissue encountered is taken en bloc with the specimen. The gallbladder (if present) is mobilized off the liver, and the cystic duct is followed to the common bile duct, which is encircled and transected. A portion of the common duct is sent for frozen section analysis. The distal duct is over sewn and a culture of the bile is sent for the identification of potential pathogens that may affect the postoperative course.

After making sure that the nasogastric tube has been withdrawn appropriately, a linear stapling device is used to transect the stomach from the middle of the greater curve to the angularis incisura on the lesser curve. The proximal stomach is then placed behind retractors for later anastomosis.

The jejunum is transected with a linear stapler, approximately 15 cm distal to the ligament of Treitz, and the proximal jejunal vessels are divided with ties, clips, staplers or shears. The proximal end is mobilized back to the duodenal-jejunal junction, and the third and fourth portions of the duodenum are dissected off the retroperitoneum. This allows the duodenum to be passed under the superior mesenteric artery and vein, and over to the right side of the abdomen.

The pancreas is now transected with a knife or cautery, taking care to identify the main pancreatic duct and protect the superior mesenteric vein. It is helpful to place four stay sutures in a figure-of-eight around the pancreatic neck for traction and control prior to transection. Hemorrhage is controlled with sutures or cautery while being careful to avoid injury to the distal pancreatic duct.

The specimen is now anchored only by the retroperitoneal attachments of the medial uncinate process. Various methods are described for completing the dissection along this plain. It is important to dissect the portal vein off the uncinate process with care, otherwise the venous branches may get torn, resulting in substantial blood loss. These may be transected using multiple clamps and ligatures, clips, staplers, or shears. Once the vein is free, it is crucial to stay along the superior mesenteric artery to maximize the retroperitoneal margin. Pancreaticoduodenal arterial branches may be encountered during this dissection and can bleed substantially, but are usually readily identified and controllable. The specimen is then sent to pathology for gross and microscopic evaluation. It is a good practice for the surgeon to orient the specimen for the pathologist, and to demonstrate the retroperitoneal margin.

If extended node dissection is desired, then the retropancreatic tissue over the vena cava and aorta, and porta-caval nodes are taken. They can either be resected en bloc with the main specimen or as a separate specimen, while waiting on results of the pancreatic margin.

Reconstruction: There are numerous techniques described for all the three (pancreatic, biliary, intestinal) anastomoses. Some of the more common are described.

Reconstruction typically begins with the pancreatic anastomosis. Pancreaticojejunostomy is most often performed in an end-to-side fashion; two techniques are described here. Using either a running or interrupted technique, the capsule (with some parenchyma) of the pancreas is sewn to the seromuscular layer of the jejunum

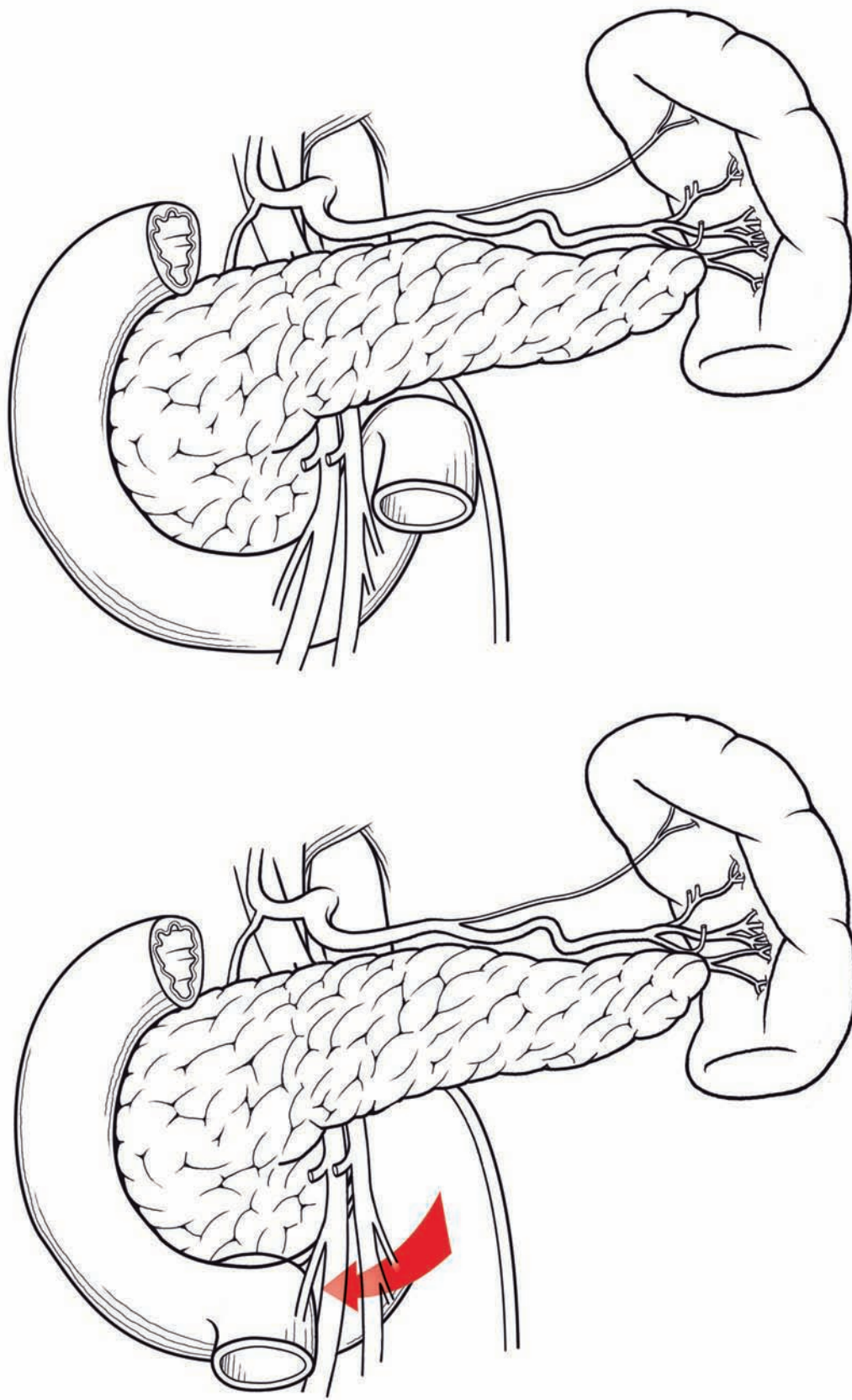


Fig. 12-10

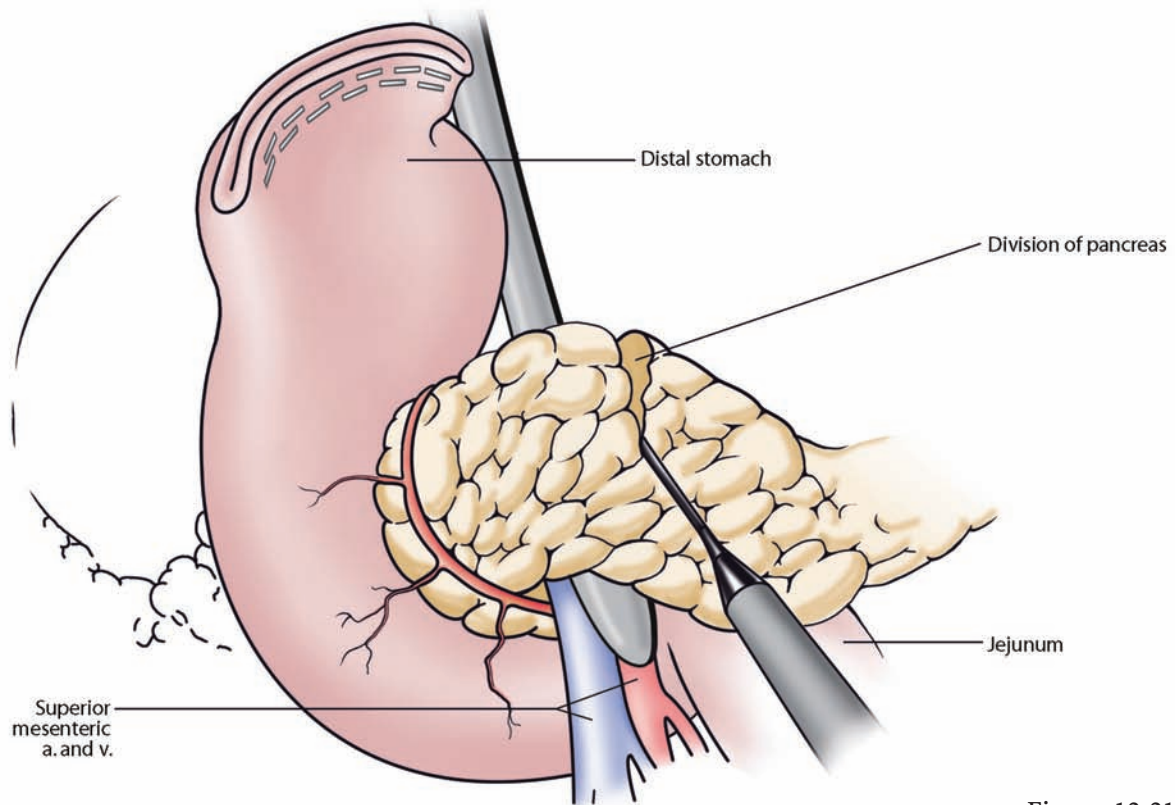


Figure 12.21

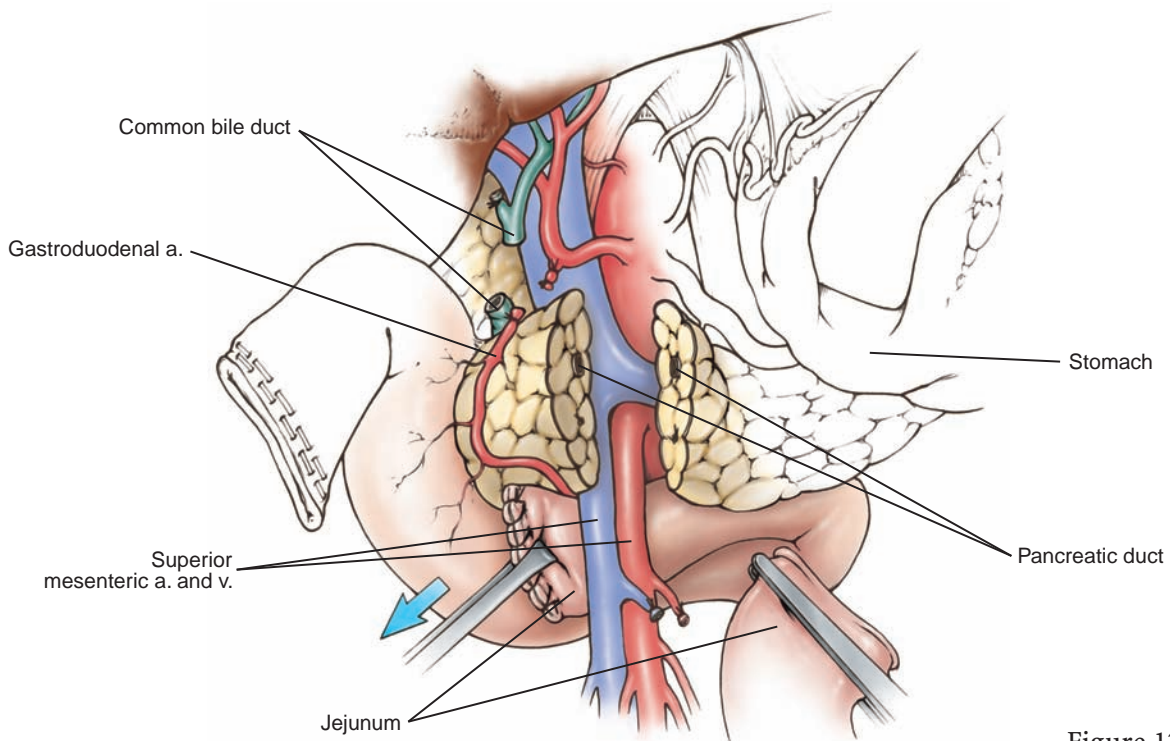


Figure 12.22

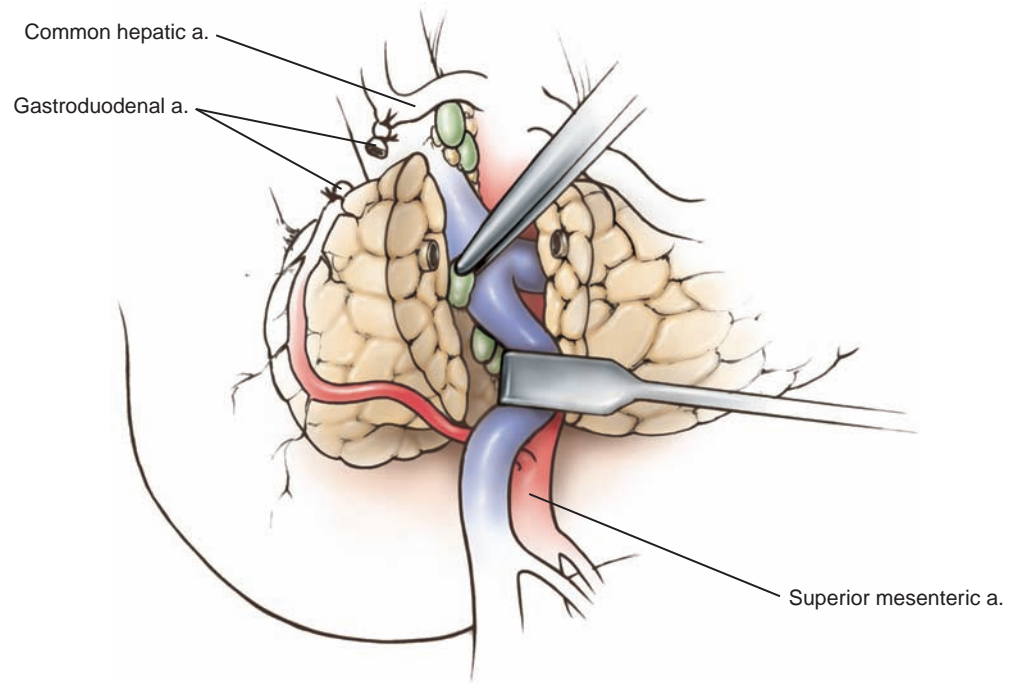


Figure 12.23

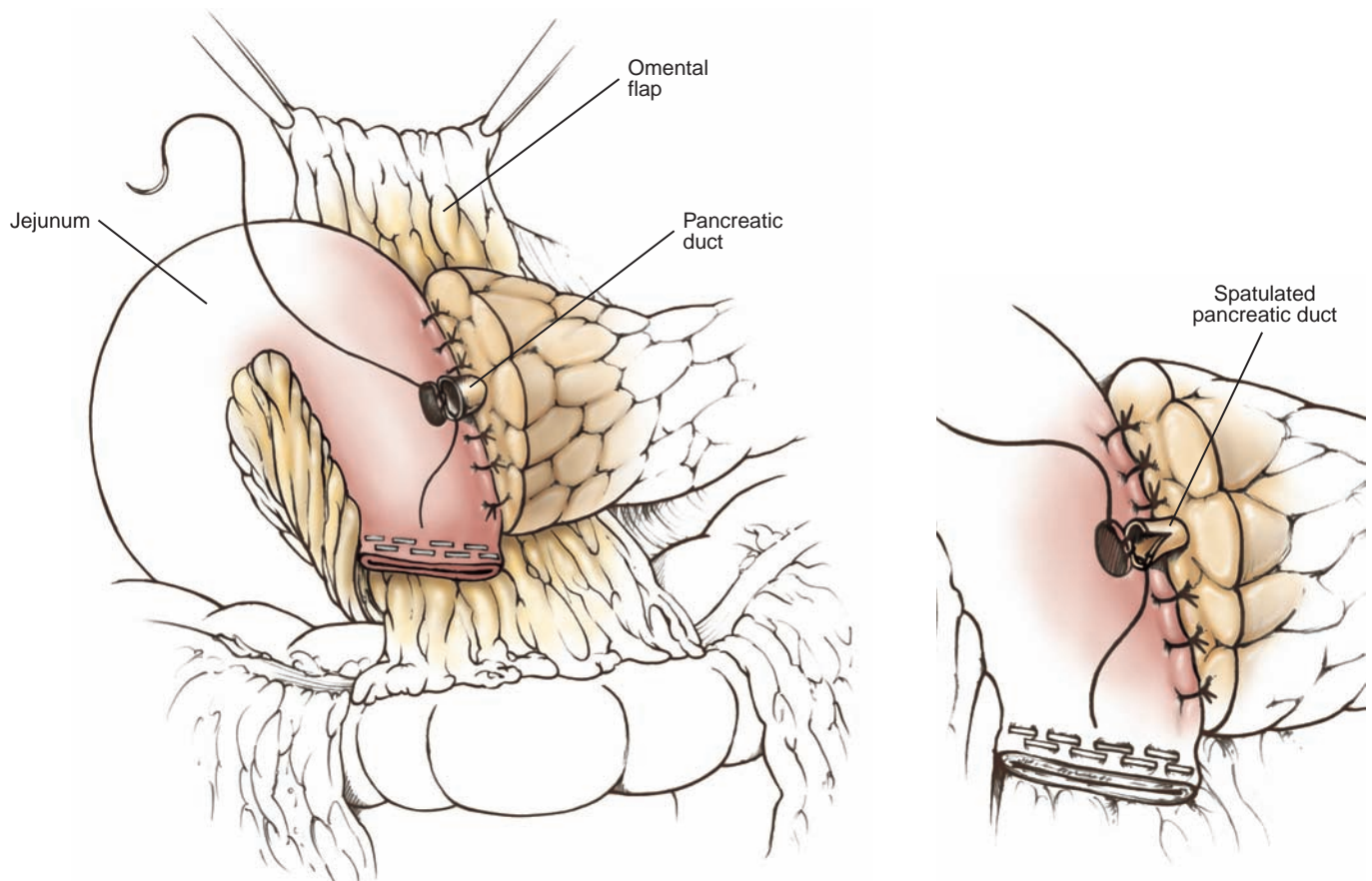


Figure 12.24

with silk or absorbable suture. Care should be taken to avoid obstructing the pancreatic duct which is usually relatively posterior and closer to the superior pancreatic border. The bowel is pierced with cautery opposite the duct, and double-armed 5-0 absorbable, monofilament sutures are used to sew the mucosa of the pancreatic duct to full thickness bowel wall using six to eight sutures in a circumferential manner. Another approach is to score the bowel wall from end-to-end of the suture line to encourage apposition of the pancreatic cut surface to the mucosal layer of the bowel. After tying down the duct-to-mucosa sutures, an anterior row is sewn from the pancreatic capsule to the bowel wall to complete the anastomosis. For small ducts, a portion of a 5-French pediatric feeding tube can be used as a stent.

Alternatively, the pancreatic stump may be dunked into the jejunum. It is important to mobilize the pancreatic stump adequately for dunking. A running suture line of absorbable or nonabsorbable suture is placed from the capsule of the pancreas along the posterior wall to the seromuscular layer of the bowel. It is important not to incorporate the cut edge of the gland (or the end will not dunk), and to take shallow bites in the region of the pancreatic duct to avoid structuring. After the posterior wall is sewn, an incision is made in the bowel along the length of the cut face of the pancreas, parallel to the posterior suture line. Next, a running suture line is placed on the posterior wall again, but this time from the cut surface of the pancreas to the cut surface of the bowel. This is continued anteriorly and circumferentially. Finally, an anterior suture line is run from the anterior pancreatic capsule to the anterior seromuscular layer of the bowel, completing the invagination process. This technique can be awkward at times, depending on the thickness and the fat content of the pancreas, and the size and the edema of the bowel. It is best to communicate with the anesthesia team to minimize fluid administration during the case, thereby limiting bowel edema. Multiple variations of the above techniques have been described including pancreaticogastrostomy (discussed further in section on central pancreatectomy). It is important to be comfortable with more than one technique and to use the method best suited for tissue quality and exposure.

As with the pancreatic anastomosis, there are several options for choledochojejunostomy, depending on duct diameter and tissue integrity. The most common technique is to join these structures in an end-to-side fashion, approximately 10–20 cm downstream from the pancreaticojejunostomy. Since most bile ducts are dilated in this circumstance, a running, single-layer technique is reasonable with absorbable suture. A jejunotomy is made in the appropriate location, and the back wall is sutured from medial to lateral, tying the suture line at both the ends. The anterior row is then sutured in the same fashion. The anterior edge may be spatulated (at 12 o'clock) for additional luminal diameter.

Blumgart and Kelly developed a practical technique for smaller ducts. They described placing interrupted sutures in the anterior wall inside out from 3 o'clock to 9 o'clock, leaving the needles on for later use. The posterior wall is sewn either interrupted or running, with the bile duct held open by gentle traction on the anterior sutures. When using the interrupted technique, the jejunum is parachuted down to the bile duct after the posterior row sutures are placed. Now, the anterior sutures are

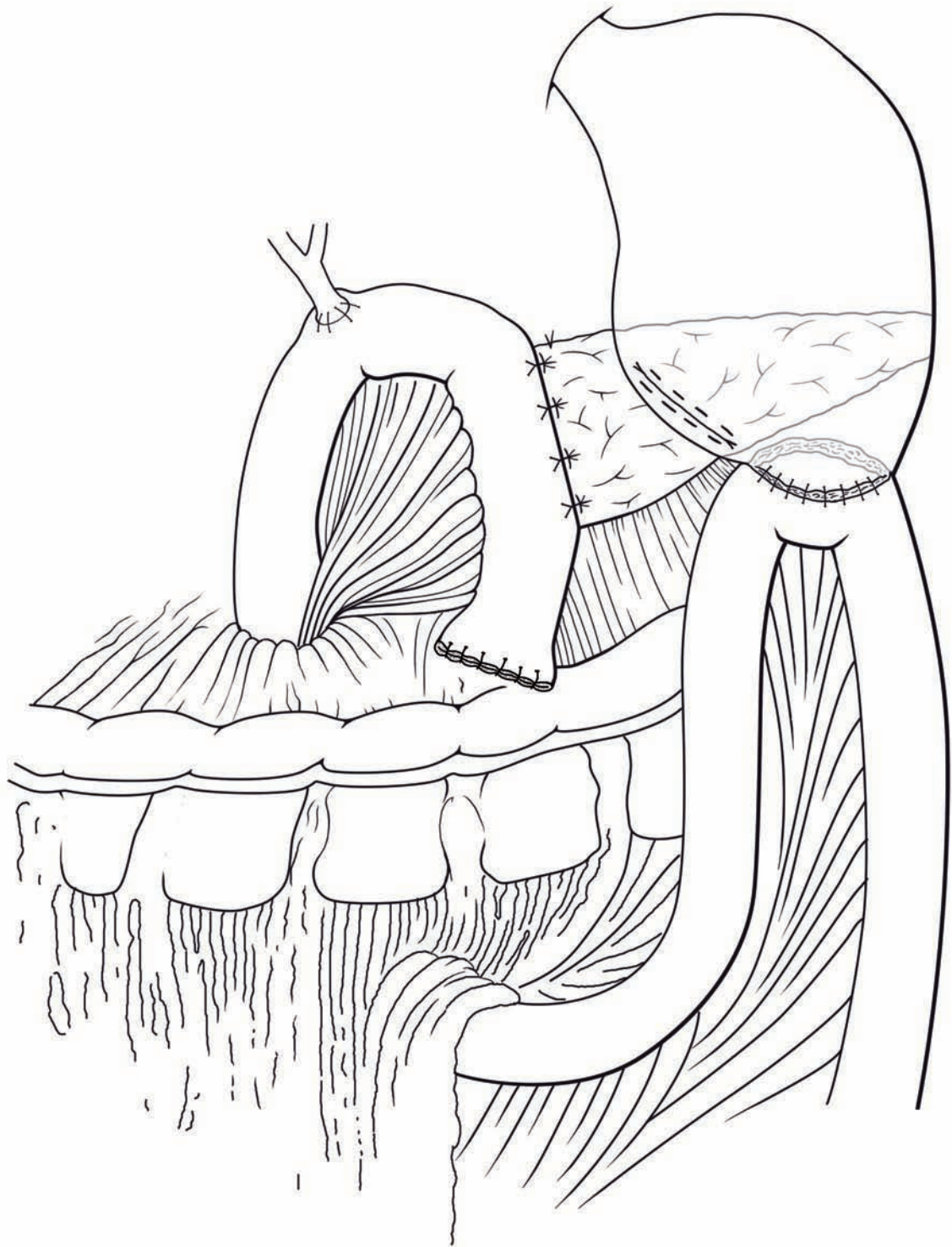


Fig. 12-10

placed in the bowel from outside to inside, and tied. All the knots are tied inside the lumen; therefore, using monofilament absorbable suture is necessary.

We prefer an antecolic gastrojejunostomy to the prior staple line in the stomach. In cases of hemi-gastrectomy, the lateral half of the stomach is used to fashion the

Figure 12.26

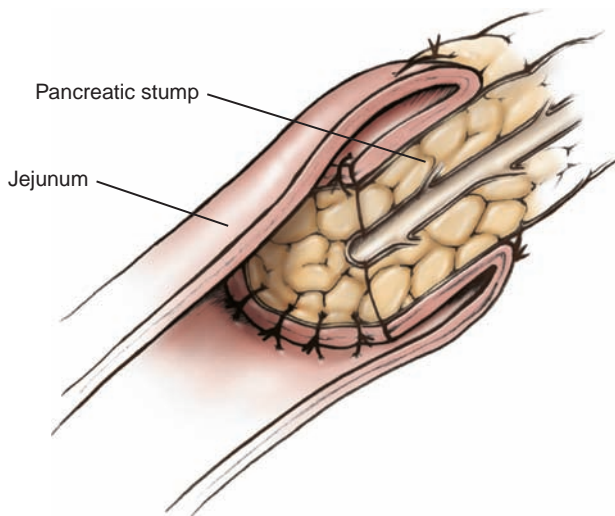
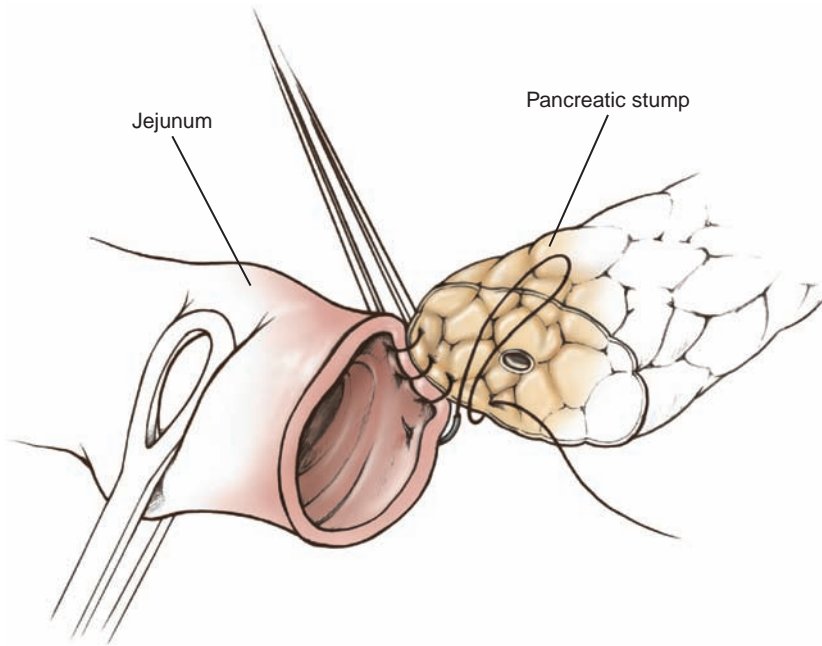


Figure 12.27

suture line. Typically, this is sewn in two layers. Alternatively, a stapled anastomosis works well. Finally, a closed suction drain (or two) is placed posterior to the biliary and pancreatic anastomoses. A feeding jejunostomy tube may be placed 20–30 cm downstream from the gastrojejunostomy, according to surgeon preference.

Venous resection: When venous resection is deemed necessary, the splenic vein is divided near its origin and over sewn. The pancreas is divided, and the retroperitoneal dissection is completed as far as possible, as described above. The specimen should then be attached by the superior mesenteric and portal veins only. Proximal and distal control are obtained with Rommell tourniquets, and/or vascular clamps and gentle systemic heparinization is given (5,000 units). After 3 min, the clamps

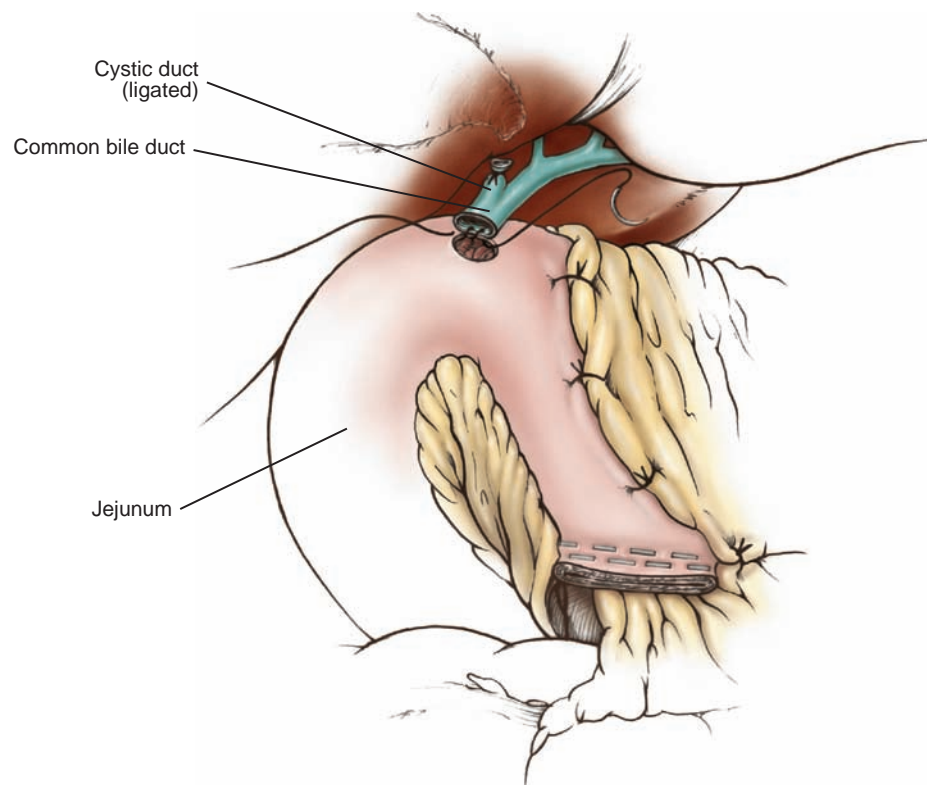


Figure 12.28

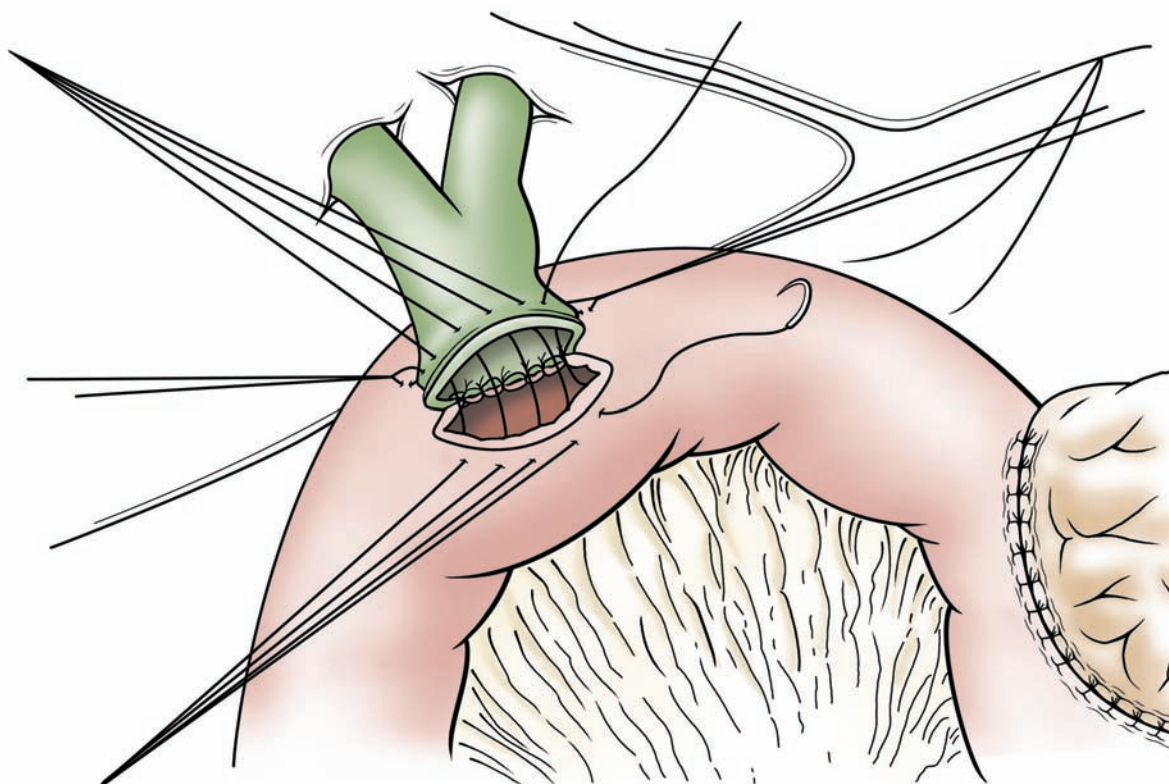


Figure 12.29

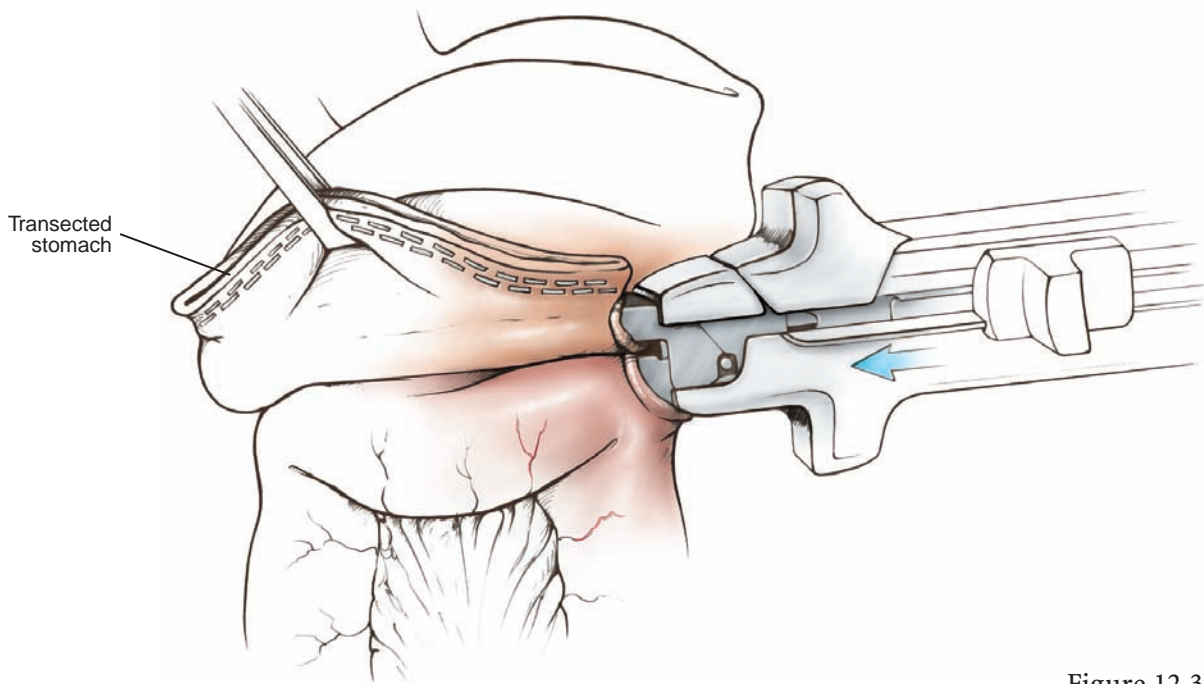


Figure 12.30

are applied, and the specimen with a portion of vein is removed sharply. It is desirable to limit the clamp time to reduce venous engorgement of the intestines, and hypoperfusion of the liver. The venous walls are prepared and a primary, spatulated end-to-end SMV-portal vein anastomosis is sutured with 5-0 or 6-0 monofilament, nonabsorbable suture, using standard vascular techniques. To prevent stricturing and thrombosis, a little extra space is left in the suture line upon tying it ("growth factor") to prevent an "hourglass" appearance. In cases where primary end-to-end reconstruction is not possible, interposition with a portion of internal jugular vein or 8–10 mm reinforced polytetrafluoroethylene (PTFE) graft may be used. Some surgeons advocate reimplantation of the splenic vein to prevent the development of left sided portal hypertension. Occasionally, a smaller venous resection is possible with patch repair using autologous or cryo-prepared saphenous vein, or bovine pericardium. Arterial resections for periampullary cancers are uncommonly performed and are controversial.

A popular variant of the classic pancreaticoduodenectomy preserves the entire stomach and the pylorus. Intestinal continuity is established via anastomosis between the proximal duodenum and the jejunum in an end-to-side fashion (duojejunostomy). Theoretically, this preserves more natural physiology of gastric emptying. During the assessment phase, the bile duct and the pancreas are managed in the same way. The blood supply coursing through the gastrohepatic ligament is preserved, as much as possible. Moreover, when the gastrocolic attachments are divided between clamps, it is done inferior to the gastroepiploic arteries, thereby conserving their supply to the greater curvature. The first portion of the duodenum is mobilized 2–3 cm beyond the

Pancreaticoduodenectomy with Pylorus Preservation

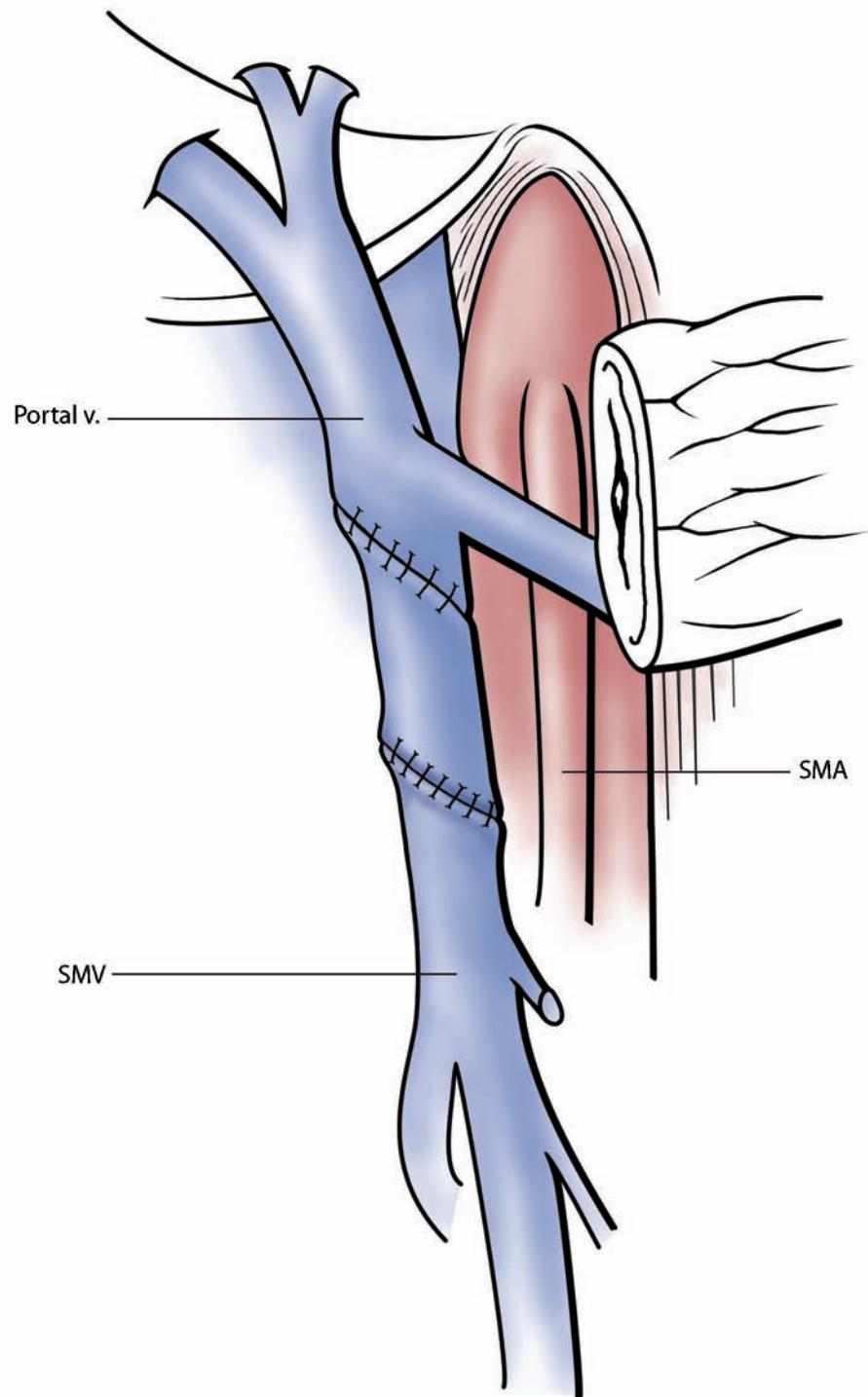


Figure 12.31

pylorus. This leaves an adequate cuff of duodenum for subsequent duodenojejunostomy. The right gastric artery typically arises off the proper hepatic artery, yielding an adequate blood supply to the pylorus and proximal duodenum. This artery is often preserved in its normal position, but its preservation is not critical. The duodenum is then transected 2–3 cm beyond the pylorus with a linear stapler, after confirming that the nasogastric tube has been withdrawn sufficiently.

The procedure then continues as described earlier. Reconstruction of enteric continuity in the pylorus-preserving operation is performed downstream (and following) the pancreaticojejunostomy and the hepaticojejunostomy, with an end-to-side duodenojejunostomy. It is preferable to bring the jejunum up to the stomach in an antecolic fashion for improved emptying. A two-layer anastomosis is created using interrupted seromuscular silk sutures or running seromuscular PDS, followed by a running absorbable inner layer (PDS). This inner layer is made hemostatic and watertight using over-and-over locking sutures for the posterior row and Connell sutures for the anterior row. The anastomosis is completed with an anterior layer of seromuscular silk or vicryl sutures, being careful not to imbricate too much tissue, which may result in stenosis.

The pylorus-preserving approach is contraindicated for tumors involving the proximal duodenum or the pancreatic neck, thereby compromising surgical margins. If the pylorus becomes ischemic prior to anastomosis, the intestinal anastomosis should be converted to the classical approach.

Indications for left pancreatectomy include resection of primary and some secondary neoplasms of the pancreas, including en-bloc resection of tumors of other organs that are inseparable from the pancreatic body and/or the tail (e.g., GIST). Unfortunately, primary adenocarcinoma of the body and the tail of the pancreas typically presents later in the course of the disease, with vague or nonspecific symptoms. These tumors are usually larger and often exhibit local invasion of the celiac axis or the mesenteric vessels, and/or distant metastases, by the time the patient is evaluated for surgical

Left (Distal) Pancreatectomy with Splenectomy

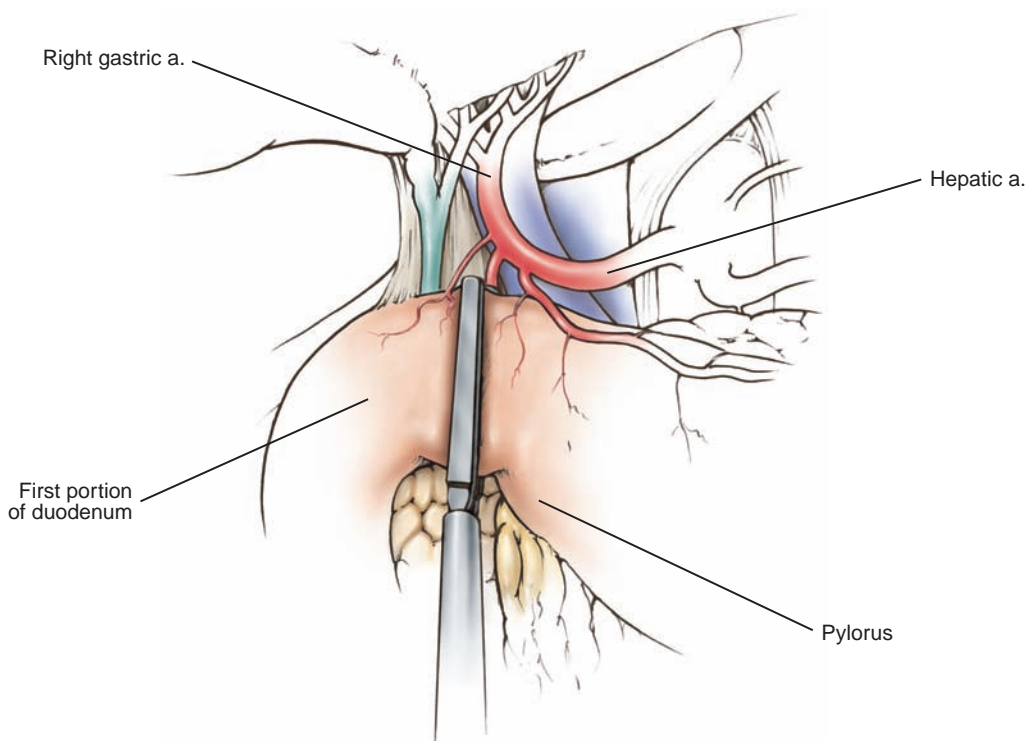


Figure 12.32

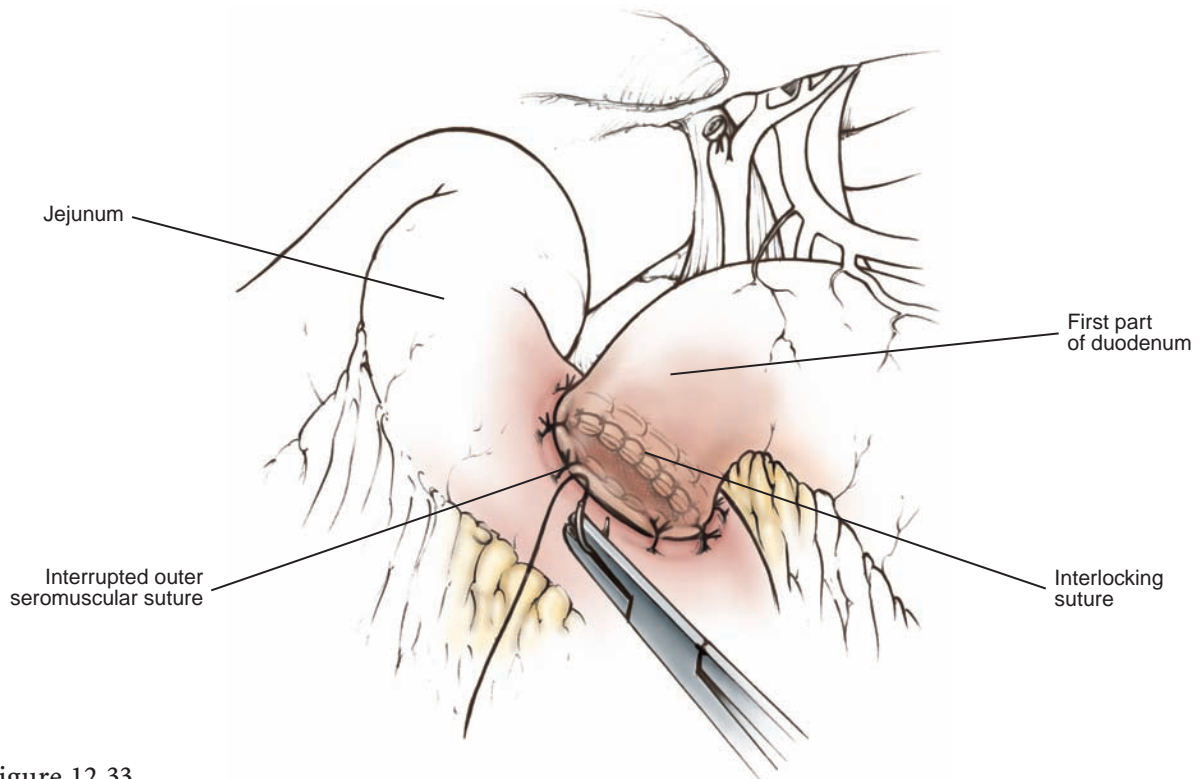


Figure 12.33

consideration. As such, the majority are unresectable at presentation. Left pancreatectomy is more commonly used to manage pancreatic endocrine tumors and cystic neoplasms. By convention, preoperative vaccination against encapsulated bacteria (*Pneumococcus*, *Haemophilus*, and *Meningococcus*) is administered when possible, approximately 2 weeks prior to procedure.

Open approach: Three different incisions can be used for this operation. In non-obese patients, an upper midline incision with infraumbilical extension may be sufficient, and it helps to avoid cutting the muscle. In most cases, a left subcostal incision with extension across the midline provides excellent exposure. Finally, for very large distal tumors, a left hockey stick incision may be appropriate. Supine position for the open approach is preferred.

Exploration for distant metastatic disease is performed in four quadrants. In the setting of distant disease, removal of the pancreas primary may be beneficial in patients with low-grade tumors (e.g., well-differentiated endocrine neoplasms). The gastroduodenal omentum is divided between clamps, and the stomach is retracted superiorly. The vasa brevia are likewise divided between clamps, exposing the entire anterior surface of the pancreas and the spleen. The spleno-phrenic and spleno-colic attachments are likewise divided and the splenic flexure of the colon is retracted inferiorly. When performed early in the operation, these maneuvers remove the stomach and the colon from consideration for the remainder of the procedure and provide excellent exposure.

The peritoneum at the inferior border of the pancreas is incised, taking care not to injure the superior or inferior mesenteric veins. The inferior mesenteric vein is identified, cleared of surrounding tissues, ligated and divided. This allows mobilization of the inferior border of the pancreas through an avascular plane. The spleen is freed from the diaphragm and the retroperitoneum by the division of its lateral and posterior attachments, allowing medial rotation of the spleen and the pancreatic tail as a unit, and this dissection continues past the point of the tumor along the pancreatic tail or body.

With the pancreas and the spleen rolled medially, the splenic artery is identified at the superior border of the gland. It is isolated from the surrounding tissues near its origin off the celiac axis, clamped and suture ligated, or divided with an appropriate surgical stapler. A site proximal to the tumor is identified where the pancreas is to be transected. It is important to consider both, tumor margin and parenchymal preservation. Postoperative diabetes mellitus is a concern following major pancreatic parenchymal loss, especially in younger patients with indolent tumors; however, the surgeon must weigh this option against the possibility of leaving residual tumor behind. At this point, the splenic vein is isolated from the pancreas, if possible, and ligated with a surgical stapler. Alternatively, the vein may be stapled along with the pancreas in the next step. Care is taken not to impinge on the superior mesenteric vein.

If the site for transection of the pancreas is relatively soft, a linear stapling device may be used. If the gland has become fibrotic from chronic pancreatitis, it is divided with an electrocautery. Bleeding points are controlled with figure-of-eight sutures. Whether transected with a stapler or electrocautery, the end of the gland may be further secured with interrupted interlocking mattress sutures. Particular attention is paid to the region of the main pancreatic duct, which if readily apparent is separately ligated. Once the end of the gland is secured, the resection bed is inspected for bleeding points, and hemostasis is assured. A closed suction drain is placed in the pancreatic bed near the stump of the pancreas and brought out through the left abdomen.

Laparoscopic approach: The laparoscopic approach to left pancreatic resection is performed more commonly. Positioning may be supine or in lazy right-lateral decubitus on a beanbag, with the operative table slightly flexed. The surgeon decides on the approach: complete laparoscopic dissection or with the use of a hand port. As numerous methods are possible, the author will describe in detail the hand-access approach, as this technique is a good way to gain confidence in performing laparoscopic left pancreatectomy. The patient is placed in the lazy right decubitus position to maximize the benefits of gravity and for surgeon's comfort. It is crucial to secure the patient well to the operating table, to permit rotation during the procedure. The hand port is placed in the midline, centered on the umbilicus, and the incision length is a half centimeter smaller than the surgeon's glove size. Following insufflation, the patient is placed in reverse Trendelenburg position, and two bladeless 12-mm ports are placed in the left subcostal region. This port placement is found to be ideal for

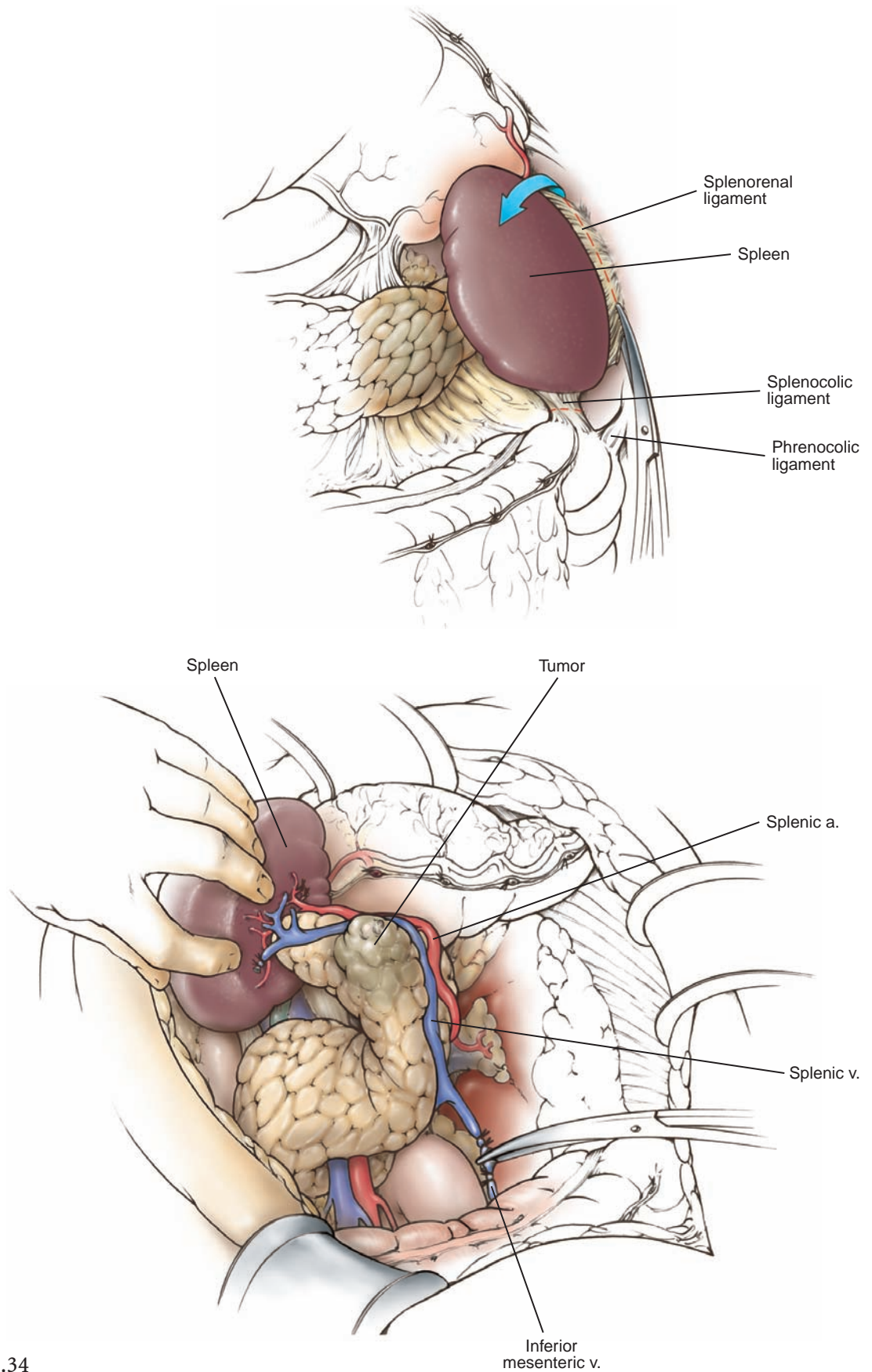


Figure 12.34

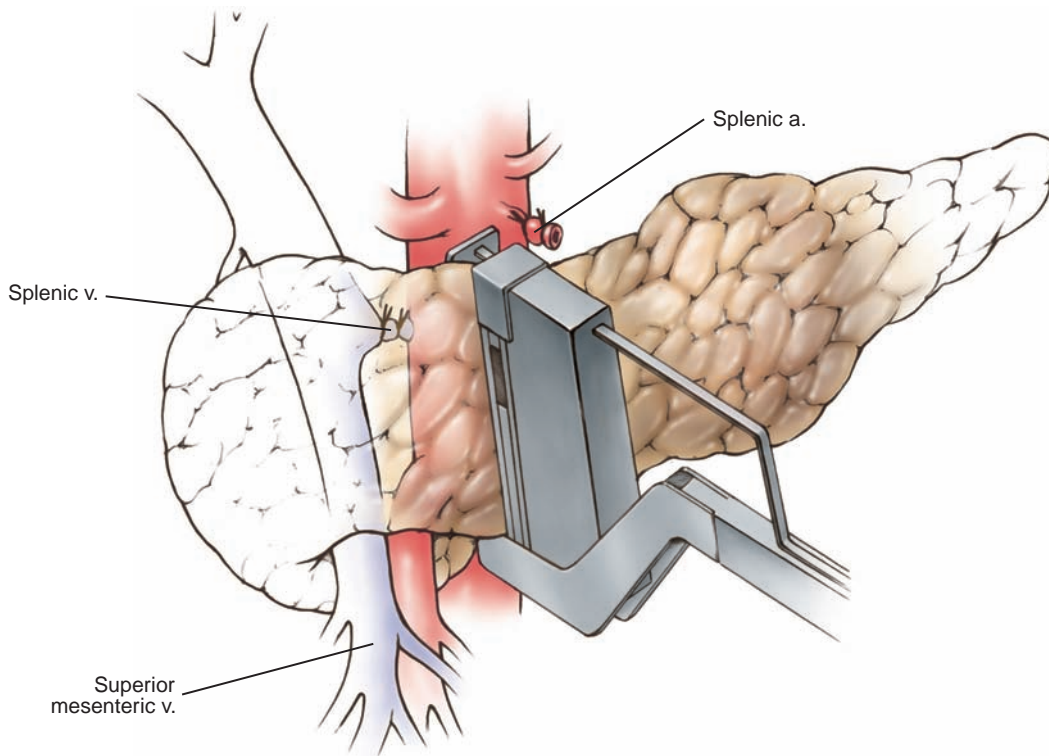
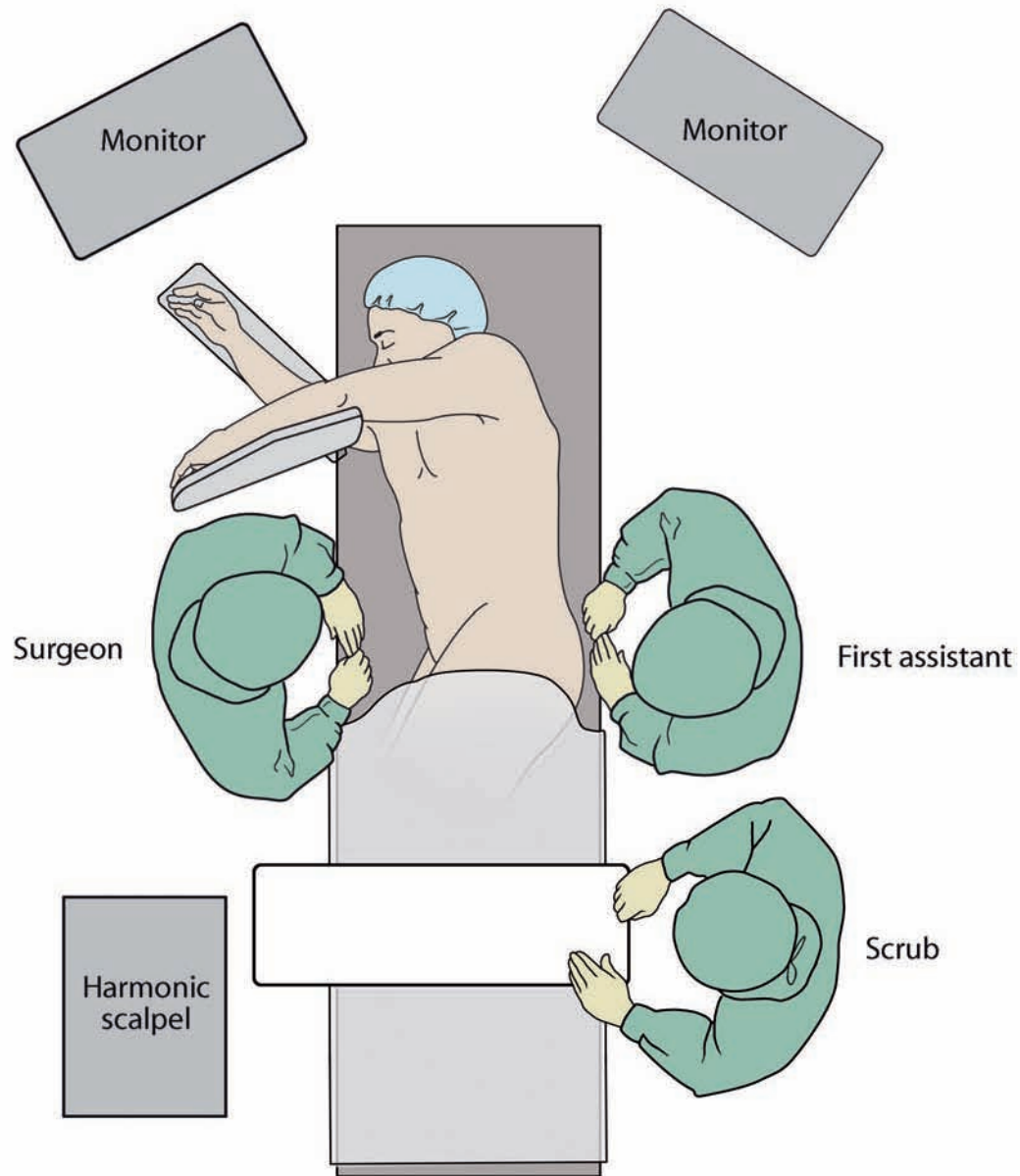


Figure 12.35

switching dissection/transection/stapling devices and 10 mm, 30° angled laparoscope, with ease. If necessary, an additional 5-mm port can be placed laterally to these ports to aid in splenic retraction during the division of the short gastric vessels. This procedure requires a surgeon who is well-versed in both pancreatic surgery and minimally invasive surgical technique, and a competent assistant.

After inspection and palpation, the lesser sac is opened using ultrasonic or thermal shears. If splenectomy is intended, the short gastric vessels are taken all the way up to the superior pole of the spleen and the left diaphragmatic crus. Additional clips may be placed along the greater curvature of the stomach to ensure hemostasis, but this is usually not necessary. Retrogastric adhesions are divided sharply and the body and the tail of the pancreas are thus exposed. The tumor is usually visible at this point; however, if a smaller, intrapancreatic lesion is not readily discernable, laparoscopic ultrasonography can be used. Options include the use of a laparoscopic wand through a 12-mm port or a finger probe brought through the hand port, to identify the lesion.

Next, the distal transverse colon and the splenic flexure are lowered from the inferior pancreatic edge and the spleen. The hand-access approach facilitates and expedites this maneuver. The surgeon must then decide on the method of pancreatic mobilization, whether medial-to-lateral or lateral-to-medial. For the medial-to-lateral approach, the inferior border of the pancreas is defined with shears, and the inferior mesenteric vein is identified and transected with a stapler or clips and scissors. Gentle dissection under the pancreatic body proximal to the tumor continues under the splenic vein, and the surgeon's left forefinger and thumb are used to retract the pancreas anteriorly and



Fig

cephalad. Often, the splenic artery can be palpated along the superior aspect of the gland. Gentle dissection under the artery with a laparoscopic right angle or Maryland dissector, allows creation of a plane through which a surgical stapler can be passed. With the stapler closed, but prior to firing the stapler, the surgeon should palpate the left and the right hepatic arteries to confirm the flow and avoid accidental ligation of the common hepatic artery. Once the artery is divided, the pancreatic parenchyma can be transected with a vascular or gastrointestinal linear stapler, depending on gland thickness and consistency. This can be performed en-bloc with the splenic vein, or alternately, the splenic vein can be dissected out and transected separately. Additional suturing of the pancreatic stump can be performed, but is not absolutely necessary.

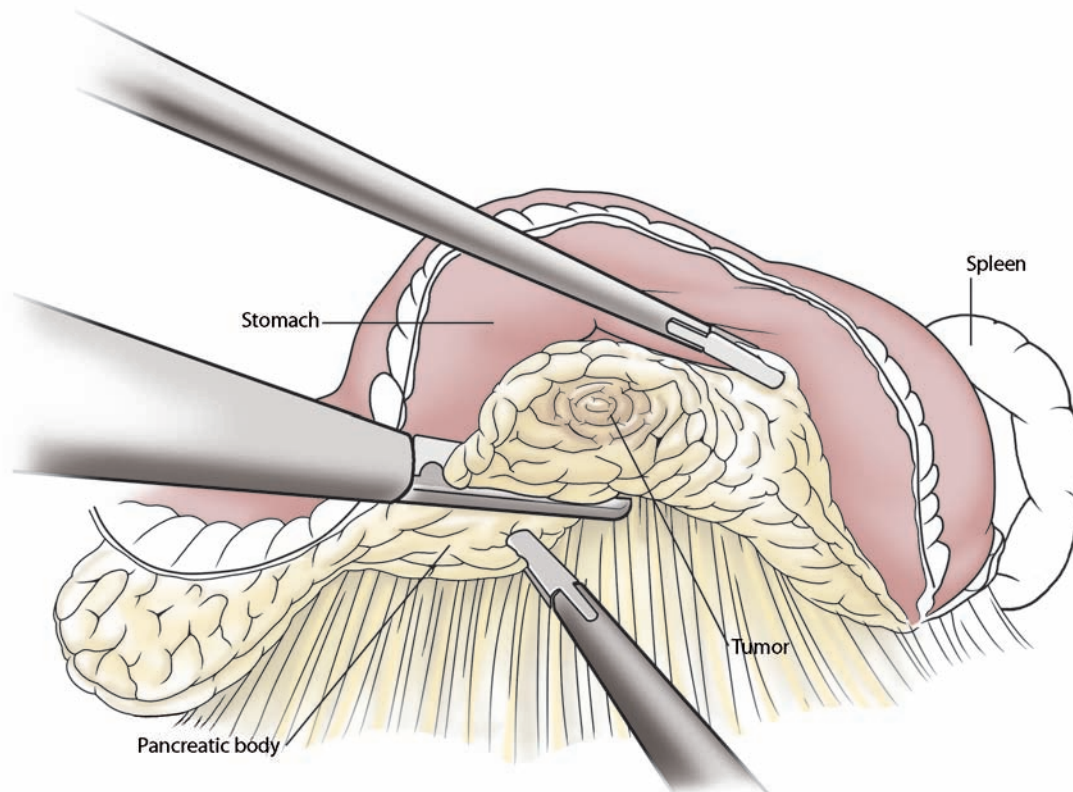


Figure 12.37

In cases of lesions approaching the pancreatic neck and portal-mesenteric confluence, the vein should be dissected free of the pancreas to avoid injury or compromise of flow. The specimen side of the pancreas is then dissected off Gerota's fascia from medial to lateral. One may encounter varying degrees of adherence in this location, and must exercise caution with respect to left renal vasculature and the left adrenal gland in more inflamed situations. The spleen is mobilized off the diaphragm and the retroperitoneum, completing the surgical mobilization.

The specimen can be removed through a protected wound or by placement in a laparoscopic bag. A drain is usually placed, and can be pulled through the existing 5-mm port site. Advantages of the hand-access approach include, speed, palpation, potential for digital control of inadvertent vascular injury, preexisting incision for rapid conversion to open technique, if necessary. Furthermore, since the specimen must be extracted, a larger incision is usually necessary.

Preservation of the spleen and splenic function is possible in some left pancreatic resections. There are two basic approaches to splenic preservation; the first involves preservation of the spleen by systematically transecting the small branches of the splenic artery and vein running to and from the pancreas, while the second approach involves transecting the splenic vessels along with the pancreas at the desired location, and again at the splenic hilum. This technique was described by Warshaw, and

**Left (distal)
Pancreatectomy
with Splenic
Preservation**

mandates intact short gastric vessels for splenic viability. Either approach can be performed open or laparoscopically. The open approach is described.

Incision and exposure is the same as for the left pancreatectomy with splenectomy. After the identification of the tumor, dissection proceeds using a medial-to-lateral approach, with care taken to preserve the splenic vessels. It is best to commence with the arterial dissection, as the artery is usually easier to separate from the parenchyma. Additionally, if the artery is damaged beyond repair, it can be ligated without causing venous congestion and increased hemorrhage. Small branch vessels can be taken with ties, clips, or shears. It is best to work from medial-to-lateral, as there is considerable variability in the arborization of the splenic vessels at the hilum. By working from medial-to-lateral, the surgeon can stay along the parenchyma, thereby dissecting the smaller vessels away from the pancreas. Generally, there is some fatty tissue at the splenic hilum that must be distinguished from the pancreatic tail. This fat is omental tissue, which remains attached to the spleen.

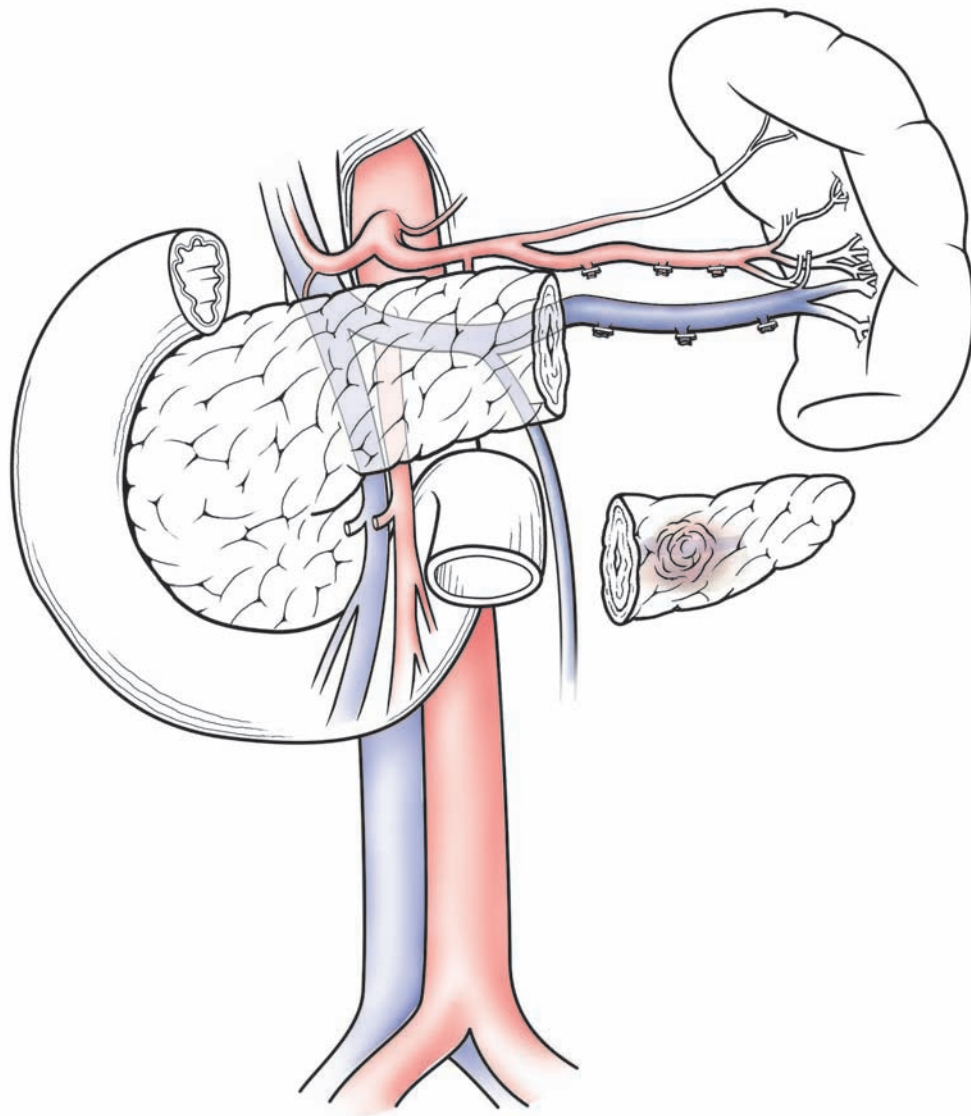


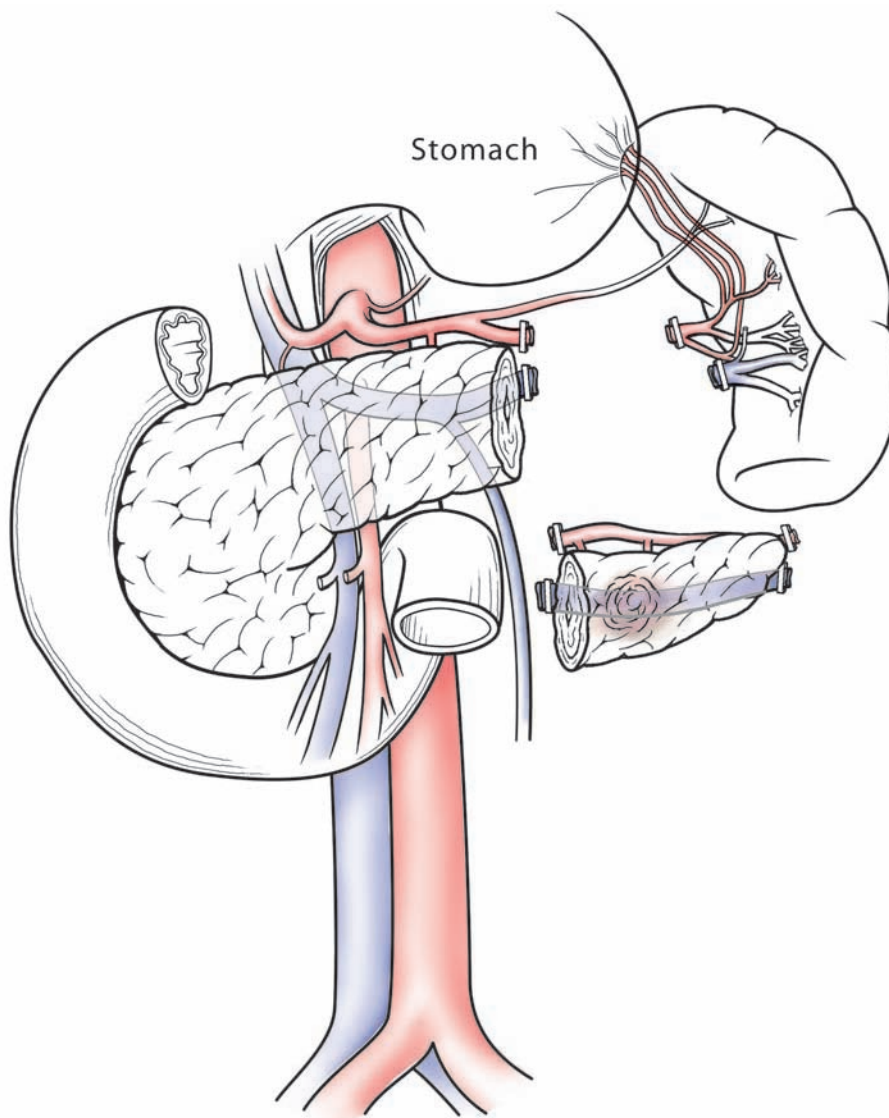
Fig. 12-10

For the Warshaw technique, the splenic vessels are divided at the pancreatic transection line along with the pancreas and again at the splenic hilum, and the spleen remains attached to the diaphragm and the retroperitoneum. Again, it is crucial that the majority of the short gastric vessels are preserved when opening the lesser sac for this technique.

Indications for central pancreatectomy are limited to relatively small, indolent tumors of the pancreatic neck and proximal body. This operation combines some techniques of the spleen-preserving left pancreatectomy and the pancreaticoduodenectomy.

Following tumor identification, the inferior border of the pancreatic neck is mobilized in the region of the superior mesenteric vein, in the same manner as for a pancreaticoduodenectomy. Similarly, the superior border of the pancreatic neck is mobilized, which is best accomplished by dissecting off the hepatic artery lymph node. This will help in identifying the origin of the splenic artery, which must be

Central (Middle) Pancreatectomy



mobilized off the pancreas for a length depending on the location and the size of the tumor. The gastroduodenal artery is preserved. Dissection along the under surface of the pancreatic neck and the body continues from the SMV-portal vein confluence out along the splenic vein, beyond the point of the tumor, taking small draining branches in the same manner as in spleen-preserving, vessel preserving left pancreatectomy.

Once the tumor-bearing pancreatic neck is adequately free of the underlying mesenteric vessels, four stay sutures are placed on either side of each transection line. The proximal transection line can be divided with a linear surgical stapler, in the same way as the left pancreatectomy is performed. The distal transection line is treated in the manner of a pancreaticoduodenectomy to preserve the patency and the integrity of the pancreatic duct orifice and mucosa. Surgeons performing this technique must be conscious of the peripancreatic course of the distal common bile duct, to avoid inadvertent injury to this structure.

Reconstruction to the left (distal) pancreatic stump is performed with jejunum in a roux-en-y fashion. Either of the techniques of anastomosis as described in the pancreaticoduodenectomy is possible. Alternatively, the distal pancreatic stump can be dunked into the posterior wall of the stomach. This can be accomplished by creating an anterior gastrotomy and pulling stay sutures attached to the mobilized pancreas up through a posterior gastrotomy. Two running suture lines secure the pancreas to the posterior gastric wall: gastric mucosa-to-pancreatic cut edge and seromuscular surface of stomach-to-pancreatic capsule in a circumferential manner. Care must be taken not to obstruct the distal pancreatic duct with either of the suture lines. The anterior gastrotomy is then sutured, and a closed suction drain is left near the anastomosis and adjacent to the proximal pancreatic stump.

Enucleation of Insulinoma

Recent advances in imaging techniques have made the preoperative diagnosis and localization of insulinoma more confident. Fine-cut spiral CT scans and arteriograms depict the location of insulinoma in up to 80% of cases. Endoscopic ultrasonography, by experienced personnel is sensitive for mass lesions of the pancreatic head and uncinate process as small as 5 mm, but somewhat less sensitive for body and tail lesions. Preoperative SMV-portal venous sampling and mapping for insulin levels may assist with localization in more challenging cases. Finally, exploration with intraoperative ultrasonography may be necessary.

Open approach: The abdomen is explored through an upper midline incision and a Bookwalter retractor is placed. The gastocolic omentum is divided, the stomach is retracted superiorly, and mobilization of the portion of the pancreas containing the lesion is performed. A Kocher maneuver is done for lesions of the pancreatic head, while the body and the tail are mobilized for more distal lesions. It is important to expose and mobilize the entire pancreas, for thorough intraoperative ultrasonography and palpation, in cases where preoperative localization is unsuccessful, or when multifocal disease is suspected. The inferior border of the pancreas is identified, and the overlying peritoneum divided with an electrocautery or a sharp dissection. The pancreas is then elevated from the retroperitoneum in the avascular plane between

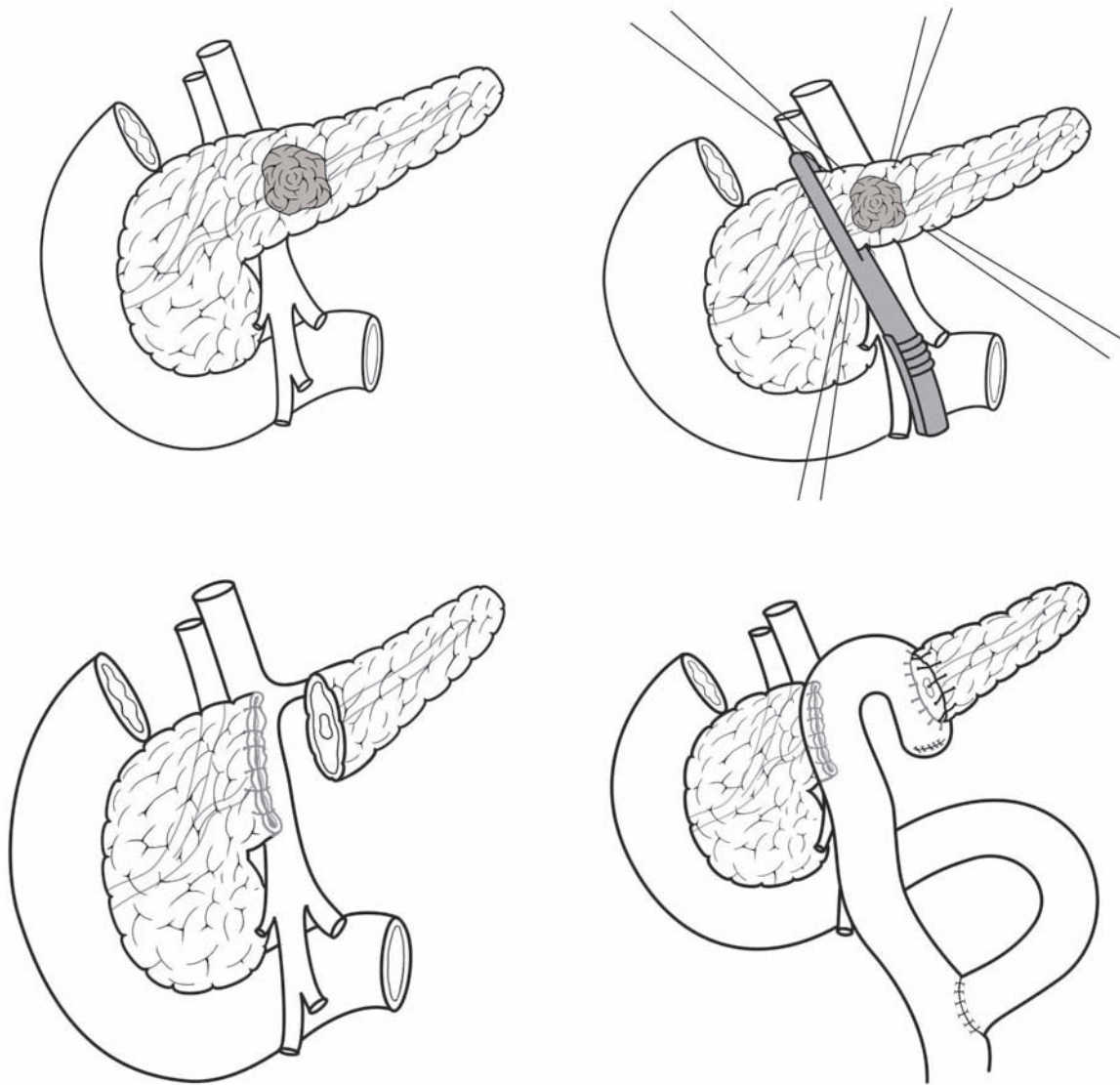


Figure 12.40

its posterior surface and Gerota's fascia. The surgeon then palpates the pancreas. Palpation of the head and neck is performed, although the pancreas is the thickest in this area, making palpation of small tumors difficult.

Insulinomas are reddish brown, rubbery tumors, typically 1–2.5 cm in diameter. If the tumor is located in the body or the tail and exhibits local invasion, or is buried in the pancreatic substance, left pancreatectomy should be considered. Similarly, if the lesion is buried in the head or uncinata process and intimately associated with the pancreatic duct, pancreaticoduodenectomy is necessary. Most insulinomas, however, are on the surface of the gland and can be enucleated.

Enucleation is accomplished by sharply incising the pancreatic capsule around the evident portion of the tumor. The pancreatic substance is then dissected free from the wall of the tumor, and small clips or sutures are placed on bleeding points in

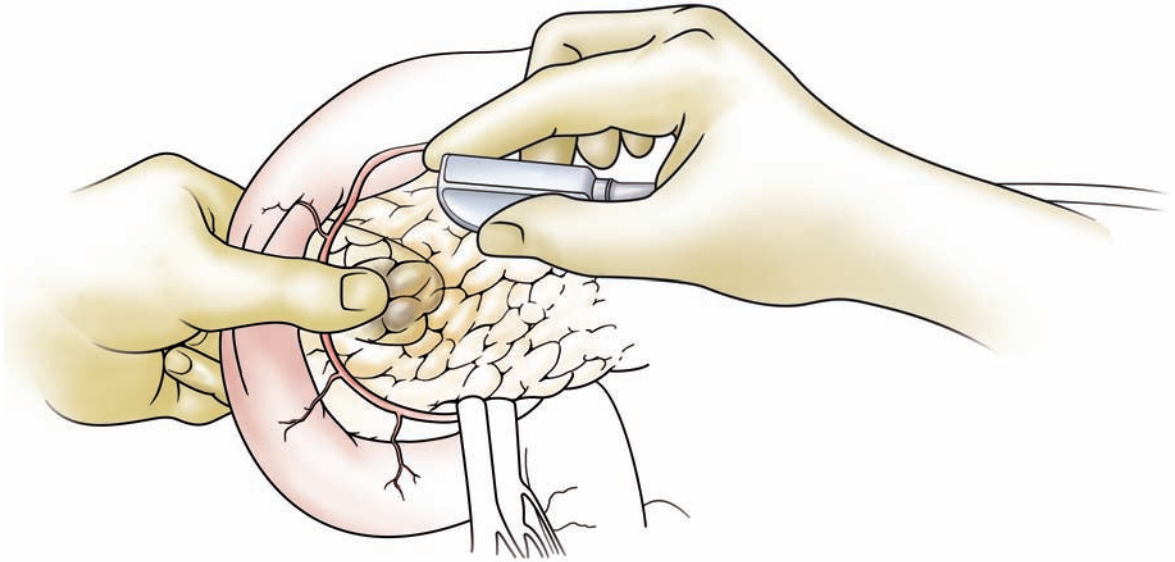


Figure 12.41

the pancreatic substance. Electrocautery is applied to the wall of the lesion, allowing rapid and bloodless excision of the tumor. There is no ductal communication with these tumors; however, ducts may be injured during the dissection, and these should be searched for and suture ligated. Again, caution must be exercised in the region of the main pancreatic duct when dissecting out the tumor, and when applying cautery or sutures to the parenchyma. When hemostasis is assured, a closed suction drain is placed in the lesser sac near the site of the tumor excision and brought out through the abdominal wall.

Laparoscopic approach: It is best to employ the laparoscopic approach in cases where the tumor is clearly localized though preoperative imaging, especially when the tumor is situated in a peripheral portion of the gland. Port placement should provide both, ease of access as well as surgeon comfort. A periumbilical incision is appropriate for the laparoscope, and three or four 5-mm ports allow for “triangulation,” and appropriate retraction. After opening the lesser sac, a laparoscopic Bookwalter retractor with a liver retractor can be used to provide self-retaining exposure of the gland, by keeping the posterior wall of the stomach off the pancreas. Intraoperative ultrasonography is helpful for determining the extent of tumor and proximity to the main pancreatic duct. The harmonic scalpel is an excellent tool for excising the tumor off the pancreas. It seals small ducts and also provides hemostasis quite efficiently. Once excised and hemostasis is achieved, the tumor is placed in a laparoscopic specimen retrieval bag and removed through the periumbilical port site. A closed suction drain is brought out through one of the 5-mm port sites.

Local Excision of Ampullary Tumor

Tumors of the ampulla of Vater are relatively uncommon, with adenocarcinoma being most frequently encountered. Resectable adenocarcinoma of the ampulla requires pancreaticoduodenectomy. Other tumors found in this location include adenomas

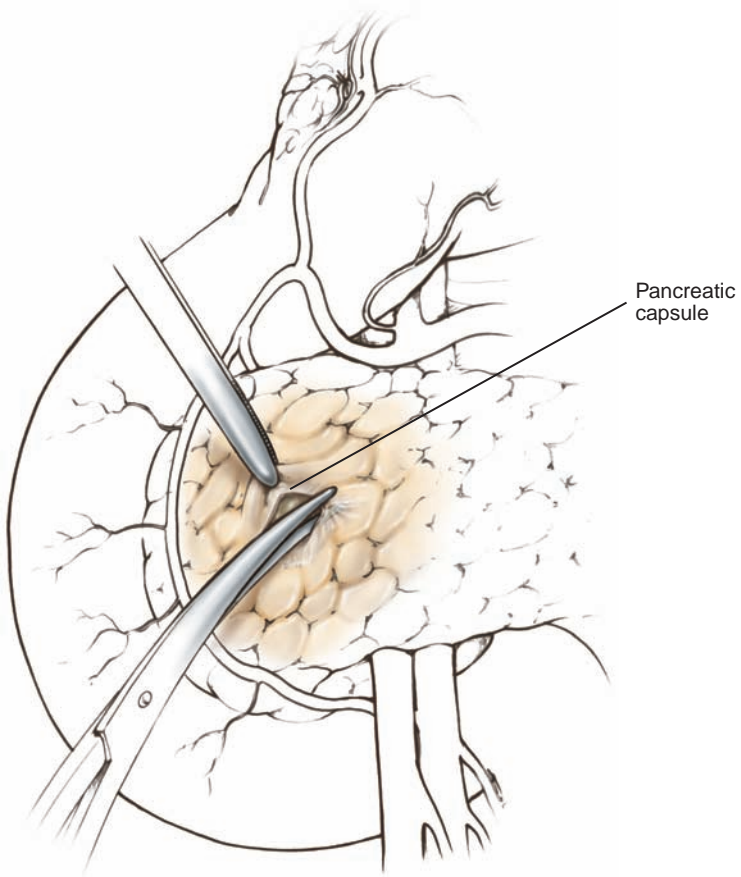


Figure 12.42

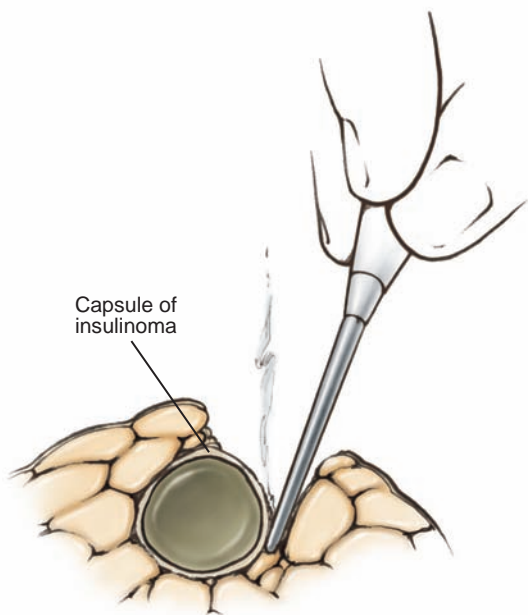


Figure 12.43

and neuroendocrine tumors, many of which can be managed with local resection. It is of note that adenomas with histologic evidence of high grade dysplasia should be treated as cancers; however, local excision remains an option for patients in poor general medical condition.

Abdominal exploration is performed through a right subcostal or midline incision, and the Kocher maneuver is performed. Often, the mass is palpable, especially if an endoscopic stent is in place. A small lateral duodenotomy is created in the second portion of the duodenum, centered on the presumed location of the tumor. Once the lesion is confirmed, the duodenotomy is extended appropriately. A blunt Adson-Beckman retractor provides excellent exposure in most cases, without causing undue trauma to the duodenal wall. Stay sutures are placed circumferentially in the duodenal

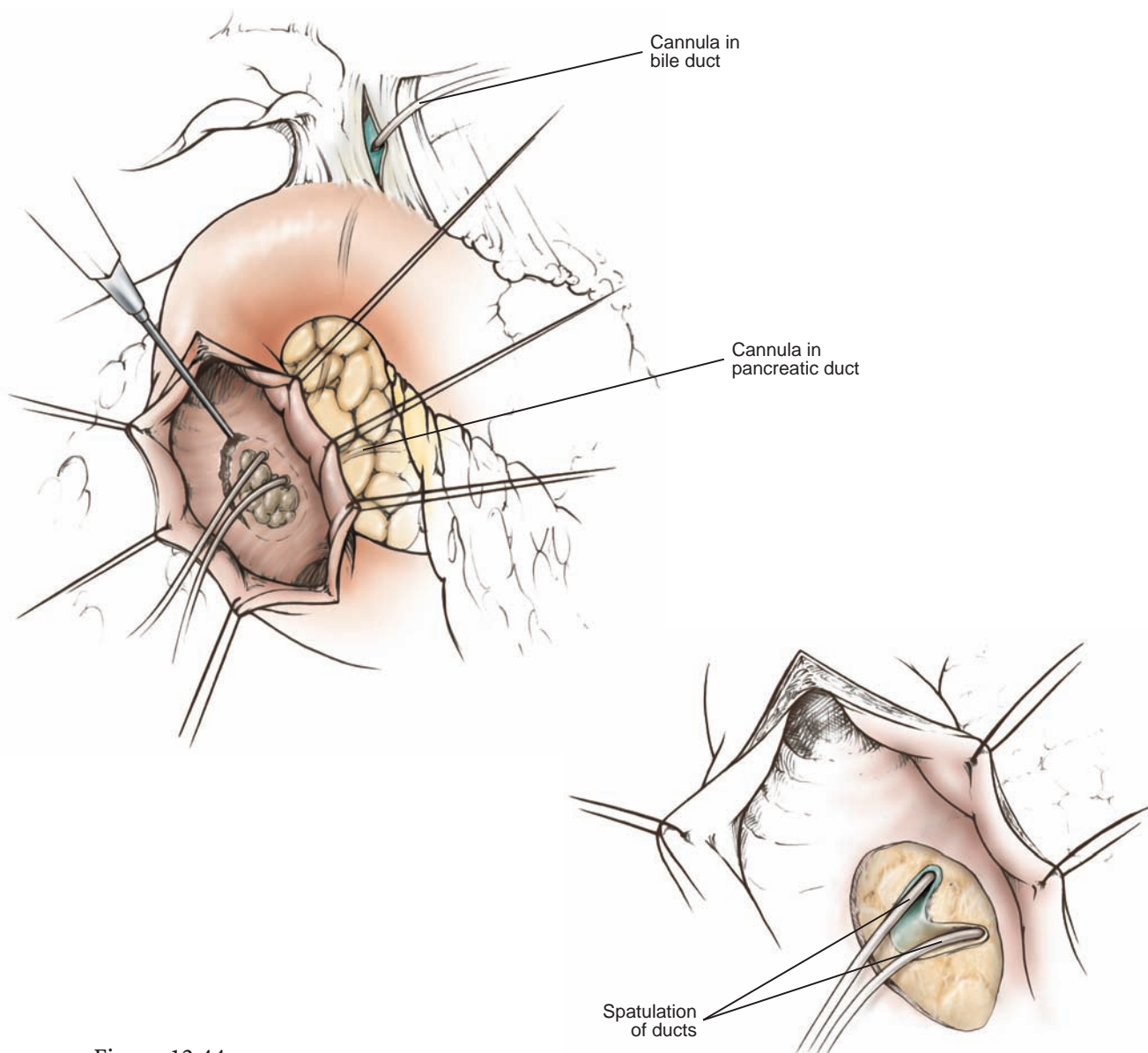


Figure 12.44

wall near the tumor, but far away so that they can be maintained even after the tumor is excised.

Lacrimal duct probes are placed in the bile duct and pancreatic ducts as soon as possible to ensure their locations. The bile duct is in the 11-o'clock position, coursing cephalad through or behind the pancreatic substance. If a biliary stent has been placed, it can be used to confirm the bile duct's location. It may be necessary to resect a portion of the tumor or enter the duodenal wall directly to identify the exact position of the pancreatic duct. Intravenous secretin increases pancreatic secretion and can be administered to aid in the identification of the pancreatic duct.

Circumferential resection of the duodenal mucosa to a depth necessary to excise the tumor is performed with needle electrocautery. If adenomatous tissue extends along the bile duct, the duct may be spatulated to access this deeper tissue. Radial and deep margins should be assessed for complete resection, and multiple sections should be assessed for evidence of high grade dysplasia or cancer. If negative margins cannot be obtained, or if high grade dysplasia or carcinoma is encountered, then a pancreaticoduodenectomy is indicated.

The bile and the pancreatic ducts will have been transected or spatulated at variable distances from the duodenal mucosa. The reconstruction is critical to ensure adequate biliary and pancreatic drainage and to repair the transduodenal defect. Loupe magnification is useful for accurate reconstruction.

Reconstruction is accomplished by approximating the common walls of the pancreatic and the bile ducts with absorbable, monofilament 5-0 suture in an interrupted fashion.

Circumferential reapproximation of the duodenal mucosa to the pancreatic and bile duct mucosae is performed using the same technique.

Following reconstruction, the ducts should be probed with biliary dilators to ensure appropriate size. A diameter of at least 6 mm for the bile duct and 4 mm for the pancreatic duct is preferred.

Once adequate patency is confirmed, the duodenotomy is closed transversely. A closed-suction drain is left at the surgeon's discretion.

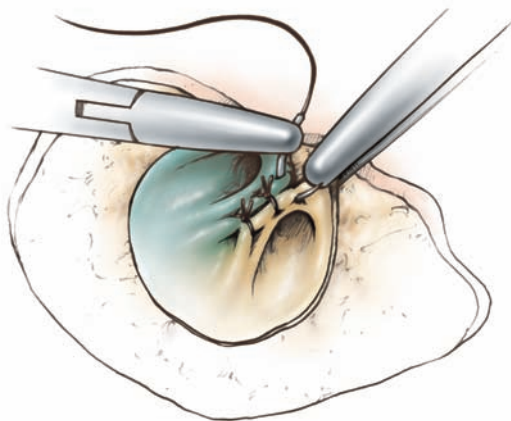


Figure 12.45

Figure 12.46



Management of non-Ampullary Duodenal Tumor

When compared with the rest of the gastrointestinal tract, duodenal tumors are uncommon. By contrast, a high percentage (40%) of small bowel adenocarcinomas of the small intestine develop in the duodenum, despite the fact that the duodenum represents less than 10% of the length of the entire small bowel.

GISTs and neuroendocrine tumors, among other lesions, are also observed in the duodenum, although less commonly than in other locations. In considering surgical approach, several characteristics must be assessed: benign vs. malignant; tumor size; precise location; luminal vs. exophytic; mobile vs. fixed.

Benign Tumors

For small, benign lesions, enucleation or wedge excision with primary repair is sufficient. For enucleation or wedge excision, the duodenum is Kocherized and elevated. The tumor is identified, and if it encompasses less than half the circumference of the duodenum, proximal and distal stay sutures are placed to assist with resection and subsequent duodenorrhaphy. The tumor is excised with a surrounding border of normal duodenal wall, while protecting the major and minor papillae. The defect is then closed in two layers with a running absorbable, transmural layer of sutures and serial seromuscular Lembert sutures. For the benign leiomyoma in the submucosal plane, this same procedure is followed, but the seromuscular layers are incised directly over the tumor and it is enucleated. Hemostasis is assured, and these layers are reapproximated with interrupted silk sutures.

Enucleation should be considered if the tumor lies close to the ampulla of Vater, and the age and the condition of the patient do not permit a more radical operation.

Larger tumors may require formal resection, as primary closure, without undue duodenal stenosis may not be possible.

Malignant Tumors

Primary duodenal adenocarcinoma in the region of the second portion is best managed with pancreaticoduodenectomy, to ensure clear surgical margins, and provide for nodal evaluation.

Small cancers of D1 (proximal to the ampulla) may be managed with en-bloc distal gastrectomy. For distal lesions (D3 and D4) segmental resection may suffice. Palliative bypass procedures may be used for larger, unresectable tumor of the duodenum.

Extrapancreatic gastrinoma, causing Zollinger–Ellison (ZE) syndrome, is another unusual duodenal tumor. These are usually small and difficult to identify, and may require intraoperative assessment with palpation and ultrasonography.

In managing tumors of the duodenum, surgeons should consider the blood supply, and avoid ligating both the superior and the inferior pancreaticoduodenal arteries. Such action will result in ischemia of the duodenum. They should also consider that 10% of the patients have only one pancreatic duct, the accessory duct (of Santorini). Inadvertent ligation of this duct, which is always located just beneath the gastroduodenal artery, would result in complete pancreatic exocrine obstruction and possible profound pancreatitis.

The first portion of the duodenum is surgically treated by segmental resection, or extended distal gastrectomy to include D1, with either Bilroth I or Bilroth II reconstruction. Pancreaticoduodenectomy is used for tumors in the second portion of the duodenum.

Duodenal Resection

Through a midline or right subcostal incision, an extended Cattell–Brasch maneuver is performed. The dissection should extend from the hepatic flexure to the cecum, in order to separate cecum and the terminal ileum from Gerota's fascia overlying the right kidney. The second, third, and fourth portions of the duodenum should now be visualized by medial and upward retraction of the right colon and the ileum. This maneuver moves the superior mesenteric vessels away from the third portion of the duodenum, thereby providing necessary access to this structure.

Resection of Third or Fourth Portion of the Duodenum

The tumor is evaluated. If it is fixed to the pancreas, pancreatic resection (pancreaticoduodenectomy or other) may be required. If the tumor and the duodenal wall free of the pancreas without compromising the tumor margins, segmental duodenal resection is performed. This is done by placing gentle traction on the affected portion of the duodenum with Babcock clamps, and identifying, ligating and dividing the small mesenteric vessels to and from this portion of the duodenum with clamps, clips, ties, or shears. This can be a tedious process depending on the tumor-induced desmoplastic response and the extent of dissection necessary, and should be performed meticulously to avoid inadvertent injury to the proximal mesenteric vessels. The duodenum is then transected with linear surgical staplers, providing for adequate tumor margins, without encroaching on the region of the ampulla of Vater.

Continuity is then reestablished with end-to-end or side-to-side duodenojejunostomy, after the closure of the duodenal stump. The free end of the jejunum can be approximated and sewn to the vertical portion (D2) of the duodenum. This is best achieved by Kocherizing the duodenum, and sewing the antimesenteric border of the jejunum to the antipancreatic border of D2. The small bowel and the right colon are carefully replaced in the normal position, and the abdomen is closed with or without drainage.

Anatomic Basis of the Complications of Pancreaticoduodenectomy

- Major**
 - Pancreatic fistula, as a result of failed pancreaticojejunal anastomosis: This may occur in 10–20% of cases due to poor integrity of the pancreatic tissue, small diameter of the main pancreatic duct, or poor surgical technique. This complication can be mild or life threatening.
 - Hemorrhage as a result of infection, inflammation, or inadequate surgical hemostasis: This can occur intraluminally at any of the anastomotic sites, in the peritoneal cavity.
 - Leak or stricture at the biliary anastomosis with biliary fistula and/or abscess formation: In general, biliary stricture is an uncommon occurrence after this operation, because of the post-obstructive dilatation of the bile duct seen in most cases.
 - Immediate and long-term development of diabetes mellitus: Removal of the pancreatic head and the uncinate process will lead to diabetes in patients with marginal endocrine function prior to resection.
- Minor**
 - Delayed gastric emptying secondary to edema at the gastrojejunostomy or duodenojejunostomy, loss of the duodenal pacemaker, or vagal interruption.
 - Possible pancreatic exocrine insufficiency due to the damage of the residual gland by ongoing or recurrent pancreatitis.

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Techniques in laparoscopic pancreatic surgery are described.

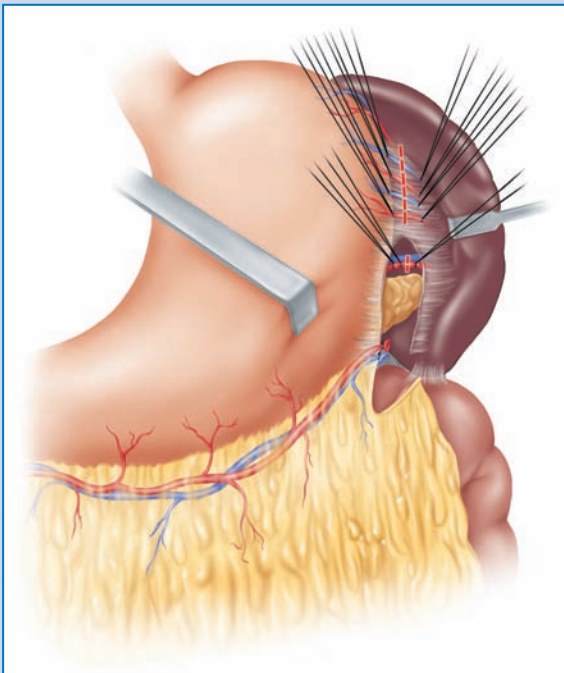
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Spleen

John E. Skandalakis,
Lee J. Skandalakis,
Panagiotis N. Skandalakis,
John F. Sweeney



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Introduction

Primary tumors of the spleen are rare (Morgenstern et al.). Although lymphoma can arise primarily in the spleen, it is not treated surgically. Splenectomy is sometimes required because of isolated metastases of epithelial tumors, such as melanoma. Excluding trauma, benign hematologic diseases are the most common indication for splenectomy. Immune thrombocytopenic purpura (ITP) is the most common indication for splenectomy and comprises more than 70% of patients undergoing splenectomy for benign disease. Additional benign hematologic conditions that are indications for splenectomy include patients with congenital hemolytic anemia, metabolism abnormalities, hemoglobinopathies, and erythrocyte structure abnormalities (e.g., hereditary spherocytosis and elliptocytosis).

Splenectomy may be indicated as a diagnostic tool or for palliation in patients with malignant hematologic disease. Surgical staging is utilized most often in Hodgkin's disease, resulting in a change in diagnosis and subsequent impact on therapy and prognosis in up to 30–40% of patients. Splenectomy can also provide relief to patients with symptomatic splenomegaly, which may or may not be accompanied by hypersplenism. Patients with malignant hematologic diseases are more likely to have massively enlarged spleens (>1,000 g), resulting in significant discomfort and pain, as well as early satiety. When splenomegaly is accompanied by cytopenias (hypersplenism), the cytopenia is often improved or sometimes cured by the removal of the spleen.

In this chapter, open approaches to splenectomy are discussed, with specific note on the staging procedures for Hodgkin's disease. Also included is a discussion of laparoscopic splenectomy, a procedure that has become the standard approach for splenectomy in many centers around the world.

Surgical Anatomy

John E. Skandalakis

Topography

The spleen is located in the left upper quadrant of the abdomen, in a niche formed by the diaphragm above (posterolateral), the stomach medially (anteromedial), the left kidney and left adrenal gland posteriorly (posteromedial), the phrenocolic ligament below, and the chest wall (9th–11th left ribs) laterally. The spleen is concealed at the left hypochondrium and cannot be palpated under normal conditions.

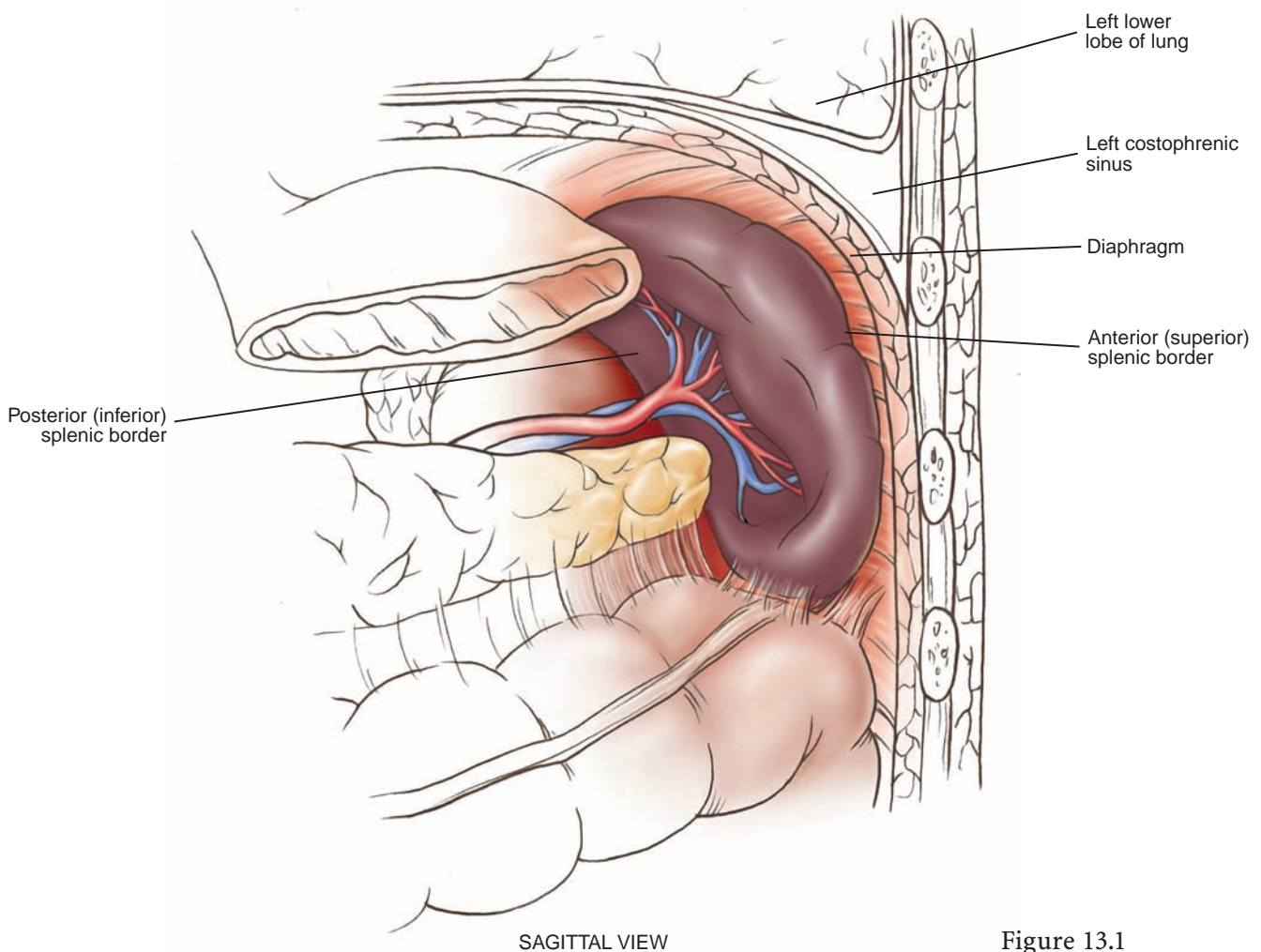


Figure 13.1

The spleen is associated with the posterior portions of the left 9th, 10th, and 11th ribs. It is separated from them by the diaphragm and the costodiaphragmatic recess. The patient with fractures of the left 9th–11th ribs is a prime candidate for underlying splenic rupture and should be closely monitored.

The spleen is oriented obliquely; its upper end is about 5 cm from the dorsal midline and approximates the level of the spinous processes of the 10th and 11th thoracic vertebrae. The lower end lies just behind the midaxillary line. The average spleen is 5 cm wide and 14 cm long, as seen on radiographs. The organ descends about 2–5 cm at deep inspiration.

The spleen is always located in front of the splenic flexure in splenomegaly, and vascular adhesions are almost always present. An enlarged spleen is often fixed heavily with the colon. If splenomegaly is present, intestinal preparation is essential for elective splenectomy.

The upper third of the spleen relates to the lower lobe of the left lung, the middle third to the left costophrenic sinus, and the lower third to the left pleura and costal origin of the diaphragm. In most persons, the lower splenic pole is related to the upper half of the first lumbar vertebra or to the upper half of the fifth lumbar vertebra. Most frequently, the lower splenic pole is related to the upper third of the third lumbar vertebra.

Spleens vary in weight. Extremes of 1 oz to 20 pounds, including both healthy and diseased organs, have been reported. The spleen responds readily to stimuli, increasing in volume with a rise in blood pressure and after meals. It decreases in volume after exercise or immediately postmortem. Like lymphoid tissue elsewhere in the body, the lymphoid tissue of the spleen undergoes diminution after the age of 10 years. After the age of 60, there is some involution of the spleen as a whole.

Shape, Surfaces, and Borders

Knowledge of the surfaces, borders, and topographic anatomy of the spleen permits the radiologist to view and read the spleen correctly. The shape, surfaces, and borders of the spleen should also be carefully noted by the surgeon to alert him or her to possible trouble that may arise during splenectomy. The careful surgeon will proceed with deliberation to prevent bleeding from the spleen, the greater curvature of the stomach, and perhaps from the capsule of the left kidney.

Michels described three basic spleen shapes: wedge, in 44% of specimens; tetrahedral, in 42%; and triangular, in 14%.

Michels' alternate description of spleen shape according to arterial distribution may, however, have greater surgical relevance. The two types are compact or simple distribution, as seen in 30% of the specimens, and "Medusa-like" distribution, as seen in 70%. The compact type has almost even borders and a narrow hilus in which the arterial branches are few and large; the distributed type has notched borders and a large hilus in which the arterial branches are small and numerous.

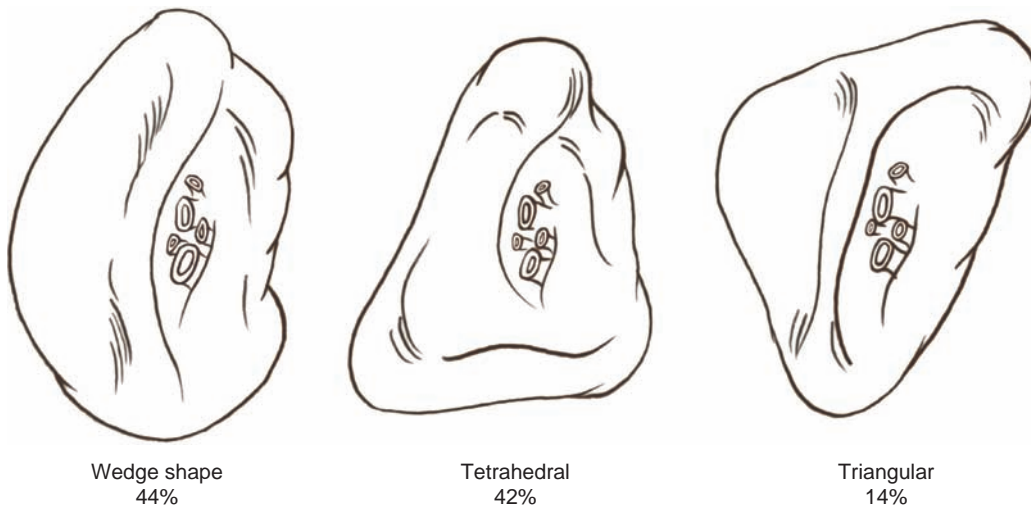


Figure 13.2

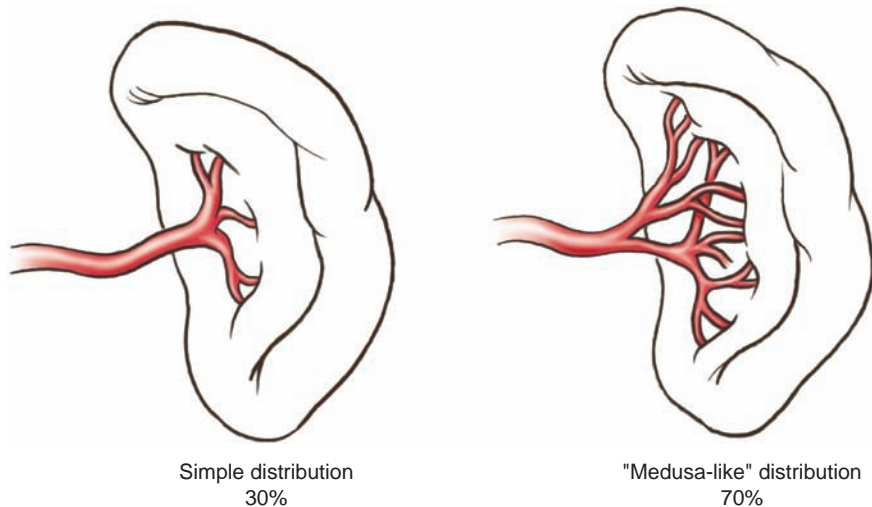


Figure 13.3

If a notched anterior border is present in an enlarged spleen, it may still be palpated. Furthermore, Michels advises surgeons that a notched anterior border is a warning sign of a difficult splenectomy. Spleens with notched borders have multiple arteries (more than two) entering the medial surface of the spleen, and polar arteries are common.

We have also observed these types of vascular distribution in notched and unnotched spleens in laboratory dissections and operating room splenectomies. A notched spleen has multiple arteries that should be ligated carefully, one by one, close to the splenic portas.

The spleen can be said to have two surfaces: parietal and visceral. The relations of the convex parietal surface are with the diaphragm; the relations of the concave visceral surface are with the stomach, the kidney, the colon, and the tail of the pancreas

(gastric, renal, colonic, and pancreatic). The tail of the pancreas must be separated cautiously from the spleen to prevent pancreatic injury. The pancreatosplenic ligament should be ligated when present. Although the convex parietal surface related to the diaphragm is in most cases avascular, it is wise to ligate the short or long splenorenal ligament.

The spleen has two borders: superior (anterior) and inferior (posterior). The superior border separates the gastric and the diaphragmatic areas; the inferior border separates the renal and diaphragmatic areas. Since the posterior splenic border is related to the renal and diaphragmatic areas, separation should be toward the diaphragm to prevent injury to the renal capsule.

Peritoneum and Ligaments

The peritoneum covers the entire spleen in a double layer, except for the hilus. The gastrosplenic and splenorenal ligaments are the two chief ligaments of the spleen. These ligaments comprise part of the embryonic dorsal mesentery, the mesogastrium, whose leaves separate to surround the spleen.

The visceral peritoneum joins the right layer of the greater omentum at the hilus to form the gastrosplenic and splenorenal ligaments, which in turn form the splenic

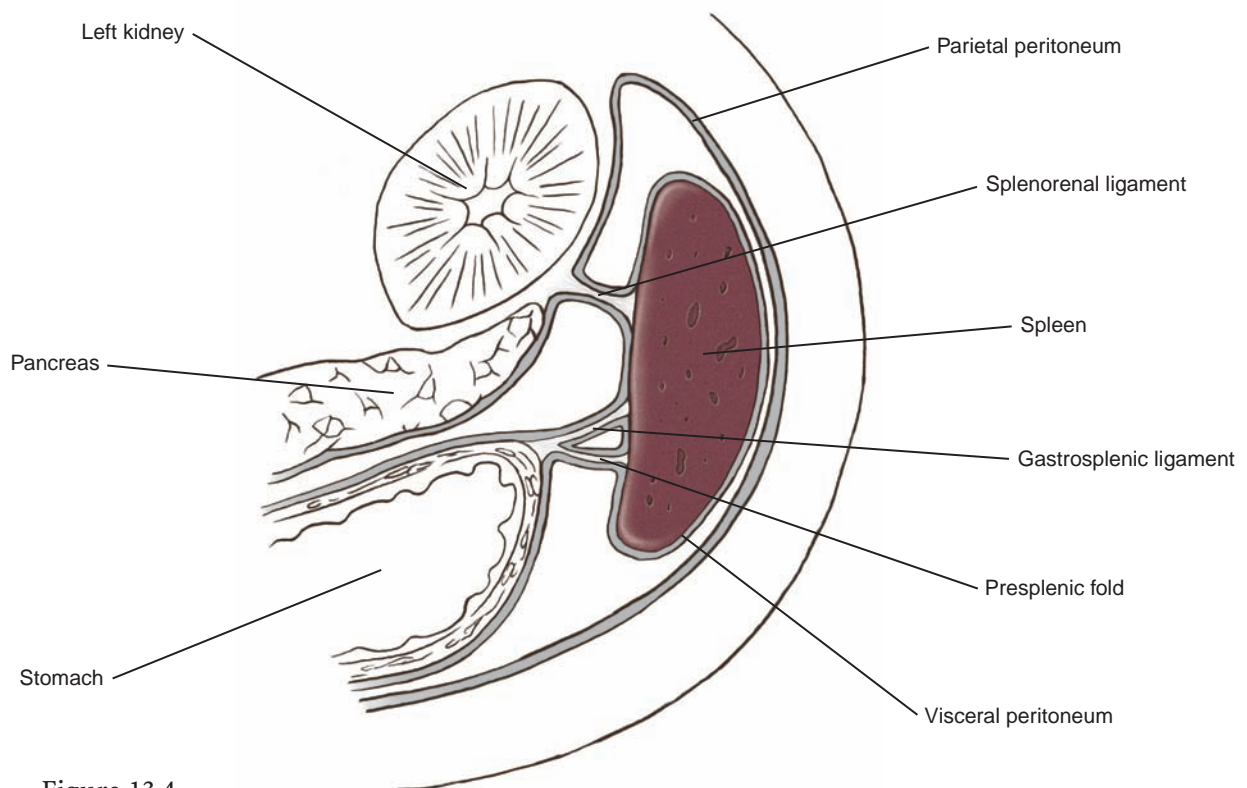


Figure 13.4

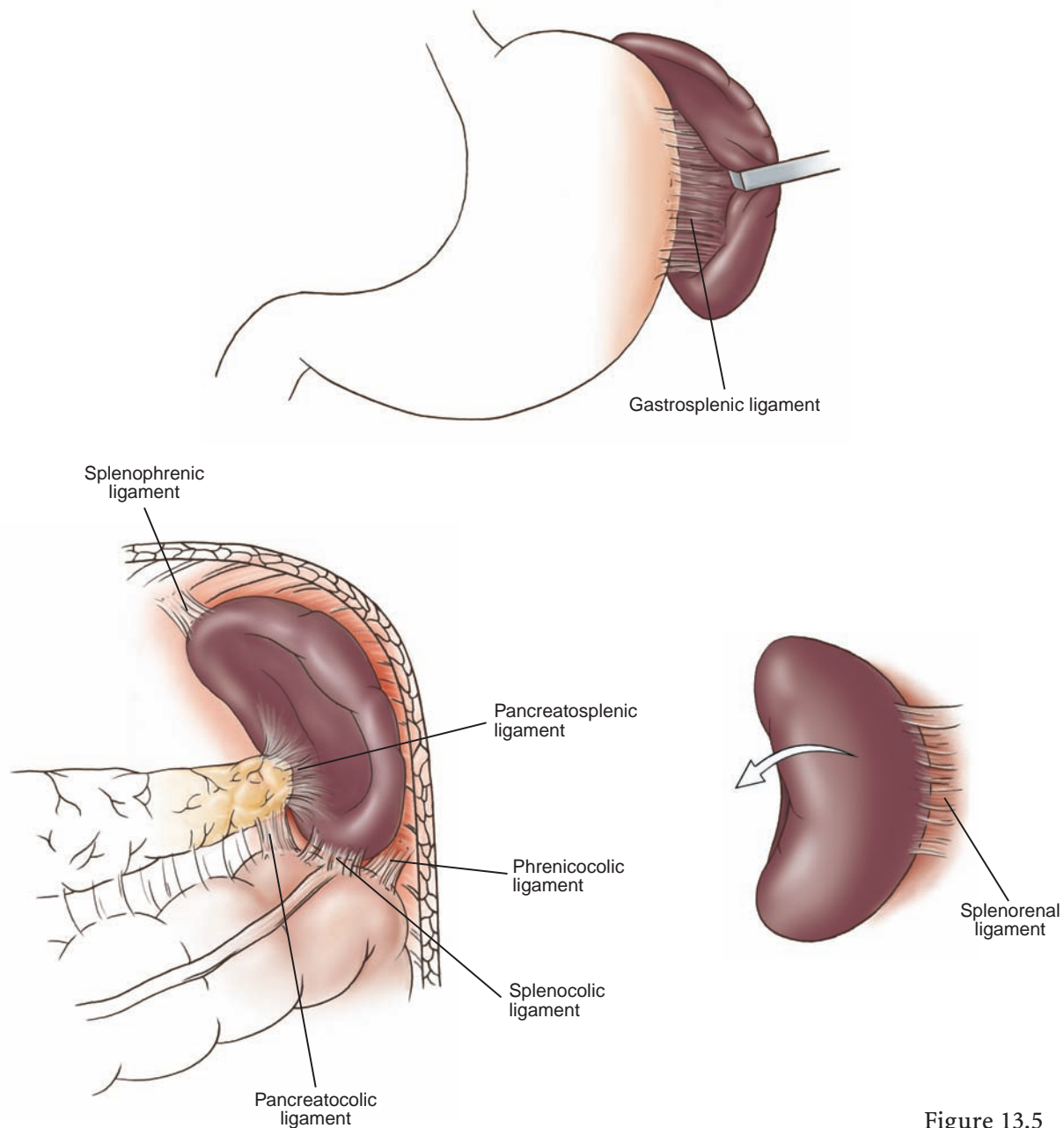


Figure 13.5

pedicle. The visceral peritoneum also forms the capsule, which is as friable and easily injured as the spleen itself.

There are several minor splenic ligaments in addition to the two chief ligaments. The names of these ligaments indicate their connections: the splenophrenic ligament, splenocolic ligament, pancreatosplenic ligament, presplenic fold, phrenocolic ligament, and pancreatocolic ligament.

The mobility of the spleen depends on the degree of laxity of the splenic ligaments and the splenic blood vessels. In our opinion, only four ligaments can affect the position of the spleen: the gastrosplenic, splenocolic, phrenocolic, and splenorenal ligaments.

Gastrosplenic Ligament

The gastrosplenic ligament is the portion of the dorsal mesentery between the stomach and the spleen. Whitesell conceived of the ligament as a triangle. Two sides form the upper portion of the greater curvature of the stomach and the medial border of the spleen. At its apex, the superior pole of the spleen lies close to the stomach and may be fixed to it. Also at the apex of this triangle, the leaves of the mesentery are reflected to the posterior body wall and to the inferior surface of the diaphragm, the splenophrenic ligament. At its base, the inferior pole lies 5–7 cm from the stomach. The gastrosplenic ligament contains the short gastric arteries above and the left gastroepiploic vessels below. During splenectomy, care must be taken to ligate the short gastric vessels and the left gastroepiploic vessels separately and to incise the gastrosplenic ligament between clamps.

Splenorenal Ligament

Curiously, the existence of the splenorenal ligament is often overlooked. This almost avascular ligament is the posterior portion of the primitive dorsal mesogastrium. The splenorenal ligament envelops the splenic vessels and the tail of the pancreas.

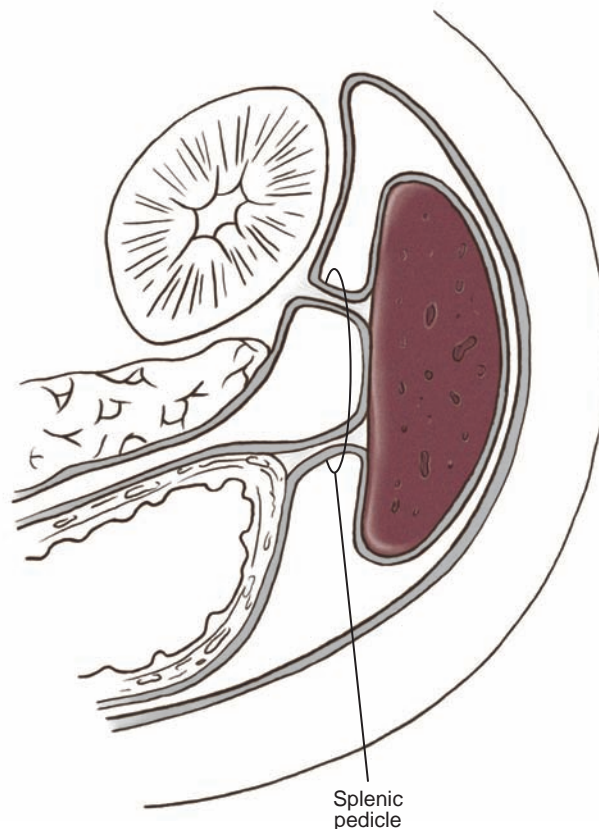


Figure 13.6

Therefore, incisions and finger excavation to mobilize the organ must be done with care. In addition, no more traction than usual should be applied to a short splenophrenic ligament, to prevent tearing the capsule, which may produce bleeding. Incision of its peritoneal layer, together with the mobilization of the tail of the pancreas, reestablishes the primitive condition.

The posterior layer of the gastrosplenic ligament forms the outer layer of the splenorenal ligament. Careless division may injure the short gastric vessels.

The extent to which the primitive dorsal mesogastrium is absorbed into the body wall determines whether the splenic pedicle is narrow or wide. The length of the splenic vessels after incision of the ligament is a greater factor than the splenorenal ligament in controlling the degree of effective mobilization of the spleen. A short splenic artery may make it impossible to deliver the spleen out of the abdomen. Splenic mobility may be increased by gently pushing the tail of the pancreas away from the hilus of the spleen.

Rosen et al. reported that the length of the splenorenal ligament ranges from 2.5 to 5.5 cm. The relations between the pancreatic tail and the splenic porta (hilum splenicum) are as follows: tail not penetrating the ligament, 24%; tail within the ligament without reaching the porta, 32%; tail reaching the porta, 27.9%; and tail penetrating the gastrosplenic ligament, 13%.

Minor Ligaments

Splenophrenic Ligament. The splenophrenic ligament is the reflection of the leaves of the mesentery to the posterior body wall and to the inferior surface of the diaphragm at the area of the upper pole of the spleen close to the stomach. It is an extension of the splenorenal ligament to the diaphragm. Although usually avascular, it should be checked for possible bleeding after division.

Splenocolic Ligament. The splenocolic ligament is a remnant of the extreme left end of the transverse mesocolon, which develops a secondary attachment to the spleen during embryonic fixation of the colon to the body wall. As a secondary attachment, it might not be expected to contain large blood vessels. However, massive bleeding may result from careless incision of the ligament; tortuous or aberrant inferior polar vessels, or a left gastroepiploic artery, may lie close enough to be injured. Because of its close relation to the lower polar and the left gastroepiploic vessels, the splenocolic ligament should be incised between clamps.

Pancreatosplenic Ligament. The pancreatosplenic ligament can be found when the tail of the pancreas does not touch the spleen. The pancreatosplenic ligament, if present and long enough, should be incised between clamps. If absent or short, careful separation of the pancreatic tail from the spleen is necessary to prevent pancreatic or splenic injury.

Presplenic Fold. A peritoneal fold lies anterior to the gastrosplenic ligament. The fold is usually free on its lateral border, but in a large diseased spleen, it may be attached. This fold may be derived from the anterior limb of the inverted-Y arrangement of some hili.

The left gastroepiploic vessels are often contained in the presplenic fold. Excessive traction during upper abdominal operations can result in a tear in the splenic capsule. Conservative procedures are then mandatory for splenic salvage. Excessive traction on the presplenic fold may produce bleeding because of its proximity to the left gastroepiploic vessels.

Phrenocolic Ligament. The phrenocolic ligament extends between the splenic flexure and the diaphragm. It is not really a splenic ligament, but the spleen rests on it. It is the “splenic floor,” but is unconnected to the spleen. The phrenocolic ligament acts as a barricade at the left gutter and is responsible, in most instances, for prohibiting the downward travel of blood from a ruptured splenic artery or from the spleen. Instead, the blood collects at the anterior pararenal space retroperitoneally or around the spleen at the left upper quadrant by displacing the colon laterally. If the phrenocolic ligament is short or fused, injury to the lower pole or the splenic flexure of the colon is remote, but possible.

It is a mistake to describe the phrenocolic ligament as the left phrenocolic ligament, because there is no corresponding right ligament; there is only one phrenocolic ligament and it is on the left side.

Pancreatocolic Ligament. The pancreatocolic ligament is the upper extension of the transverse mesocolon. Careless traction of a short or fused pancreatocolic ligament may lead to colonic or pancreatic injury.

Blood Supply

Segmental Anatomy

A number of studies have reported the separation of the spleen into lobes and segments by its arterial supply (Redmond et al.). Few mention the fact that the same segmental pattern can be observed based on venous drainage. This reflects the embryologic development of the organ, which is formed by the fusion of vascularized, isolated mesenchymal aggregates.

Gupta et al. made corrosion casts of human splenic arterial trees. In 84%, there were two splenic segments (superior and inferior); in 16% there were three segments (superior, middle, and inferior). The arterial segments were separated by avascular planes.

After studying 127 human spleens, Redmond et al. stated that the spleen is composed of anywhere from three to seven segments. Each segment has its own independent blood supply, separated by avascular planes. Segmental anatomy is not useful in tumor surgery involving the spleen.

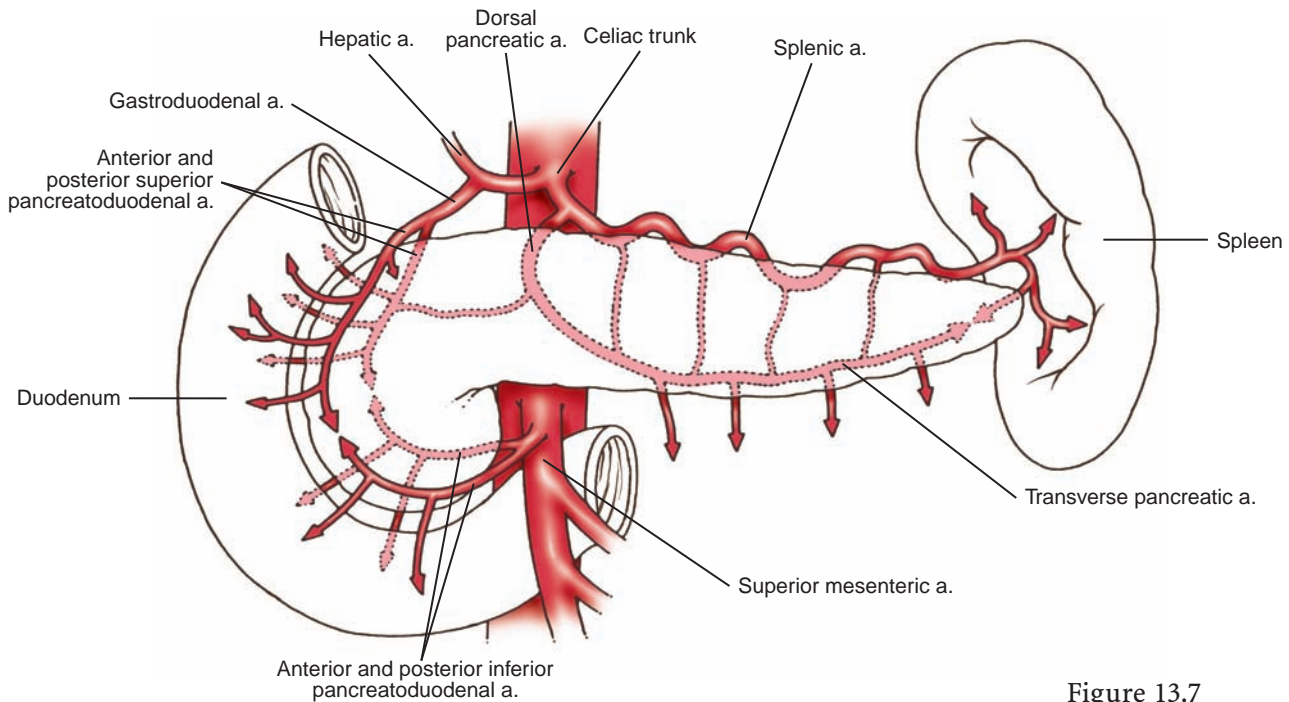


Figure 13.7

In most people, the splenic artery is a branch of the celiac trunk, together with the hepatic and left gastric arteries. The common tripodal form of the celiac trunk (82%, according to Michels) may be replaced by a dipodal or tetrapodal pattern of branching when any of these or other upper abdominal arteries arise from atypical sources (VanDamme and Bonte). The normal course of the splenic artery is as follows.

From its origin, the splenic artery crosses the left side of the aorta. It passes along the upper border of pancreas and reaches the tail in front. It then crosses the upper pole of the left kidney. The artery varies in length from 8 to 32 cm, and in diameter from 0.5 to 1.2 cm.

Waizer et al. reported on clinical implications of anatomic variations of the splenic artery. In 9 of 26 cadavers, the splenic artery made a loop to the right as soon as it emerged from the celiac artery, appearing at the border of the lesser omentum. It would thus be vulnerable to iatrogenic injury during procedures on supracolic organs.

The splenic artery forms the splenic peritoneal fold on its way to the spleen. It ends in the splenorenal ligament, forming a unique and peculiar tree, then reaches and enters the splenic porta.

According to Michels, the artery has four segments: suprapancreatic, pancreatic, prepancreatic, and prehilar segments. When we studied the splenic artery and its branches in toto, we concentrated on the last two distant segments, the prepancreatic and prehilar segments.

When angiography first provided noninvasive access to the vascular system of the spleen, we studied several angiograms, some which were selective splenic artery angiograms. The result was conclusive: Not even one of these films was a mirror image of another. Each was different, with unlimited variations, unpredictable in the

Splenic Artery

origin of its branches and in length, dilatation (width), tortuosity, and course with regard to the pancreas (above the upper border, in front or behind, or partially or totally, within the pancreatic parenchyma).

There is considerable agreement that the splenic artery most commonly bifurcates into two major branches (75% of the time) and less commonly undergoes trifurcation. Any further branching of these primary vessels three or more times yields a widely varying number of branches. These ultimately gain access to the hilus of the spleen. Reported extremes of branching range from 3 to 38.

Branches of Splenic Artery

Michels found a superior polar artery originating from the prehilar segment 65% of the time and an inferior polar artery or arteries 82% of the time. Our dissection of the splenic artery in 29 cadavers yielded the following points of origin: 27 from a hepatosplenogastric trunk, one from the common hepatic artery (hepatosplenic trunk), and one from the left gastric artery (gastrosplenic trunk).

The short gastric arteries anastomose with the cardiac branches of the left gastric artery. The short gastric arteries are the collateral circulation of the spleen. Farag et al. stated that because of the short gastric arteries, the upper third of the spleen might survive after a lower two thirds splenectomy in patients with normal size spleens.

Michels found that the left gastroepiploic artery arises from the splenic trunk 72% of the time, from the inferior terminal or its branches 22% of the time, and rarely from the middle splenic trunk or the superior terminal branch.

Other branches of the splenic artery include many small, unnamed branches. The more prominent, named branches are the dorsal pancreatic artery, the great pancreatic artery (pancreatica magna), and the caudal pancreatic artery.

The dorsal pancreatic artery is the “supreme pancreatic artery,” posterior to the splenic vein and is about 1.5 mm in diameter. Michels considers it the most variable of the celiacomesenteric vessels. The usual origin of the dorsal pancreatic artery is from the proximal 2 cm of the splenic artery (39% of specimens). However, it may arise from other arteries, including an aberrant hepatic artery.

The great pancreatic artery (arteria pancreatica magna of von Haller) is one of the largest branches of the splenic artery. It is the chief blood supplier of the distal body and the tail of the pancreas.

The caudal pancreatic artery originates from the left gastroepiploic artery or a splenic branch at the hilus of the spleen and anastomoses with the branches of the great pancreatic and transverse pancreatic arteries. The caudal pancreatic artery supplies blood to accessory splenic tissue when it is present at the hilus of the spleen.

Collateral Circulation

The splenic artery is not the only artery to supply the spleen with blood. Additional blood supply comes from the inferior or transverse pancreatic artery, short gastric arteries, left gastroepiploic artery, and other pancreatic arteries.

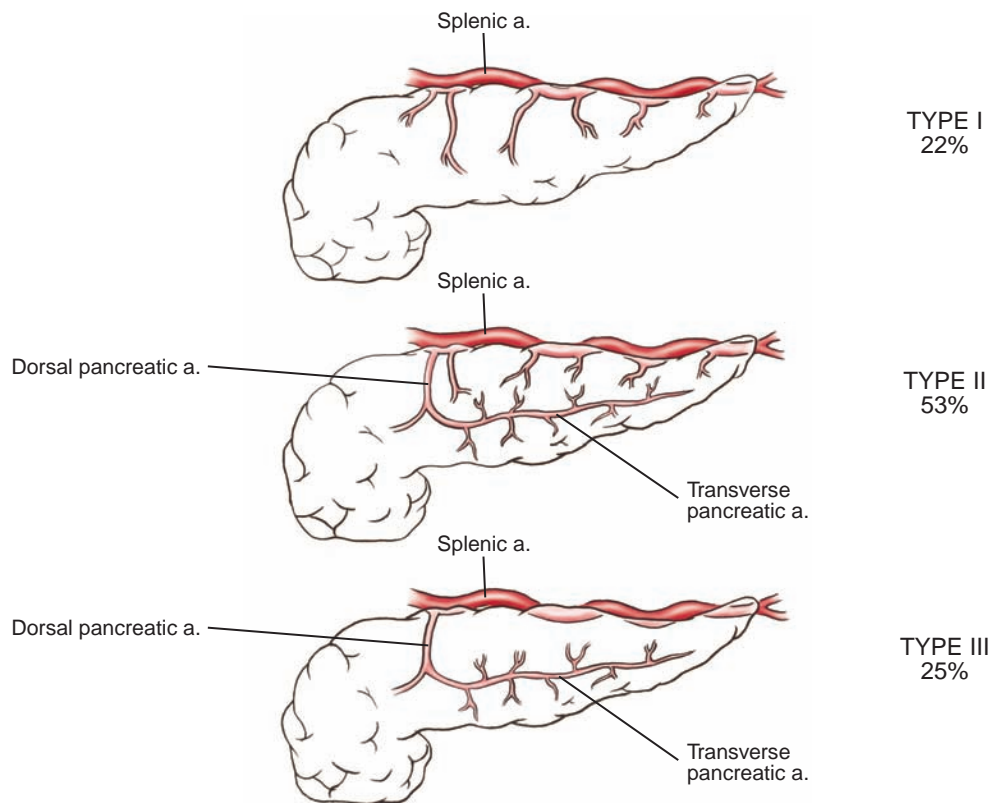
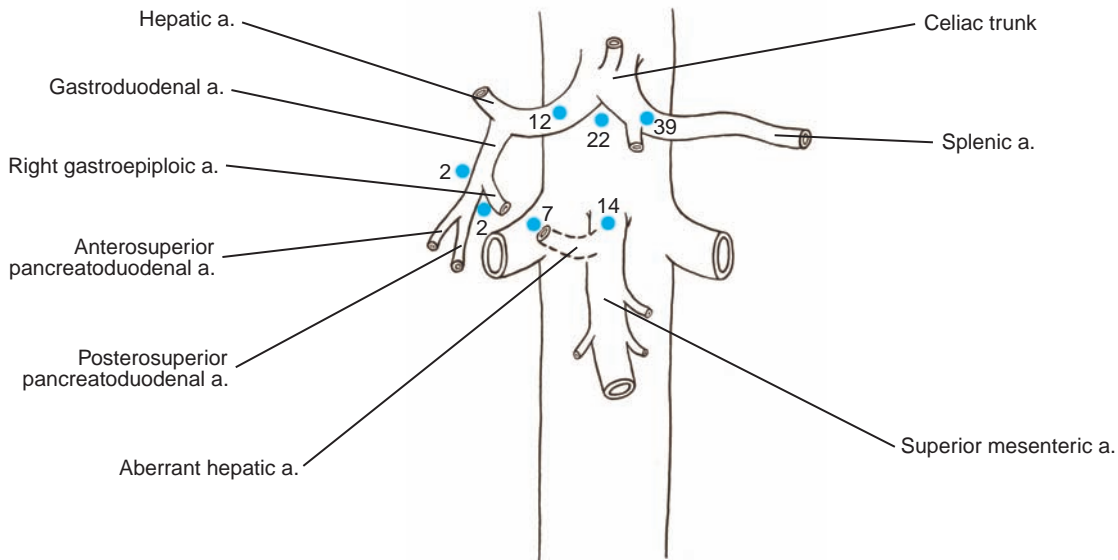


Figure 13.8

The “main splenic arteries” are, for all practical purposes, the terminal branches of the splenic artery. They are responsible for the arterial blood supply of the spleen. These arteries originate from the superior and inferior terminal arteries or from other terminal branches. The superior and inferior polar arteries most often originate from the prehilar segment and should be considered part of the main splenic artery. These arteries penetrate the splenic parenchyma above and below the portas.

The superior polar artery is nearly always present.

Venous Drainage

The splenic vein arises from the trabecular vein. 27 cadavers were dissected to study the splenic vein. The vein was formed by three trunks in 16 cases and by four trunks in eight cases. Three trunks plus the left gastroepiploic formed the splenic vein in the remaining three cases.

It must be remembered that the patterns are highly variable; no one vein resembles the next. Considerable variations are found in: the exit points of the veins, their point of confluence in the formation of the main splenic vein, and their entrance into other veins at or outside the hilus.

Douglass et al. reported one point of common ground. The short gastric veins, or most of them, are in direct communication with the spleen. They enter the upper part of the organ rather than the extrasplenic venous vessels. The drainage of the left gastroepiploic vein is into the splenic veins.

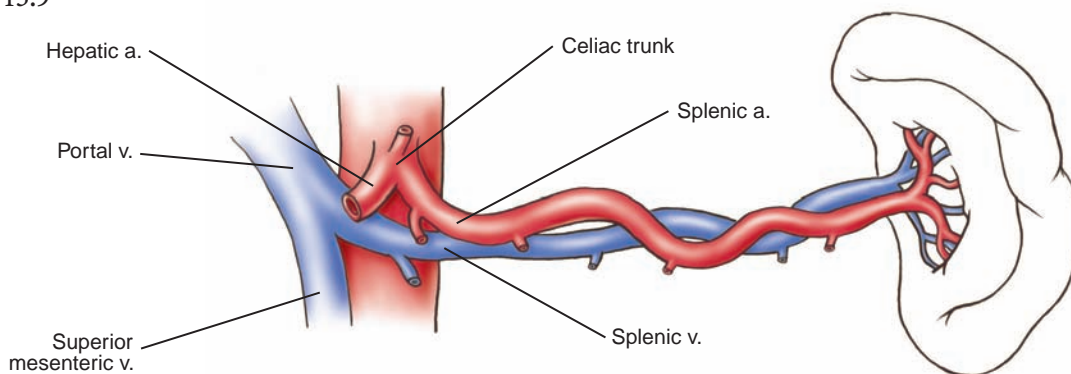
The origin of the splenic vein is in the coalescence of five or six tributaries that emerge from the splenic hilus. Although the splenic vein is of a large caliber, it does not possess the tortuosity of the splenic artery. The splenic vein passes through the splenorenal ligament with the artery and the tail of the pancreas. It passes to the right, usually inferior to the artery and behind the body of the pancreas, receiving pancreatic tributaries. The vein ends deep into the neck of the pancreas by joining the superior mesenteric vein to form the portal vein.

The splenic vein and the splenic artery travel together. Gerber et al. found three anatomic arrangements in 75 consecutive autopsies: vein entirely posterior to the artery, in 54%; vein wrapped around the artery, part posterior and part anterior to it, in 44%; and vein entirely anterior to the artery, in 2%.

Ligation of the splenic arteries is permissible if the spleen has not been mobilized. The spleen remains viable if the collateral circulation is intact (polar arteries, short gastric arteries, and left gastroepiploic arteries). However, if the color of the spleen is changed and there is evidence of ischemia, splenectomy should be performed. Splenic vein thrombosis is also an indicator for total splenectomy.

As a rule, ligation of the splenic artery should be done only if absolutely necessary (i.e., during splenectomy). It is advisable to perform proximal double ligation of the splenic artery. Ligation of the artery should precede ligation of the vein, which should not be ligated alone. Because the origin and the ultimate termination of the

Figure 13.9



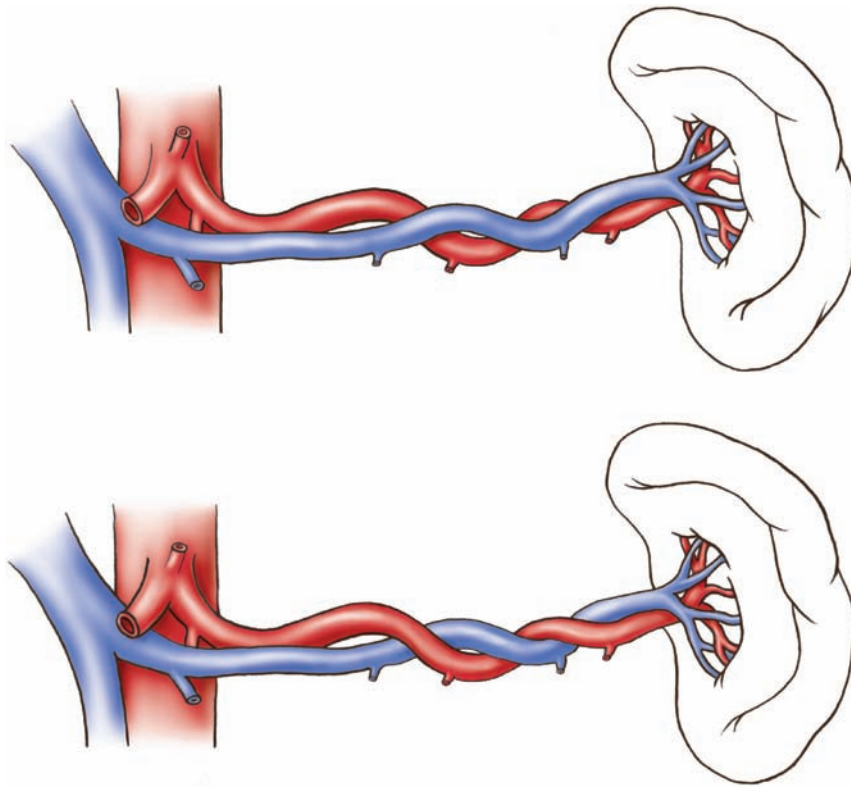


Figure 13.10

terminal arterial and venous branches are unpredictable, these vessels should be isolated and ligated close to the splenic portas to prevent bleeding. The tortuous splenic artery should be ligated with care to prevent pancreatic and splenic vein injury. Elevated segments of the tortuous splenic artery facilitate ligation without anatomic complications.

Nerve Supply

The more medial and anterior portions of the celiac plexus are the source of the splenic plexus. The splenic vessels are accompanied into the hilum by visceral nerve fibers from this plexus. According to Allen, fibers from the right vagus nerve or posterior vagal trunk also pass to the spleen. However, this configuration is questioned on the basis of study results in cats with nerve degeneration after vagotomy.

Myelinated fibers, probably sensory in function, can be identified histologically in a ratio of about 1:20 to unmyelinated autonomic fibers. These few sensory fibers terminate in the spinal cord at the level of the sixth to eighth thoracic vertebrae. The preganglionic sympathetic neurons arise in the intermediolateral cell column from this same level. They pass within the greater thoracic splanchnic nerve to the celiac ganglion and its extensions along the splenic artery. In some mammals, the

autonomic fibers terminate in the smooth muscles of the capsule, trabeculae, arteries, and veins. However, in humans the distribution of the autonomic fibers appears to be confined mostly to the branches of the splenic arteries.

Lymphatic Drainage

In the classification of the lymphatic vessels as devised by Rouviere, the splenic chain includes suprapancreatic nodes, infrapancreatic nodes, and afferent and efferent lymph vessels. Pancreatic tumors divide the splenic nodes into the hilus of the spleen and the tail of the pancreas.

The splenopancreatic glands are located along the splenic artery. This is the largest group of “splenic lymph nodes.” A small number can also be found in the area of the short gastric vessels. The origin of the splenic lymphatic vessels is the splenic capsule and the trabeculae. The splenic nodes accept vessels from the stomach and the pancreas.

One of the peculiarities of this enigmatic organ is the lack of provision for lymphatic drainage of the splenic pulp. The lymph nodes described above just happen to be located in the splenic neighborhood. Their destiny is to drain the stomach rather than the spleen. The dilemma of the surgeon is whether the spleen should be removed when the “splenic” lymph nodes are involved with disease. We do not have the answer for this. Antibiotics and active immunization against pneumococci are definitely of tremendous help against postsplenectomy sepsis. Partial splenectomy may prove to be the answer, even though Dearth et al. discussed the problems of false negative results in staging of Hodgkin’s disease.

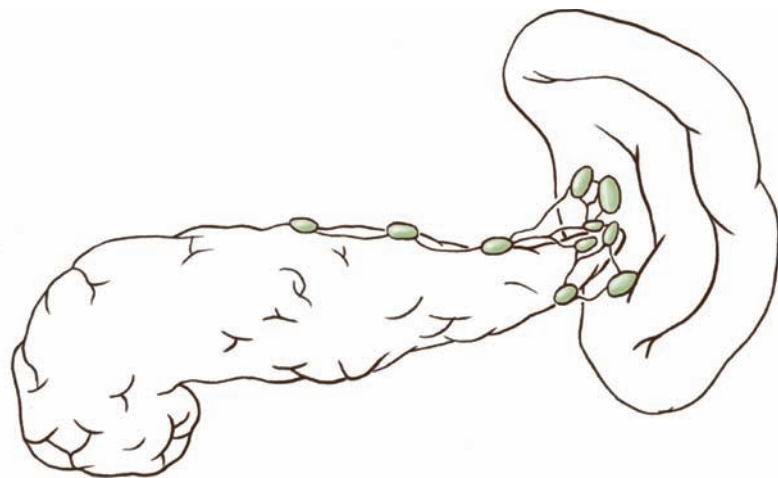


Figure 13.11

Surgical Applications

Open Splenectomy

Lee J. Skandalakis and Panagiotis N. Skandalakis

Open splenectomy for ITP (the most common indication for splenectomy) is rather straightforward. However, splenectomy in the setting of malignant hematologic disease is usually much more challenging. Patients in the latter group often have significant splenomegaly with the spleen often extending down to the iliac crest. The sheer weight and size of this type of spleen make it difficult to move or lift the organ without rupturing the capsule or one of its attachments. Patience and some special technical maneuvers are required for splenectomy in this setting. Splenectomy may also be performed as part of a staging laparotomy for Hodgkin's disease or to remove the spleen as a margin to adjacent tumors.

Incisions

Surgeon preference and the size of the spleen will dictate the type of incision to be made. Although the subcostal incision gives adequate exposure, the midline incision is preferred in most indications for splenectomy (trauma, hypersplenism with coagulation problems, staging laparotomy for Hodgkin's disease, massive splenomegaly). However, the subcostal incision is appropriate when there is a diagnosis of a splenic mass in a normal or twice normal sized organ or when no additional abdominal procedures are planned. Since these conditions occur infrequently, most surgeons perform splenectomy through a midline incision. Thoracoabdominal incisions are used rarely. The bed of the eighth or 9th rib may be used for massive splenomegaly. There seems to be no difference in postoperative complications with midline and subcostal incisions. Therefore, the surgeon should choose the incision that gives the best exposure for the operation planned.

The midline incision offers several important advantages for splenectomy. First, the surgeon can safely remove the spleen, no matter its size, with a large enough incision and an adequate exposure of the left upper quadrant. Second, the incision can be made quickly and easily, with minimal blood loss. Third, the midline incision allows the surgeon to explore the entire abdomen.

If there is a well-developed presplenic fold, the anterior approach to the splenic artery at the pedicle may demonstrate six sheets of peritoneum, fat, lymph nodes, and pancreas fused into a single mass. Both the lesser sac and the space between

the presplenic fold and the gastrosplenic ligament may be obliterated. Only a single (posterior) leaf of the splenorenal ligament is encountered in a posterior approach to the splenic artery.

Indications for Splenectomy

Table 13.1 Indications for Splenectomy

Control or stage primary disease	Chronic or severe hypersplenism
Autoimmune anemia	Agnogenic myeloid metaplasia
Hereditary elliptocytosis	Lymphoproliferative disorder (non-Hodgkin's lymphoma, chronic lymphocytic leukemia, chronic myelocytic leukemia)
Hereditary spherocytosis	Chronic myelocytic leukemia
Immune thrombocytopenic purpura	Hairy cell leukemia
Thrombotic thrombocytopenic purpura	Felty's syndrome
Primary splenic neoplasm	Gaucher's disease
Splenic abscess	Thalassemia major
Splenic cyst	Acquired immunodeficiencies (human immunodeficiency virus)
Hodgkin's lymphoma	
Splenic vein thrombosis	
Splenomegaly caused by hemodialysis	

Splenectomy for Enlarged Spleen

The incision is made. Access to the lesser sac is gained by clamping, incising, and ligating the left part of the gastrocolic ligament, and the gastroepiploic artery and vein.

The short gastric arteries and veins are clamped, divided, and ligated one by one. The splenic artery at the superior border of the body of the pancreas is easily located and ligated in continuity, carefully and doubly. Ligatures are placed as distally as possible. In the setting of massive splenomegaly, early ligation of the splenic artery will allow for autotransfusion of blood from the spleen, decreasing the splenic size and minimizing blood loss. Alternatively, the division of the splenic artery may follow mobilization of the spleen.

The spleen is mobilized by the division of several ligaments using electrocautery to minimize blood loss. Most of the ligaments are avascular. After creating a small window at the splenorenal ligament, the index finger is inserted deep. Blunt and sharp dissection is used to separate the spleen from the renal covering by proceeding slowly caudad and cephalad. The splenocolic and splenophrenic ligaments are clamped, divided, and ligated.

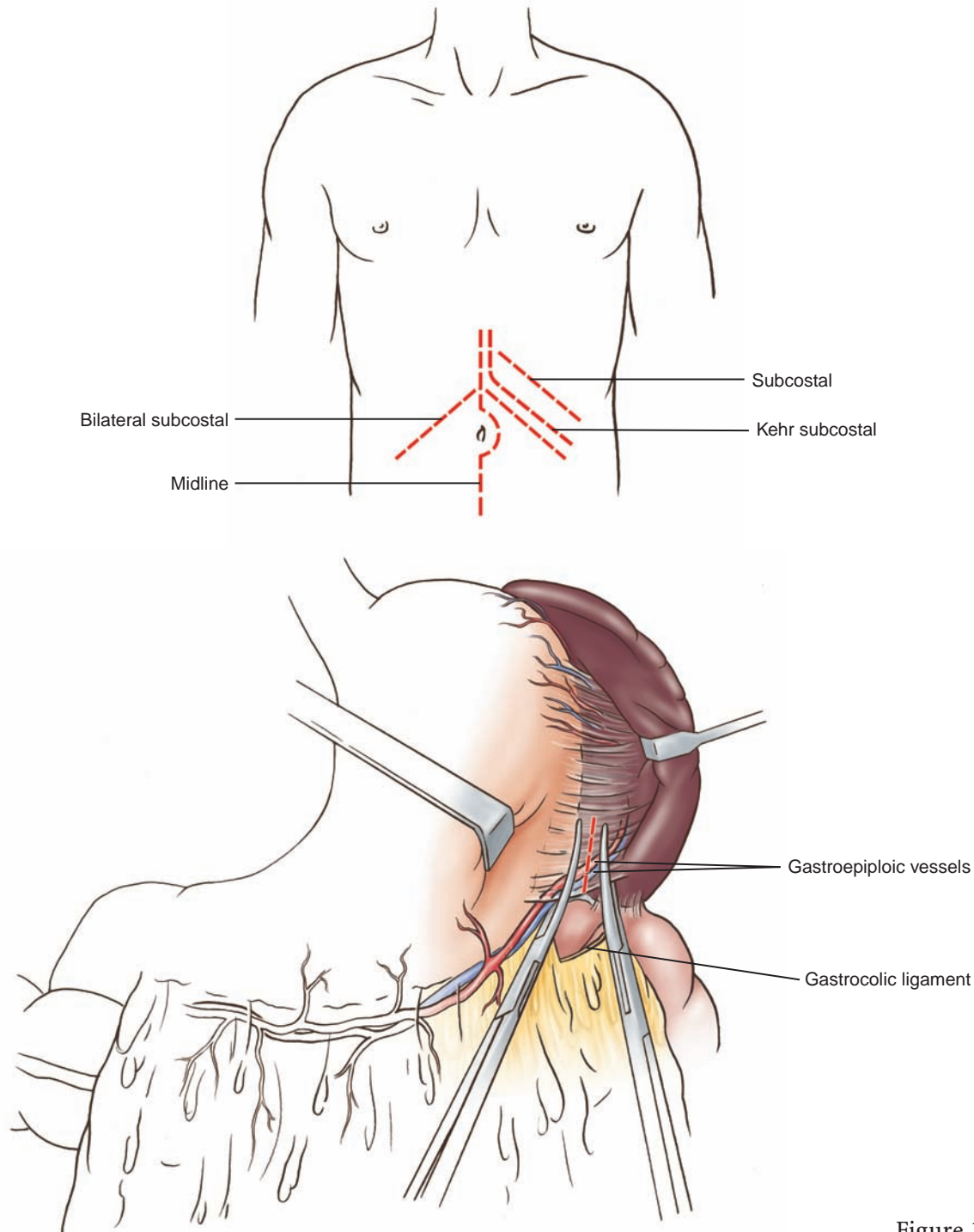


Figure 13.12

With a wide window, now large enough to insert four fingers or the hand in toto, the surgeon should elevate the spleen and the tail and part of the body of the pancreas. The spleen is carefully delivered outside the peritoneal cavity, with the only attachment being one of the branches of the splenic arteries and veins. The tail of the pancreas should be handled with care.

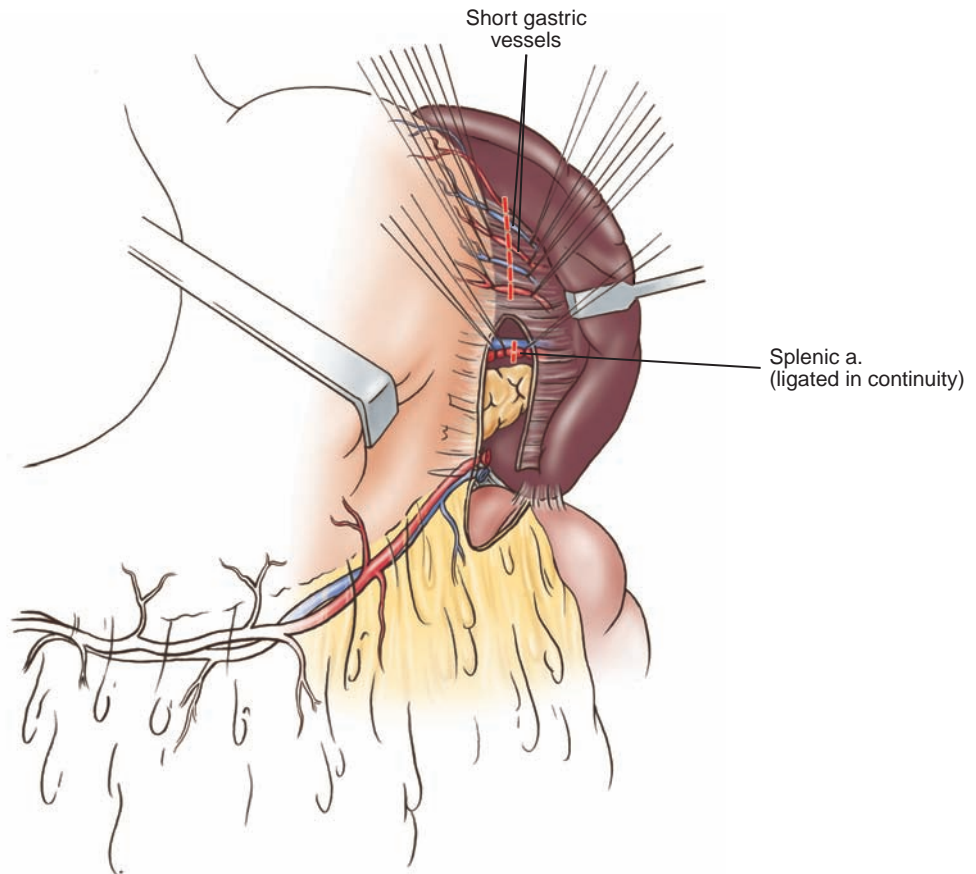


Figure 13.13

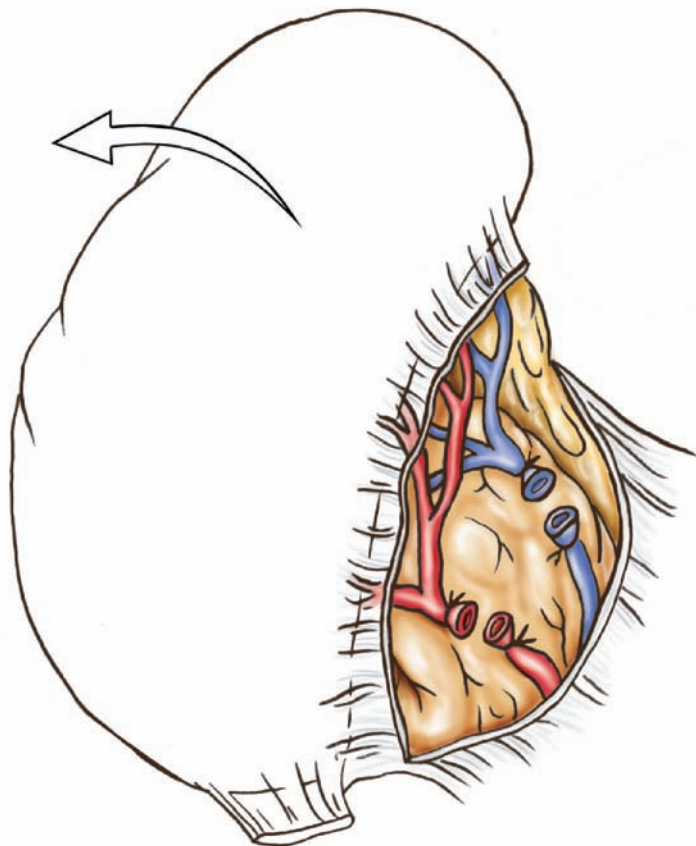


Figure 13.14

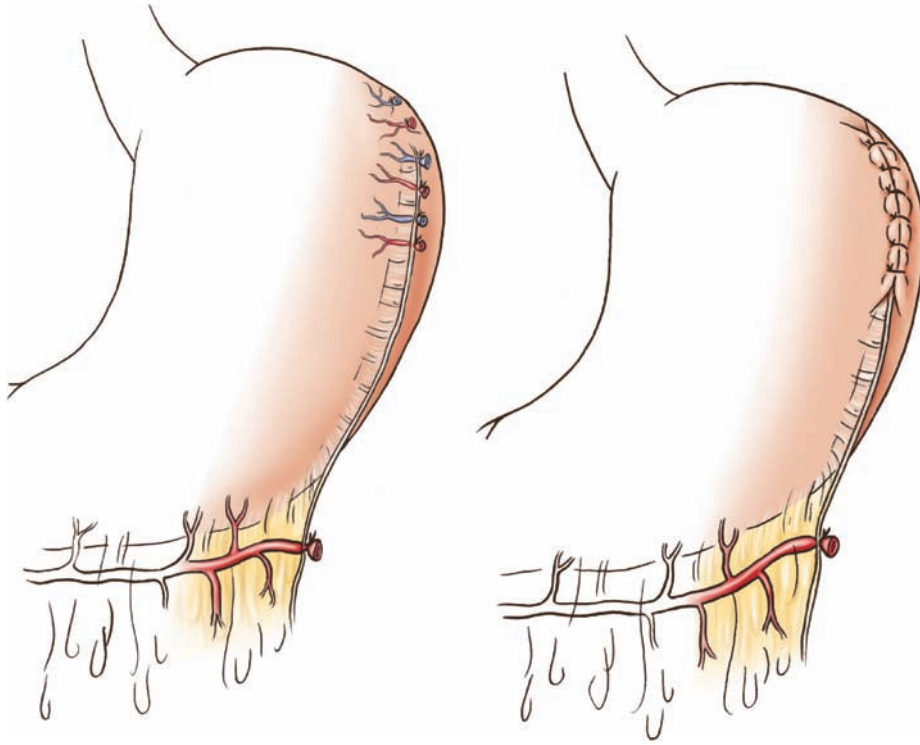


Figure 13.15

All the branches of the splenic artery are clamped, divided, and ligated close to the hilum. The splenic vein and its branches are very friable, and the clamps should be used with great caution. The main vein is encircled with double suture material, tied carefully with ligature, and the spleen removed.

The site is inspected for bleeding and for accessory spleens. Inspection for bleeding proceeds from above downward, starting at the diaphragm and continuing to the greater curvature of stomach, pancreatic tail, gastrosplenic ligament, splenorenal ligament, splenocolic ligament, and splenic bed, and other ligaments. Complete hemostasis is essential. The greater curvature may be inverted with continuous 00 suture to prevent postoperative bleeding and possible necrosis in the area of the short gastric arteries. The search for accessory spleens is done after an inspection for bleeding.

The use of drains after splenectomy is controversial. The main problem with placing drains in the splenic bed is the possibility of an ascending infection of the skin resulting in an abscess. Thus the drain would cause, rather than prevent, a subphrenic abscess. When drains are used, they should be closed suction drains and should be removed in 2–5 days unless a large amount of drainage (more than 50–75 mL) indicates the possibility of a fistula.

Splenectomy for Staging Hodgkin's Disease

Improvements in radiologic staging of Hodgkin's disease have virtually eliminated the need for staging procedures for Hodgkin's disease. When performed, they should include the following:

1. A detailed exploratory laparotomy
2. An examination of the nodes, and wedge and needle biopsies of both lobes of the liver
3. A total splenectomy with splenic lymph node biopsy
4. A retroperitoneal exploration of the celiac axis, hepatoduodenopancreatic lymph nodes, periaortic lymph nodes, inferior vena cava lymph nodes, iliac lymph nodes, and mesenteric lymph nodes of the small, and large intestines for lymph node biopsy
5. A biopsy of the iliac crest marrow
6. A search for accessory spleens
7. The placement of metal clips at the splenic pedicle, areas of lymph nodes where biopsies have been done, areas of lymph nodes where biopsies have not been performed, and the site of ovarian translocation

Anatomic Basis of Complications

- Injury to the splenic artery or vein results in severe bleeding. Ligation is necessary.
- Injury to the short gastric vessels causes severe bleeding.
- Injury of the tail or body of the pancreas causes postoperative pancreatitis.
- Imbrication is advised if there is injury to the greater curvature of the stomach.
- Injury to the diaphragm.
- Injury to the left kidney.
- Injury to the left colon or splenic flexure.

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Laparoscopic Splenectomy

John F. Sweeney

Minimally invasive surgery is associated with reduced postoperative pain, earlier return to normal activity and improved cosmesis when compared to open surgery (1, 2). Since laparoscopic cholecystectomy was shown to meet these criteria in the late 1980s and early 1990s (3), minimally invasive surgical techniques have been applied to a variety of abdominal and thoracic procedures. Removal of the spleen laparoscopically is facilitated by the fact that the anatomic landmarks are relatively consistent, the operation is extirpative and does not require reconstruction, and in most cases, the spleen does not need to be preserved for pathology and so it can be morcellated in the abdominal cavity prior to removal (4). The first laparoscopic splenectomy (LS) was reported in 1991 by Delaitre and Maignien (5), and since then, LS has been shown in several retrospective studies to have equivalent or superior short-term and long-term outcomes, when compared to open splenectomy (6–8).

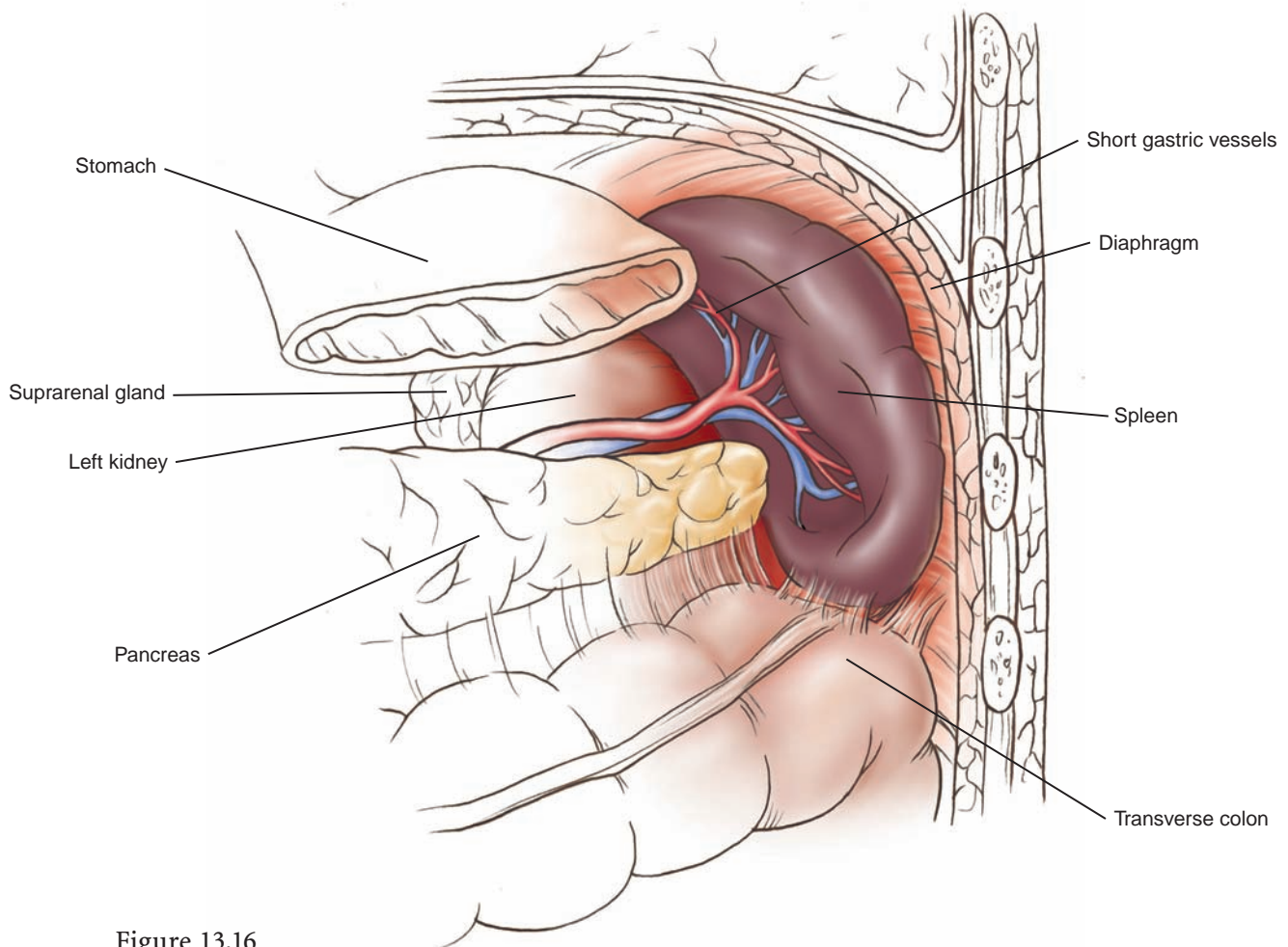


Figure 13.16

Preoperative Preparation

The patient's preoperative preparation includes the administration of polyvalent pneumococcal vaccine at least 2 weeks before surgery. The evening before surgery, patients commence a clear liquid diet and take a mild laxative several hours before bedtime (one bottle of magnesium citrate at 7:00 pm) to decompress the colon and facilitate laparoscopic visualization of the left upper quadrant and the spleen. Several units of packed red blood cells are cross matched, and in patients with idiopathic thrombocytopenic purpura, platelets are cross matched for administration after the splenic artery has been ligated intraoperatively if there is failure of clot formation.

Pneumatic compression boots are applied immediately preoperatively, and a preoperative antibiotic (1 gm cephazolin) is given. Patients who have been receiving corticosteroids within 6 months of surgery are given stress doses of intravenous corticosteroids. Before transport to the operating room, a stabilizing bean bag is placed on the operating table to enable subsequent patient positioning and stabilization.

After endotracheal induction of general anesthesia, a Foley catheter and an orogastric tube are placed.

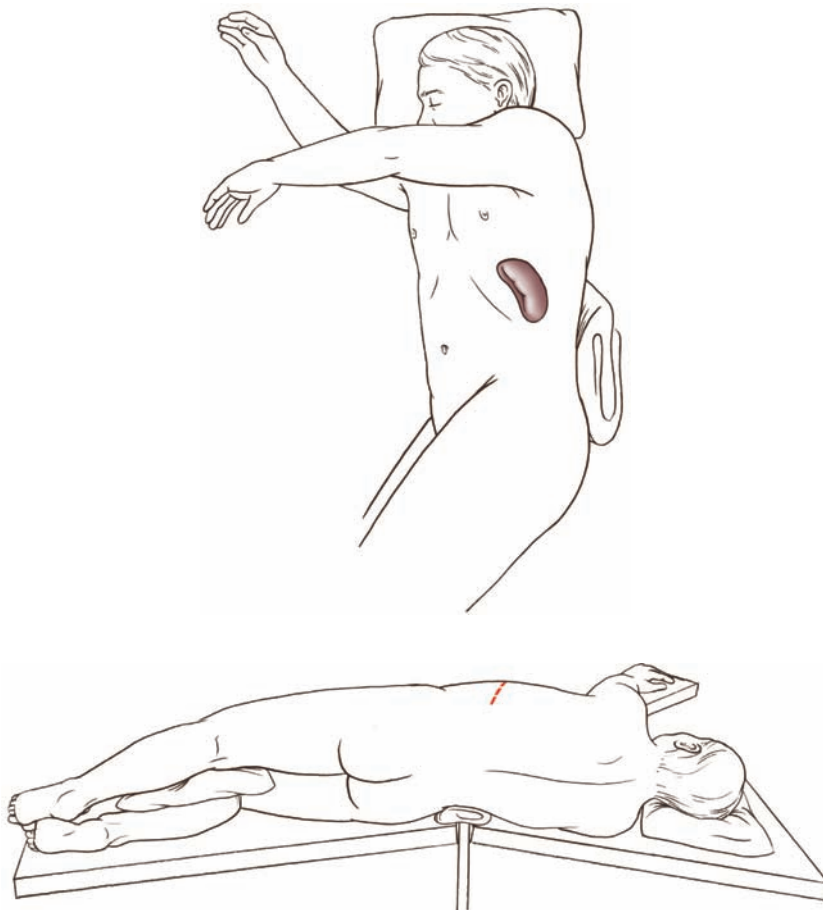


Figure 13.17

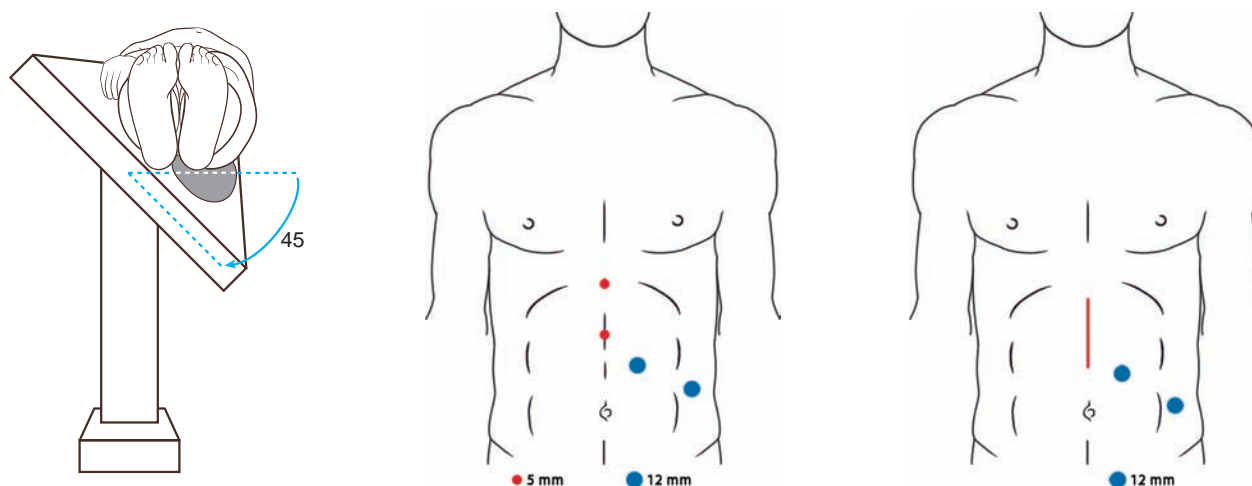


Figure 13.18

The patient is positioned in the incomplete right lateral decubitus position at an angle of 45°. This allows the patient's position to be changed from nearly supine to nearly lateral by tilting the operating table. In this way, a combined supine and lateral approach can be realized.

It is important to position the patient with the iliac crest immediately over the table's kidney rest and mid-break point. The kidney rest is elevated and the table flexed, allowing more distance between the iliac crest and the left lower costal margin in the midaxillary line. The beanbag stabilizing device is activated, and the patient's hip is secured to the table with loosely applied tape. Legs are padded with pillows, and an axillary roll is placed. The left arm is hung over the chest on a sling. The arm must be far enough cephalad to clear the operative field and allow obstruction-free use of the laparoscopic instruments. All pressure points are adequately padded.

The skin is prepared and draped so that either laparoscopy or open surgery can be performed. The table is tilted 30° to the left to place the patient in the near-supine position. Before incisions are made, the area is anesthetized with long-lasting local anesthetic.

Operative Technique

We prefer to obtain intra-abdominal access via the open technique, with the placement of a 12-mm Hasson trochar approximately 3–4 cm below the costal margin in the left mid-clavicular line. The abdomen is then insufflated to a pressure of 15 mmHg with carbon dioxide, and a 10-mm, 30° laparoscope is introduced into the abdomen.

Two 5-mm trochars are then placed in the upper midline or to the left of the midline along the costal margin. The first 5-mm trochar is placed 3–4 cm below the

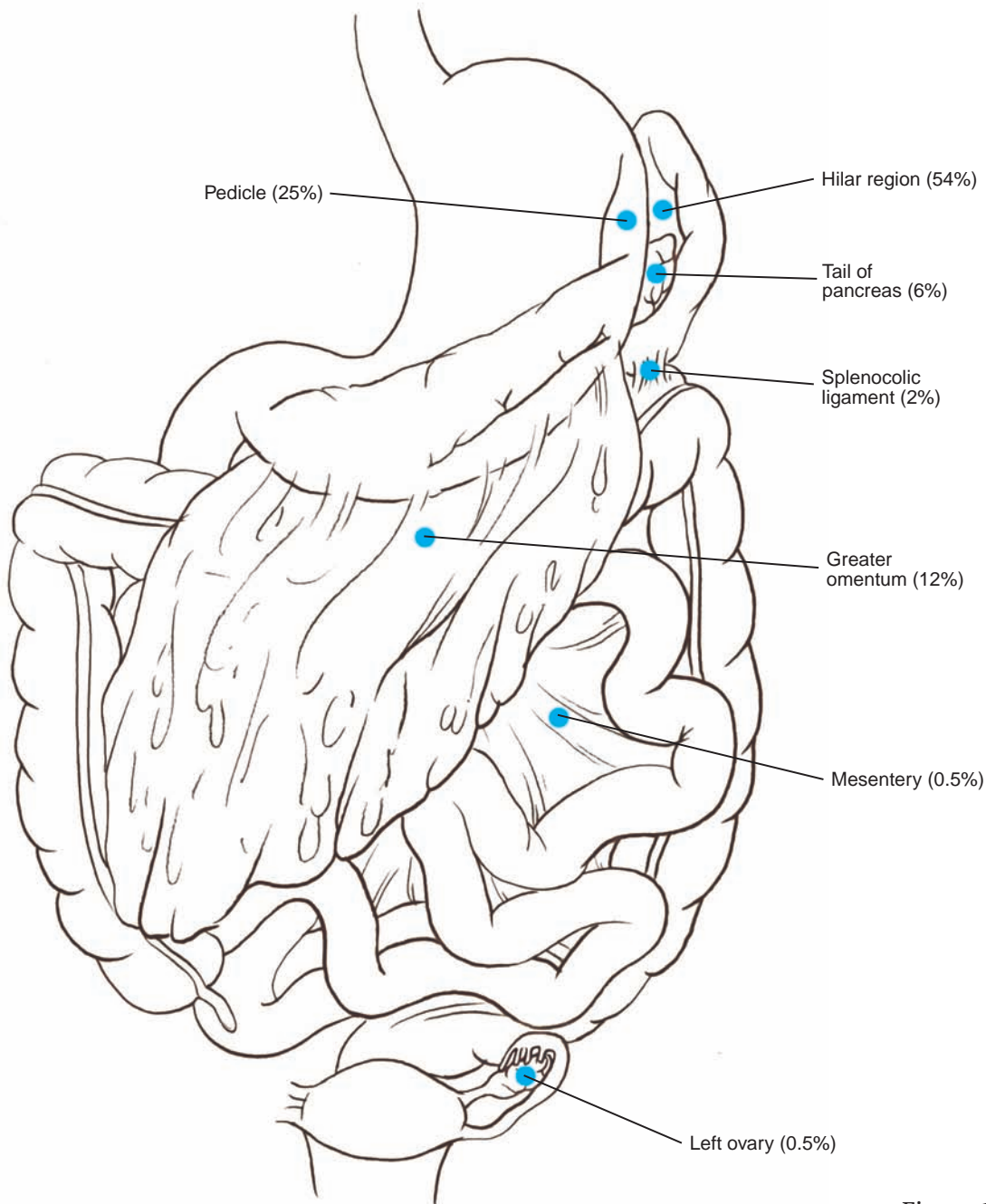


Figure 13.19

xiphoid process and the second trochar is placed in between the subxiphoid 5-mm trochar and the Hasson trochar. The abdomen is inspected with special attention to the greater omentum and splenocolic regions, which are the common locations for accessory splenic tissue. Following the division of the splenocolic ligament and the mobilization of the splenic flexure, an additional 12-mm trochar is placed in the left anterior axillary line, below the costal margin.

The patient is then placed in steep reverse Trendelenburg position and the table rolled to the patient's right, giving a true left lateral decubitus position.

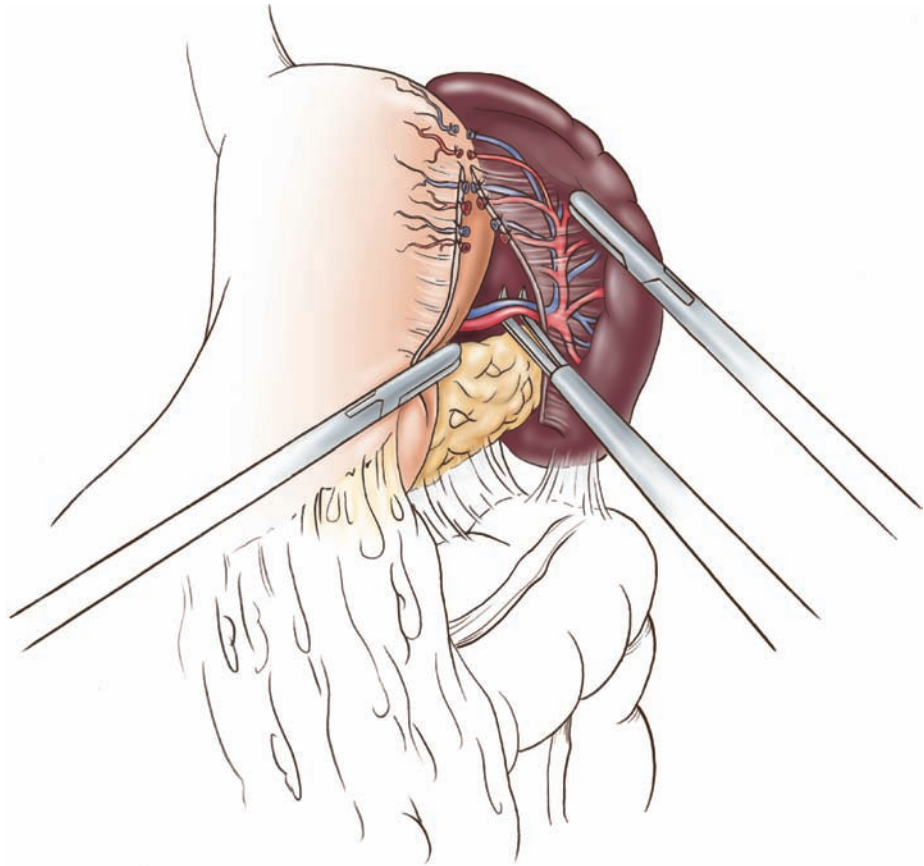


Figure 13.20

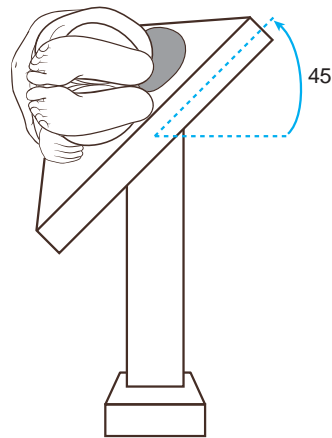


Figure 13.21

Ultrasonic shears are used to divide the gastrosplenic ligament and short gastric blood vessels, allowing the stomach to fall to the patient's right and providing excellent exposure to the splenic hilum.

The splenic artery can then be easily identified and ligated with hemoclips if desired, at this point of the case. Attention is then turned towards the mobilization of the lower pole of the spleen. The splenophrenic and splenorenal ligaments are divided using ultrasonic shears. If a lower pole vessel is encountered at this point, it is divided using an endoscopic stapling device with a vascular cartridge. This approach allows

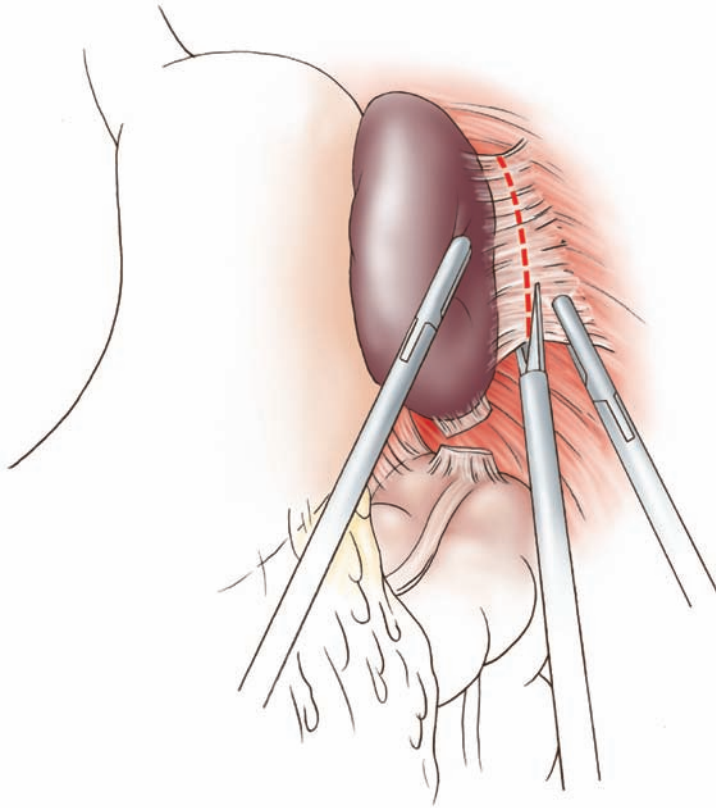


Figure 13.22

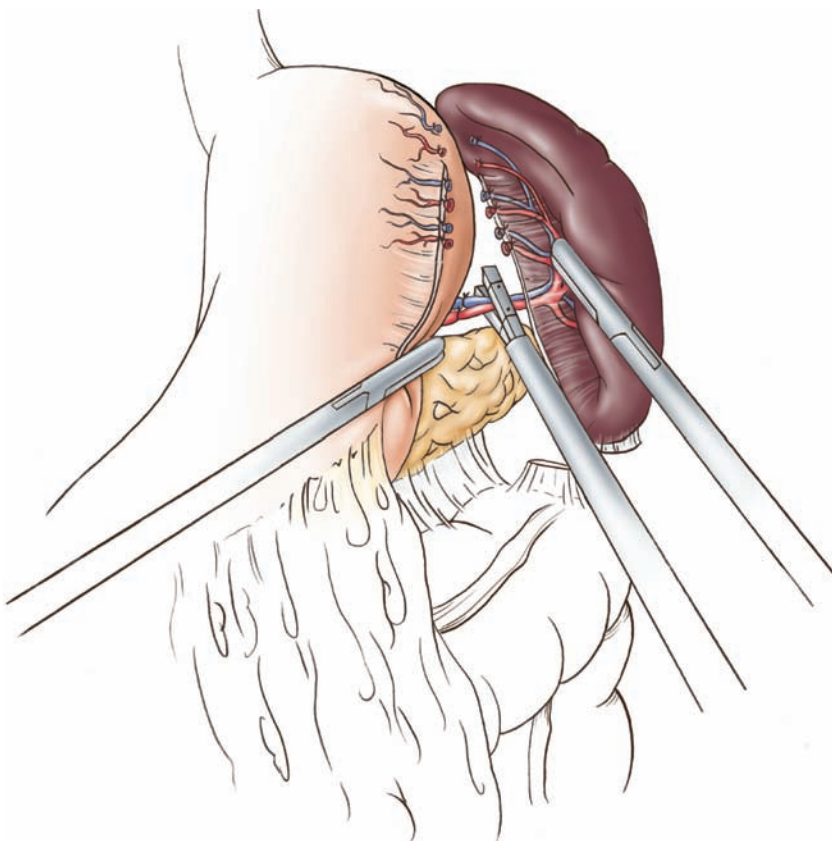


Figure 13.23

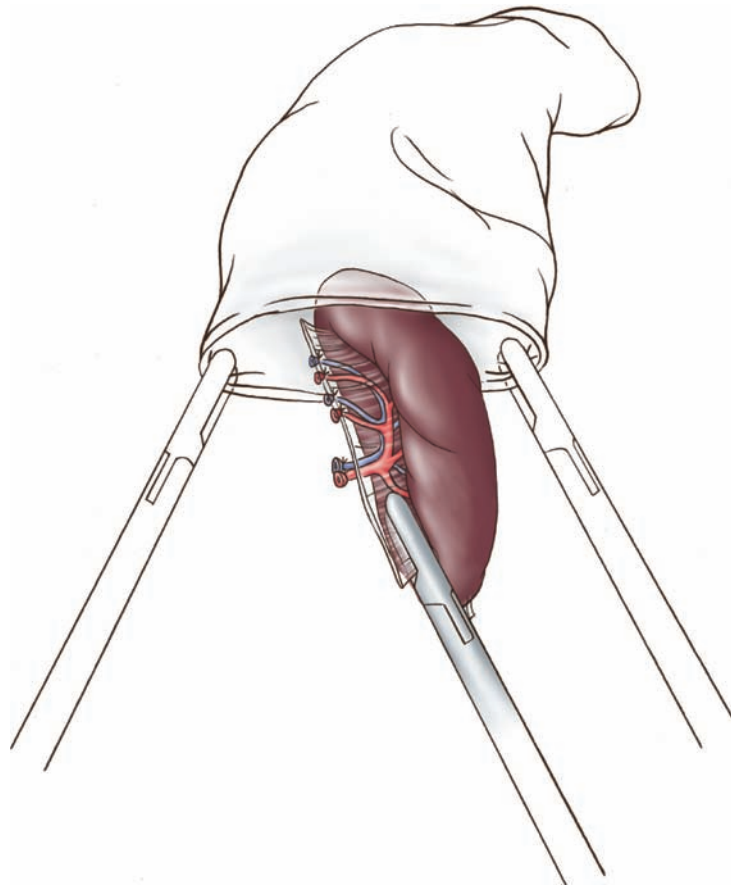


Figure 13.24

for the visualization of the splenic hilum and the tail of the pancreas by retracting the spleen towards the abdominal wall. The superior splenophrenic attachments to the upper pole of the spleen are left intact to prevent torsion of the spleen during division of the hilum. The endoscopic stapling device with a vascular cartridge is then used to divide the well exposed splenic hilum. Several fires of the stapler may be necessary.

Following the division of the remaining upper pole attachments, the spleen is placed into a specimen retrieval bag. The mouth of the bag is brought through the 12 mm Hasson trochar site and the spleen is then morcellated with sponge forceps and removed in pieces.

Special care must be taken to avoid ripping the endoscopic bag during this process in order to prevent spillage of splenic tissue in the abdomen. The left upper quadrant is irrigated and inspected for hemostasis. A second search for accessory splenic tissue is undertaken before the 12-mm fascial openings are securely closed with absorbable suture and the skin incisions are closed with subcuticular 4-0 suture. The orogastric tube is removed in the operating room, and the patient is taken to the recovery room.

The laparoscopic splenectomy can be converted to hand-assisted laparoscopic splenectomy (HALS) if difficult anatomy, dense adhesions due to a previous upper abdominal surgery or excessive splenomegaly, is encountered. Preoperatively, the

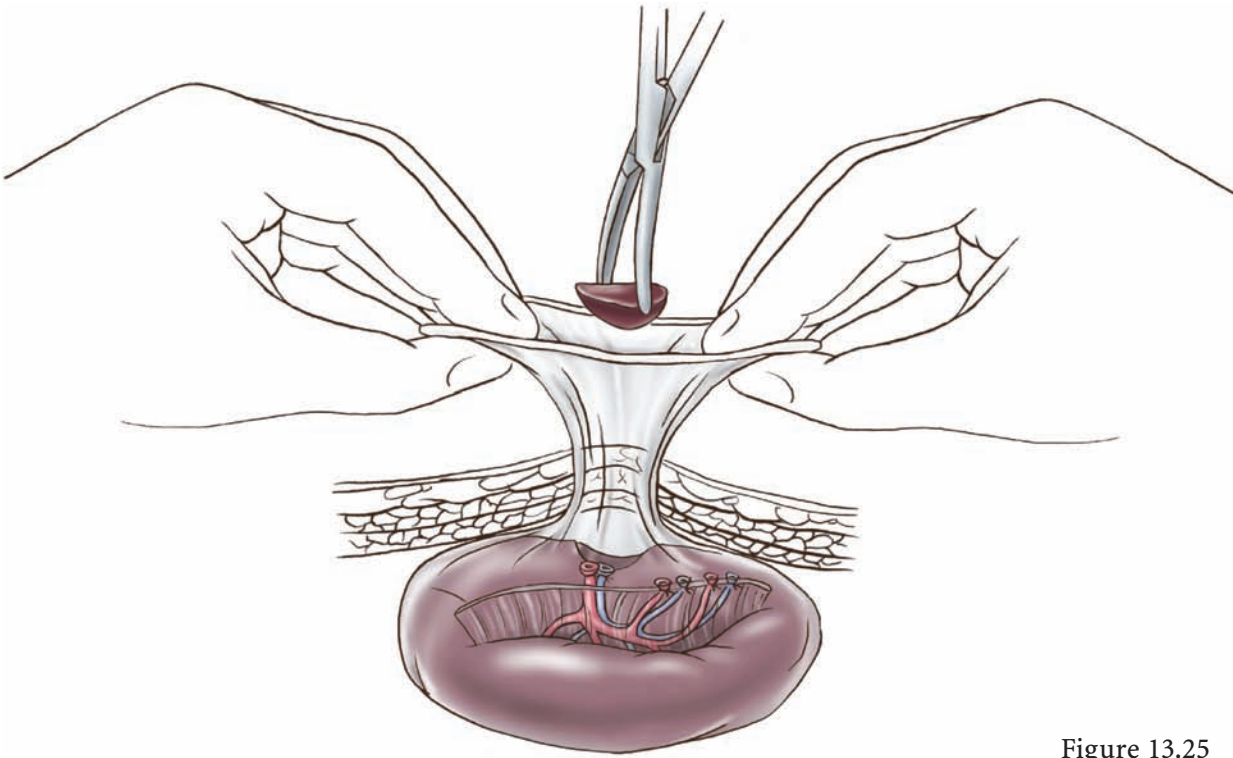


Figure 13.25

decision to proceed with HALS is made for patients with very large spleens or if the spleen must be removed intact for pathologic examination. When HALS is indicated preoperatively, we still place all trochars as described for a laparoscopic splenectomy, and proceed with the division of the gastrosplenic ligament and short gastric blood vessels. This provides excellent exposure to the splenic hilum and allows for early ligation of the splenic artery which, we feel, is an essential step in patients with significant splenomegaly. We then create an incision connecting the two 5-mm trochars about 7 cm in size in the left paramedian position. The left hand is then placed into the abdomen, which is then reinsufflated. There are several commercially available hand-port devices, which can be used for HALS. However, we do not routinely use a hand port device and can contain any gas leakage by tightening the incision around the surgeon's wrist using a penetrating towel clamp. The spleen is then mobilized as described for a total laparoscopic splenectomy with the left hand providing gentle traction, while at the same time preventing injury to the splenic capsule by the ultrasonic shears or a laparoscopic grasper. After the splenic hilum is divided and the spleen completely mobilized, it is placed in a specimen retrieval bag. A sterile radiograph cassette bag can be placed in the abdomen through the hand incision to retrieve those spleens that do not fit in the large specimen retrieval bags. The fascia is closed with sutures of appropriate strength and the abdomen is then reinsufflated and inspected for hemostasis as described above.

Postoperative Care

Postoperatively, the patient is allowed clear liquids orally, and ambulates on the night of surgery. The Foley catheter is removed the following morning. Pain is controlled with intermittent parenteral narcotics until the patient is able to take oral pain medication. Diet is advanced on postoperative day 1, and the patient is discharged when oral intake is tolerated and pain is controlled with oral analgesics, usually on postoperative day 2.

Laparoscopic splenectomy has become the gold standard for splenectomy in many centers around the world. There are numerous studies documenting excellent safety coupled with more rapid recovery, and return to normal activities. HALS also provides for the safe removal of the spleen in the setting of significant splenomegaly while maintaining the benefits of the laparoscopic approach.

Anatomic Basis of Complications

- Injury to the splenic artery or vein results in significant and rapid blood loss, mandating conversion to an open procedure.
- Injury to the short gastric vessels results in significant and rapid blood loss; if not controlled quickly, mandates conversion to open splenectomy.
- Injury to the tail of the pancreas leads to pancreatic leak, with resulting pancreatitis or pancreatic fistula.

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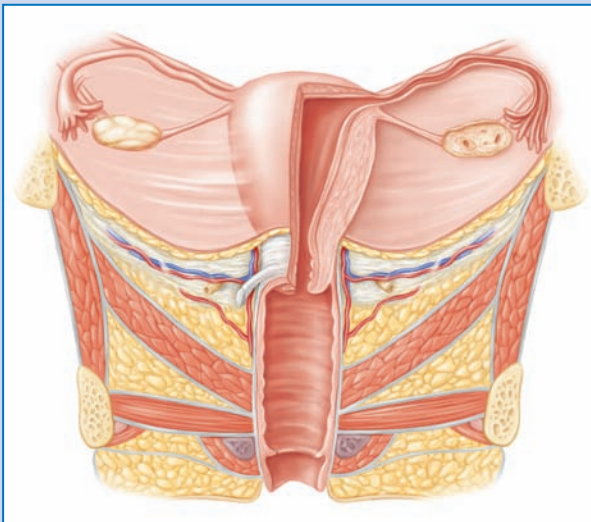
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Female Genital System

Ira R. Horowitz



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Introduction

The incidence of gynecologic malignancies as a group have an incidence second only to breast cancer. In the year 2009, approximately 192,370 new female breast cancers will be diagnosed compared to 80,720 gynecologic malignancies (cervix, 11,270; corpus uteri, 42,160; ovary, 21,550; vulva 3,580; other, 2,160). Gynecologic malignancies ranked third in estimated female cancer deaths in 2009: lung/bronchus, 70,490; breast, 40,170; and gynecologic, 28,120 (cervix, 4,070; corpus uteri, 7,780; ovary, 14,600; vulva, 900; other, 820). The incidence of cervical cancer has markedly decreased over the last 50 years with Papanicolaou (Pap) smear screening and colposcopy. Endometrial carcinoma has also decreased as a result of the changes in prescribed hormone supplementation. Unopposed, estrogens were responsible for a significant number of well-differentiated carcinomas in the menopausal patient. The addition of progesterone and liberal indications of endometrial biopsy have assisted in decreasing the incidence. In the uterus, tamoxifen is an estrogen agonist, whereas it is an antagonist in the breast. Uterine stimulation is present with patients receiving tamoxifen to treat breast cancer. All abnormal bleeding in this group of patients is a suspect for the presence of endometrial cancer. Endometrial biopsies are required to rule out this malignancy in menopausal patients with abnormal bleeding. Early diagnosis of ovarian cancer is difficult. Screening ultrasonography and CA-125 have low sensitivity and specificity when used to diagnose occult ovarian malignancies in the asymptomatic patient. As a result, even in initial examination these patients have advanced disease, with high mortality.

Clinical Anatomy

Topography Corpus/Cervix

The uterus is a pear-shaped muscle with a dome-shaped fundus. It consists of two segments: the corpus or the body, and the cervix or the isthmus. In the nulliparous patient, the corpus is approximately 8 cm long, 5 cm wide, and 2.5 cm thick. The uterine cavity resembles an inverted triangle, lined with endometrium, which is made up of glandular tissue. The normal thickness of the endometrium is 0.5 cm, with a total thickness of 1 cm. An endometrial cavity larger than 1 cm requires an evaluation to rule out the presence of a neoplastic lesion. Office endometrial sampling or hysteroscopy dilation and curettage is adequate for the evaluation of the endometria.

The cervix is divided into the portio vaginalis and the portio supravaginalis cervicis, the latter being above the cervix. Surrounding the cervix is a smooth muscle fibrous network with the uterosacral, cardinal, and pubovesical fasciae inserting in it.

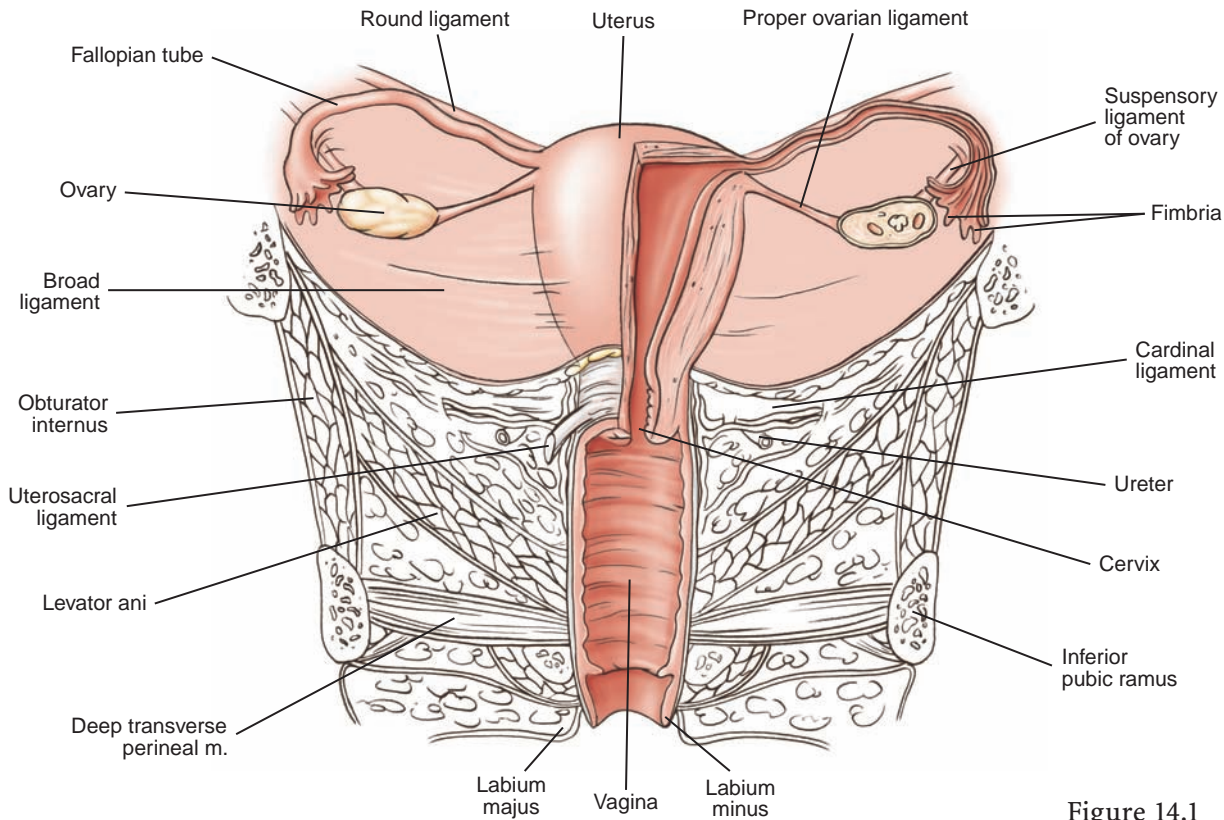


Figure 14.1

Fallopian Tube

Attached to the fundus is the fallopian tube (uterine tube). It is approximately 10–12 cm long and divided into four segments. The infundibulum with fimbria which is distally held by the ampulla is the widest portion of the fallopian tube. The third and the fourth segments are the isthmus, which is the narrowest portion, and the interstitial (or intramural) portion, where the fallopian tube passes into the uterus. The fallopian tube is composed of three layers: serosa, muscularis, and mucosa. The muscularis (tunica muscularis) is composed of an inner circular and an outer longitudinal smooth muscle layer. Columnar cells in a sample layer make up the mucosa.

Ovary

Each ovary is 2.5–5.0 cm long, 1.5–3.0 cm thick, and 0.7–1.5 cm wide and is attached by its mesenteric attachment to the broad ligament, the mesovarium. The infundibular pelvic ligament, which includes the ovarian artery and vein is present laterally while the ovarian ligament is present medially. The blood vessels enter the hilus of the ovary. The germinal epithelium lines the outside, or the capsule of the ovary. The inner medulla of the ovary is a fibromuscular layer with blood vessels. The cortex, including the stroma, consists of follicles, corpus luteum, and corpus albicans.

Pelvic Suspension

An excavation in the front of the uterus is called the anterior cul-de-sac, and the excavation in the back is called the posterior cul-de-sac, or the pouch of Douglas. The cardinal ligaments (Mackenrodt's) provide the lateral attachment from the cervix and superior vagina to the pelvic sidewall and pelvic floor. This is a fibromuscular tissue covered by the peritoneum and merges with the uterovaginal and vesicouterine endopelvic fascial envelope; posteriorly it merges with the uterosacral ligament. The uterosacral (sacral cervical or sacral uterine) ligament is a muscle fiber tissue fanning from the cervix and superior vagina to the lateral sacral borders bilaterally. The broad ligament peritoneal layers envelop the fundus and the corpus, the fallopian tube, and the infundibular pelvic ligament, which includes the ovarian artery and veins. Between the layers of the cardinal ligament are the parametria, uterine vessels, ovarian vessels, lymphatic vessels, and nerves. Peritoneum extends anteriorly to cover the bladder and posteriorly to cover the rectum, forming the anterior and posterior cul-de-sacs. The round ligament extends from the fundus through the inguinal canal to form the inguinal ligament. Sampson's vessels course through the round ligament. Suspension of the uterus is also assisted by the levator ani muscles and the pelvic fascial ligaments. An endopelvic fascia envelops the cervix and the upper vagina, extending to the pelvic sidewall, and is contiguous with the vesicouterine and rectouterine fascia.

Omentum

The omentum is a double layer of peritoneum that attaches to the stomach on the greater and lesser curvatures, and the transverse colon. The greater omentum is adherent to the greater curvature of the stomach and acts like an apron over the small bowel abdominal contents. It has been called the sentinel of the abdomen. The lesser omentum is adherent to the lesser curvature of the stomach and the undersurface of the liver. The gastrosplenic omentum (ligament) connects the spleen and the omentum. The omentum contains arteries, nerves, and lymphatic vessels and is composed predominantly of fat. The gastroepiploic vessels traverse the greater omentum inferior to the liver and the falciform ligament towards the gallbladder. Additional discussion of the anatomy of the omentum can be found in Chaps. 9 and 12.

Vagina

The vagina is a muscular cylinder approximately 8–10 cm long. The superior vagina surrounds the portion of the cervix. The most superior recess enveloping the vagina as it envelops the cervix is the anterior and the posterior fornices, and laterally, the left and right sulci. Lined by epithelium, the vagina has a deeper connective tissue layer called the lamina propria, followed by circular and longitudinal smooth muscle fibers. Adjacent to the anterior vagina is the bladder proximally and the urethra distally. The posterior vagina is divided in three portions: the vaginal portion of the pouch of Douglas superiorly, the rectum in the middle, and the peritoneal body

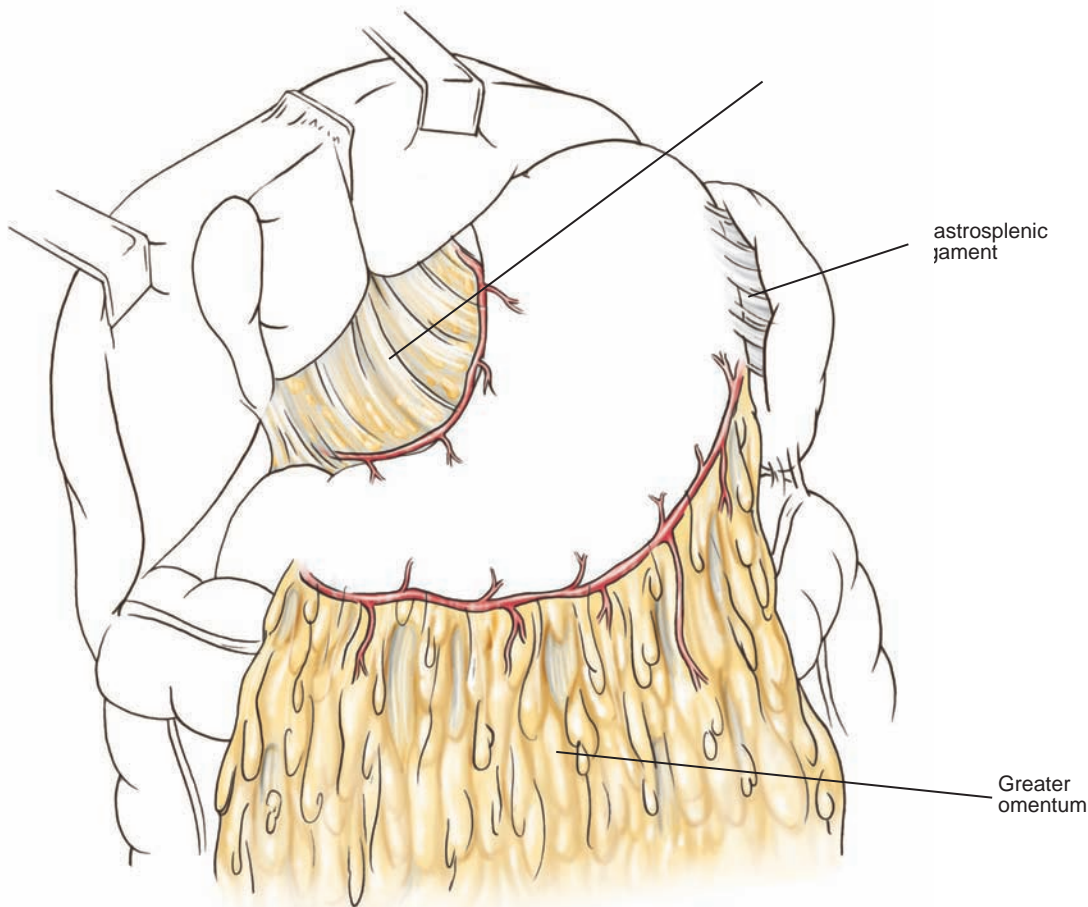


Figure 14.2

and the anus inferiorly. Laterally are the vessels of the ureter and suspensory fibrous tissue to the levator ani. Support of the vagina is predominantly by the levator ani muscles and the endopelvic fascia, which is contiguous with the uterosacral and cardinal ligaments. The middle third of the vagina is suspended laterally by attaching to the arcus tendineus fasciae pelvis on either side, while the inferior portion is suspended by the peritoneal body.

Vulva

The vulva is that portion of the female genitalia that is external to the perineal region. It includes the mons pubis, anterior commissure with the clitoris inferiorly, prepuce of the clitoris, and hood of the clitoris, followed by the glans of the clitoris. The urethral orifice is inferior to the frenulum of the clitoris. Adjacent to the urethra are the Skene's glands. The hymen is circumferential and is sentinel to the vaginal tube. Lateral to the hymenal ring is the labia minora, followed by the labia majora laterally toward the thighs. Bartholin's glands open at 5- and 7-o'clock positions inferiorly on the vulva. Between the vaginal tube and the anus is the perineal body. The vestibule includes the hymen, vaginal opening, urethral rectus, and Bartholin's and Skene's glands. The labia majora are the major skinfolds of the vulva, with hair

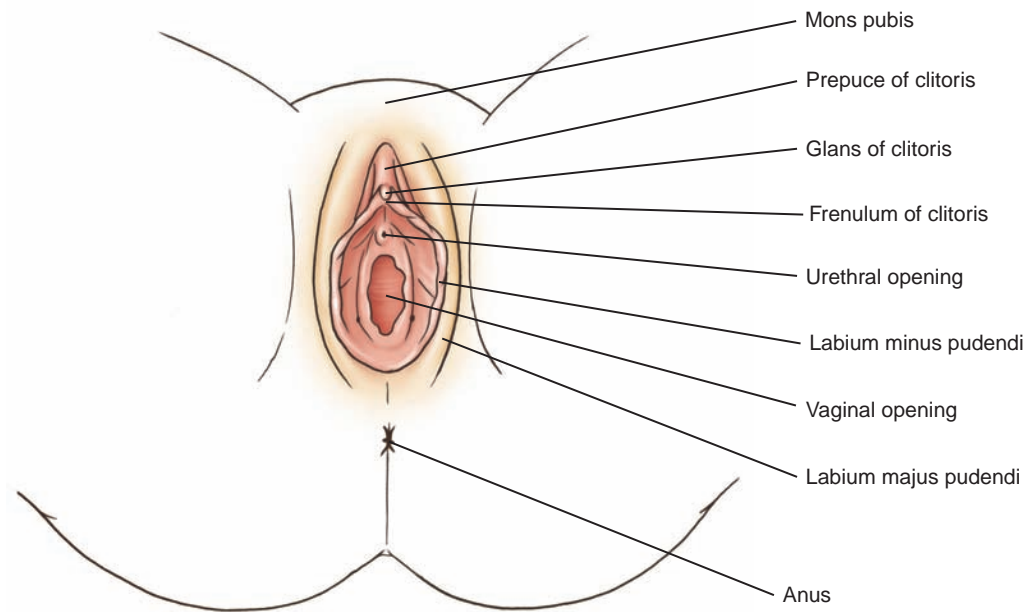


Figure 14.3

extending from the mons pubis to the perineal body. The labia minora are two smaller folds without hair and are the lateral borders of the vestibule. Labia are the anatomic homolog to the scrotum, and the clitoris is homologous to the penis in the male. The glans clitoris, covered by the prepuce, is embryologically similar to the glans of the penis and the foreskin. Erectile tissue is present in the clitoris.

Blood Supply

Arterial blood supply to the ovaries is via the ovarian arteries, which have their origin in the anterior surface of the aorta, inferior to the renal vessels. The left ovarian vein empties into the left renal vein, which then enters into the vena cava, and the right ovarian vein empties into the vena cava inferior to the right renal vein. These vessels are retroperitoneal. On reaching the most proximal aspect of the ovary closest to the fimbria, the vessels break into arcades that supply blood to the fallopian tubes and the ovaries. The arcades traverse through the mesentery adherent to these structures. The uterine artery has its origin from the hypogastric (internal iliac) artery, which branches off the common iliac artery. The uterine artery then branches into the vaginal artery, and multiple branches from the artery, which measures approximately 10 cm, supply blood to the cervix and the uterus. These branches anastomose with those of the ovarian artery in the area of the utero-ovarian ligament and round ligament, which includes Sampson's artery. The uterine artery crosses over the ureter in the cardinal ligament ("water under the bridge"). Adjacent to the uterine artery are the uterine veins, which drain the corpus and the cervix, and empty into iliac veins.

The vagina receives its blood supply from the vaginal branch of the uterine artery and the vaginal artery, which originates from the hypogastric artery. The inferior vesical artery, off the anterior division of the hypogastric artery provides a cervical and a vaginal branch. These branches anastomose to the superior and middle vesicular arteries of the hypogastric artery. The distal vagina also receives part of its blood

Figure 14.4

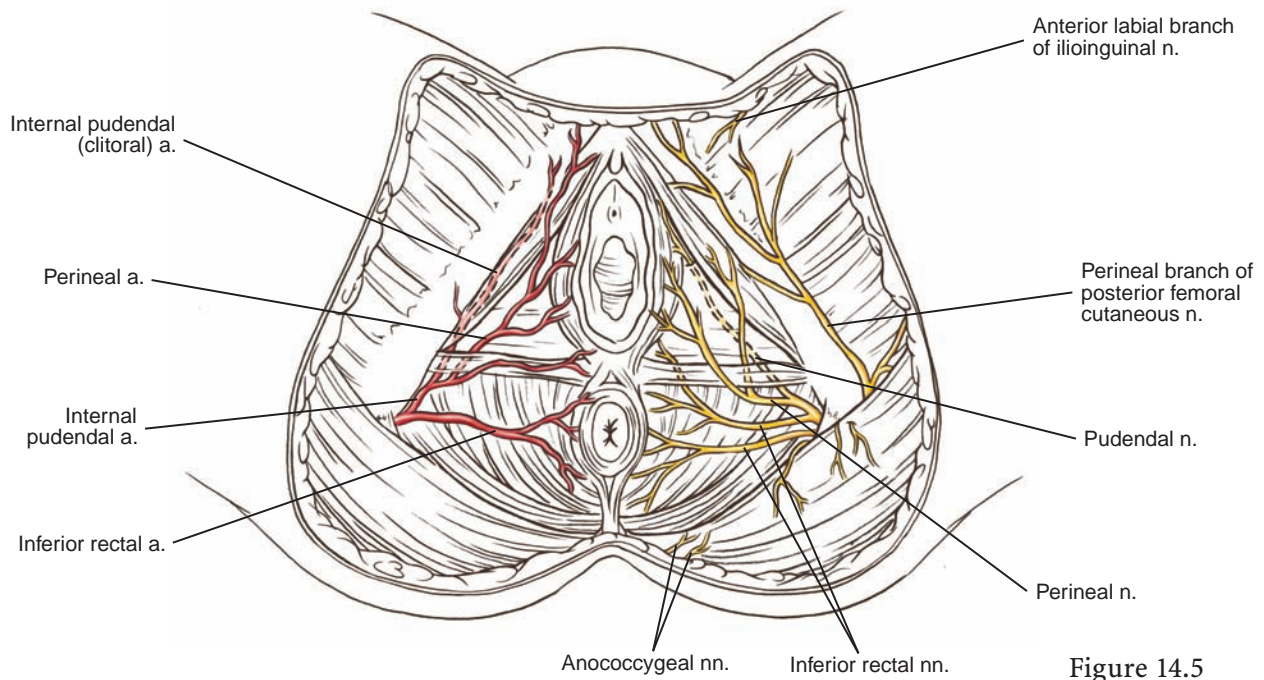
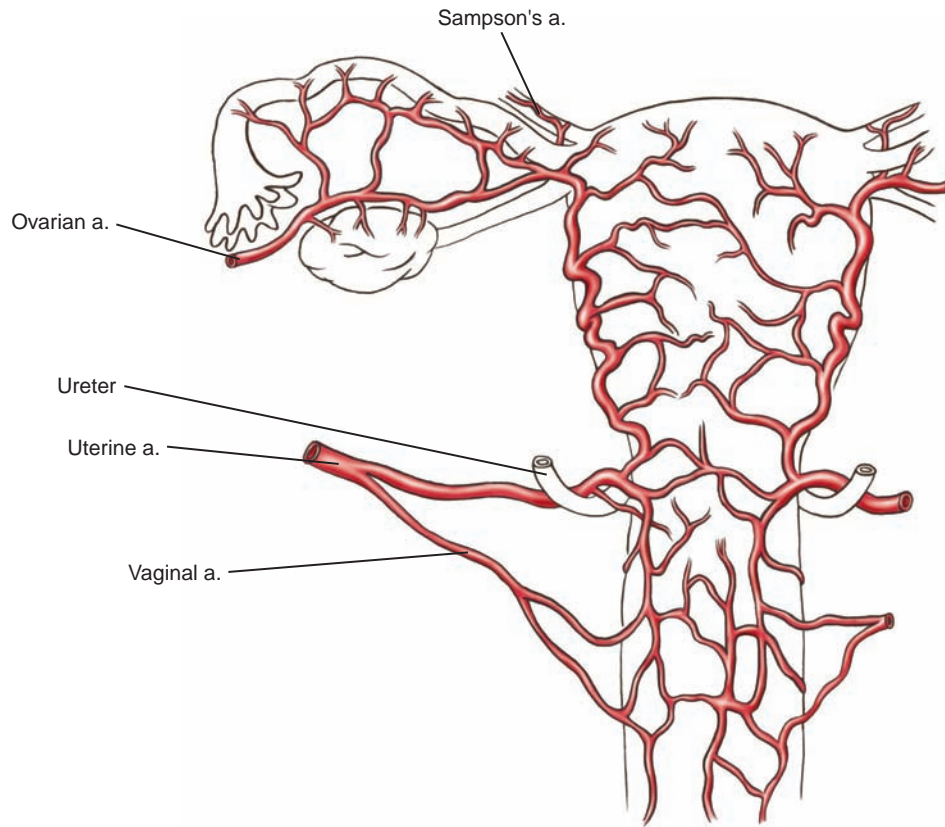


Figure 14.5

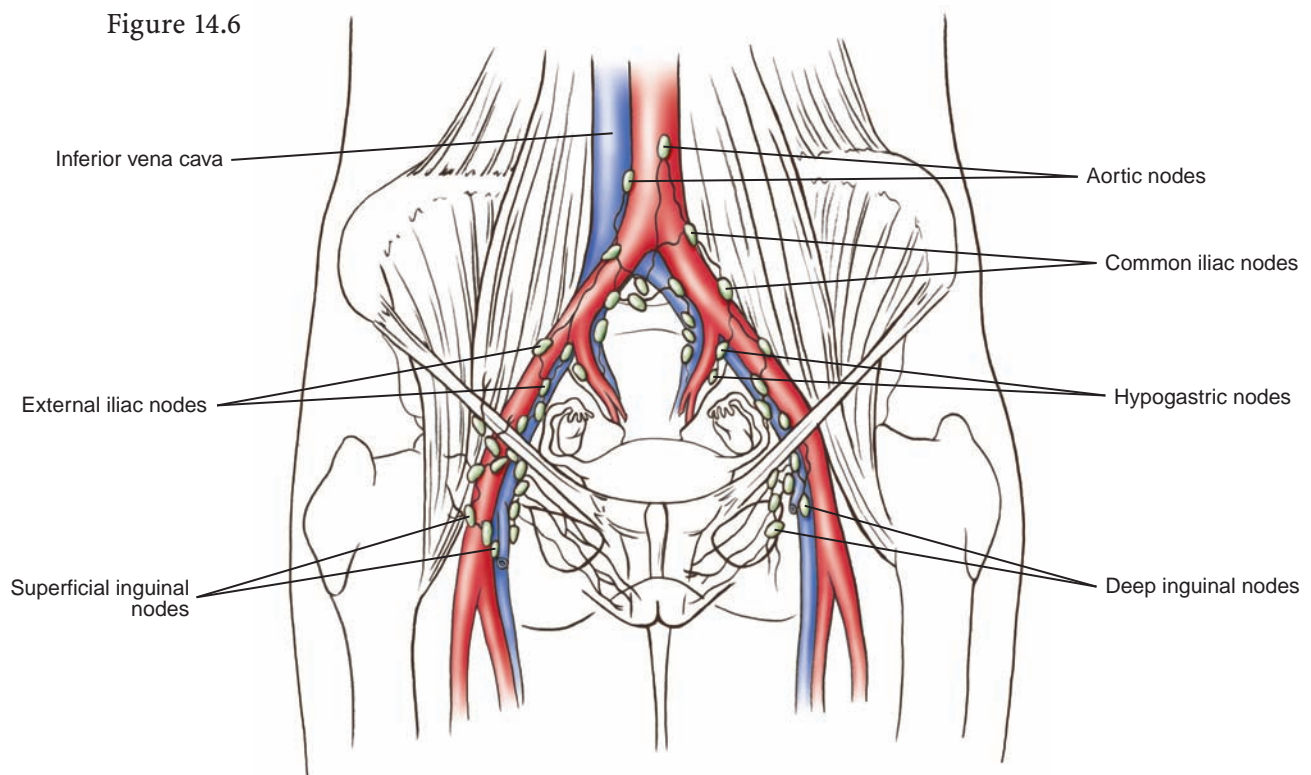
supply from the middle and inferior hemorrhoidal arteries, which also have their origin in the anterior branch of the hypogastric artery.

The blood supply to the vulva is predominantly via the internal pudendal artery and exits the pelvis at the ischial spine. The artery branches into, the superficial perineal artery which supplies the labia, the artery of the bulb to supply the vestibular bulb and erectile tissue of the vagina, the artery of the corpus cavernosum, and the artery of the clitoris.

Lymphatic Drainage

The lymphatic vessels of the ovary follow the ovarian vessels along the inferior vena cava and aorta to the level of the renal vessels. To perform an adequate lymphadenectomy for ovarian carcinoma, the resection should extend to the level of the renal vessels. Ovarian lymphatic vessels also drain through the iliac vessels, and sometimes through the femoral vessels to the inguinal lymph nodes. Corpus and cervical lymphatic vessels drain along the obturator vessels, the hypogastric, common iliac, and the external iliac arteries, and the aorta vena cava. The fundus can also drain along the round ligament to the inguinal region. Posteriorly, the cervix and corpus can also drain along the lateral sacral lymph nodes. Vaginal lymphatic vessels divide into two systems that drain the upper two thirds and the lower third. The upper two thirds drain in the same way as described for the cervix; the inferior third drains to the inguinal femoral lymph nodes in a fashion similar to the vulvar region, which includes the drainage of the superficial inguinal lymph nodes, femoral vessels, and deep pelvic lymph nodes.

Figure 14.6



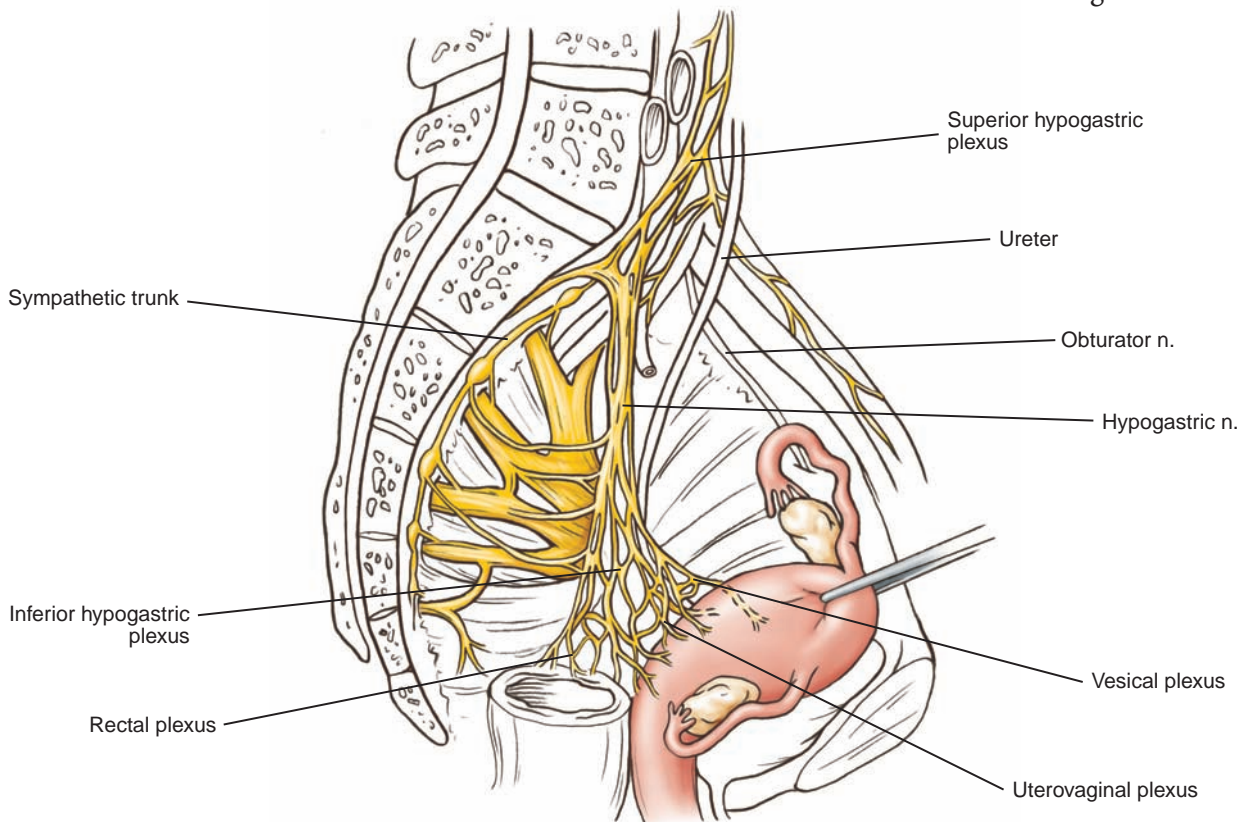
The lymphatic vessels of the vulva course along the vulva and terminate into the inguinal lymph nodes. Superficial inguinal lymph nodes are located above the cribriform fascia and below the camper's fascia. Femoral vessels are below the cribriform fascia. The lymph node under the inguinal ligament at the entrance of the femoral canal is called the sentinel node, or Cloquet's or Rosenmüller's lymph node. Below that area, the lymph nodes follow the femoral vessels to the pelvis.

The ovary and the fallopian tube receive their innervation from a plexus of nerves that course along the ovarian vessels. Sympathetic innervation is from the tenth thoracic segment and the parasympathetic innervation is from the branches of the vagus nerve.

The celiac plexus extends to the level of the superior mesentery artery and courses along the anterior surface of the aorta. These sympathetic fibers are derived from the 12 thoracic and upper lumbar segments. Then they form the presacral nerve (hypogastric plexus) at the bifurcation of the aorta. The nerve then divides into the left and right inferior hypogastric plexus (pelvic plexus). The hypogastric nerves then merge with the parasympathetic fibers from S2, S3, and S4. This nerve bundle divides into the vesico plexus in three portions: the vesico plexus, the uterovaginal plexus (Frankenhauser's ganglion), and the middle rectal plexus. The uterovaginal plexus with its nerve supply from T10 to L1, S2, S3, and S4 lies medial to the

Nerve Supply

Figure 14.7



vessels and extends to the cervix and the vagina. The obturator nerve is derived from the anterior division of L2, L3, and L4 and extends into the pelvis through the psoas muscle along the pelvic sidewall and obturator space. This is the only motor nerve that passes through the pelvis without innervating any of the pelvic organs. If injured during a radical hysterectomy with pelvic lymph node resection or tumor debulking, the patient will have difficulty adducting the thigh muscles. The adductor muscles affected, include the adductor magnus, longus, and brevis, the gracilis, and the obturator externus muscles. This can be repaired by suturing the nerve endings with a 4-0 Vicryl suture. Physical therapy is frequently required after repairing the obturator nerve.

The nerve supply to the vulva is via the internal pudendal nerve, which originates from the second, third, and fourth sacral nerves. The perineal nerve divides into three branches: the inferior hemorrhoidal nerve, which supplies the anal sphincter and the perineal skin; the dorsal nerve to the clitoris; and the perineal nerve to the labia, perineal muscle, ischiocavernosus and bulbocavernosus muscles, and urethral sphincter.

The genitofemoral nerve receives fibers from L1 and L2 and lies on the psoas muscle. Injury to the genitofemoral nerve will result in anesthesia in the medial thigh and lateral labia. Injury to the femoral cutaneous nerve, which receives its nerve supply from L2 and L3, can result in anesthesia over the anterior thigh. Injury to these nerves can occur during tumor resection or pelvic lymphadenectomy. They are frequently injured by the retractors in the pelvis or the surgeon's lack of knowledge of the innervation of the pelvis. Femoral cutaneous nerve injury can also occur from overflexion of the hips in the lithotomy position.

Types of Malignancies

Cervical Carcinoma

In the United States, more than 11,270 new cases of cervical carcinoma will be diagnosed, resulting in approximately 4070 deaths in 2009. Although the mean age for cervical carcinoma is in the sixth decade, there is a bimodal distribution that peaks in the fourth and seventh decades.

Cervical cancer is clinically staged with the International Federation of Gynecology and Obstetrics (FIGO) Staging System. Staging after diagnosing cervical cancer is with a thorough physical examination, including a bimanual rectovaginal examination to evaluate the parametria, palpate inguinal and scalene lymph nodes, and examine the vagina for contiguous spread. Permissible radiologic evaluations include intravenous pyelography, barium contrast studies, and chest and skeletal X-ray studies. Cervical biopsy, cystoscopy, and sigmoidoscopy are also permitted. Studies such as computed tomography (CT), ultrasonography, magnetic resonance imaging (MRI), radionuclide scanning, and diagnostic laparoscopy are not used in determining the initial stage.

Table 14.1 Staging of carcinoma of the cervix (FIGO 1995)

TNM classification: primary tumor (T)	FIGO classification	Definition
TX	–	Primary tumor cannot be assessed
T0	–	No evidence of primary tumor
Tis	0	Carcinoma in situ, intraepithelial carcinoma
T1	I	Cervical carcinoma confined to cervix (extension to the corpus should be disregarded)
T1a	IA	Invasive carcinoma, diagnosed microscopically only. All gross lesions even with superficial invasion are stage IB cancers. Invasion is limited to measured stromal invasion with maximum depth of 5 mm and maximum width of 7 mm ^a
T1a1	IA1	Minimal microscopically evident stromal invasion. Measured stromal invasion with maximum depth of 3 mm and maximum width of 7 mm
T1a2	IA2	Measured stromal invasion with depth from 3 to 5 mm and maximum width of 7 mm
T1b	IB	Clinical lesions confined to the cervix or preclinical lesions greater than stage IA
	IB1	Clinical lesions not greater than 4 cm in size
	IB2	Clinical lesions greater than 4 cm in size
T2	II	Cervical carcinoma invades beyond the uterus but not to the pelvic wall or to the lower third of the vagina
T2a	IIA	No obvious parametrial invasion
T2b	IIB	Obvious parametrial invasion
T3	III	Extends to the pelvic wall or involves lower third of the vagina or causes hydronephrosis or nonfunctioning kidney
T3a	IIIA	Tumor involves the lower third of the vagina. No extension to the pelvic wall
T3b	IIIB	Tumor extends to the pelvic wall or causes hydronephrosis or nonfunctioning kidney
T4	IV	Carcinoma extends beyond the true pelvis or has clinically involved the mucosa of the bladder or rectum. A bullous edema as such does not permit a case to be allotted to stage IV
T4a	IVA	Spread of the growth to adjacent organs
T4b	IVB	Spread to distant organs

^a The depth of invasion should not be more than 5 mm taken from the base of the epithelium, either surface or glandular, from which it originates. Vascular space involvement, either venous or lymphatic, should not alter the staging

Cervical carcinoma spreads by direct extension into the cervical stroma, vagina corp, and corpus. Lymphatic metastasis, hematogenous metastasis, and rarely coelomic spread may occur. Early invasive cancer of the cervix can be treated with primary surgery. Stage IA with early stroma invasion of less than 1 mm should be treated with cervical conization; if no additional invasion is noted and the patient does not desire fertility, a simple extrafascial hysterectomy is indicated. Stage IA, with 1–3 mm of invasion and no lymph vascular invasion, should be treated with conization to rule out further invasion. As with lesions less than 1 mm, an extrafascial hysterectomy is performed

when fertility is not an issue. If lymph vascular involvement is present, an extended or radical hysterectomy with pelvic lymph node dissection is required. For stage IA lesions with 3–5 mm of invasion, a radical hysterectomy with pelvic lymphadenectomy or primary radiation is recommended. Stage IB carcinoma of the cervix that includes lesions with more than 5 mm of invasion and 7 mm width are surgically resected with a type 3 radical hysterectomy with pelvic lymphadenectomy. Early stage IIA carcinoma of the cervix involving the vaginal fornix is surgically approached in a similar fashion. Large IB barrel lesions may be managed with (1) type 3 radical hysterectomy; (2) preoperative pelvic radiation of lesions more than 4 cm, followed by extrafascial hysterectomy; or (3) primary pelvic radiation. More advanced cervical carcinomas are treated with a combination of brachytherapy and teletherapy. In an attempt to identify those candidates who may benefit from periaortic irradiation, extraperitoneal periaortic lymphadenectomy is performed, with a paramedian incision. If pelvic lymph nodes are palpated, the incision is extended inferiorly to permit resection of the enlarged lymph nodes. It is difficult to sterilize markedly enlarged lymph nodes with radiation, and therefore debulking these lymph nodes assists in local control.

Large IB lesions, more than 4–5 cm in diameter, also known as IB barrel lesions, can be treated with radical hysterectomy and pelvic lymph node dissection, definitive radiation therapy, or adjuvant radiation therapy followed by a simple extrafascial abdominal hysterectomy. Advanced stage IIA, IIB, IIIA, IIIB, and IV disease should be treated with definitive radiation therapy. In patients with advanced stage IV disease, adjuvant chemotherapy is frequently used. Chemotherapy in addition to treating metastasis has also been used for large bulky lesions as a radiation sensitizer. Drugs such as hydroxyurea, cisplatin, 5-fluorouracil (5-FU), and paclitaxel (Taxol) have been used with some success.

Central cervical recurrence in patients who have not undergone radiation therapy can be treated successfully with radiation or pelvic exenteration. The latter treatment is usually reserved for patients who have already received definitive radiation therapy. Approximately, 5-year survival of 25% has been noted in patients treated with radiation for postsurgical recurrence of disease. However, patients who have undergone radiation therapy but have central recurrent cervical carcinoma are candidates for anterior, posterior, or total exenteration. Anterior exenteration includes removal of the upper vagina, the anterior portion of the vagina, bladder, and urethra and construction of a ureteral conduit. Posterior exenteration includes excision of the posterior vaginal wall and the rectum, with colostomy or reanastomosis. It is imperative that attempts are made to perform a diverting loop colostomy to ensure complete healing and closure of the anastomotic site that has been previously irradiated. These patients are at high risk for fistula formation. Five-year survival of 25–40% has been quoted with posterior exenteration.

Chemotherapy has not proved efficacious in the treatment of recurrent cervical carcinoma. Active drugs include platinum-containing regimens, with a response rate of 38–42%. Cisplatin/topotecan is one of the preferred combinations to treat recurrent disease. Paclitaxel, ifosfamide, and topotecan also appear promising as single agents.

Neoadjuvant chemotherapy (i.e., chemotherapy prior to definitive surgery and radiation therapy) has been used in Asia and Europe for the treatment of advanced cervical carcinomas to assist in decreasing tumor bulk and permit a conservative surgical resection.

Endometrial carcinoma is a surgically staged cancer, as set forth by FIGO. It is estimated that more than 42,160 cases and 7,780 deaths will occur from endometrial carcinoma in the United States. Primary surgical excision remains the most effective treatment. Adjuvant and neoadjuvant radiation therapy also has a role in advanced stages. Endometrial cancer spreads by direct extension, lymphatic dissemination, hematogenous spread, and transtubal migration of tumor cells. Papillary serous lesions spread transcoelomically, like ovarian carcinoma. Lymphatic spread is via the fundus and the infundibular pelvic ligament to the periaortic lymph nodes, as well as the hypogastric external iliac and common iliac vessels. Although rare, spread via round ligament to the inguinal region can also occur. Extrafascial hysterectomy (type 1) with pelvic and periaortic lymph node sampling is the recommended surgical procedure for all but grade 1 and grade 2 carcinomas of the endometrium, with no or minimal endometrial-myometrial invasion. Early stages requiring surgical staging include grade 3 lesions, grade 2 lesions greater than 2 cm, and myometrial invasion of more than 50%, cervical extension and aggressive histologic types, such as clear cell carcinoma and papillary serous carcinoma of the endometrium. Patients are at increased risk for nodal and peritoneal metastasis. Known stage II carcinoma of the endometrium can be treated with one of the two approaches: (1) type 2 radical hysterectomy, bilateral salpingo-oophorectomy, bilateral pelvic lymphadenectomy, and periaortic lymphadenectomy; and (2) a combination of preoperative external beam radiation therapy and intracavitary radiation therapy followed by simple extrafascial hysterectomy (type 1), bilateral salpingo-oophorectomy, periaortic lymph node dissection, and postoperative pelvic irradiation, or alternatively, type 1 hysterectomy followed by pelvic teletherapy. Many surgeons forego pelvic lymph node sampling because patients with stage II carcinoma will require pelvic irradiation (collaborative research groups require pelvic node sampling before administering protocol). Patients with stage III and IV carcinoma of the endometrium should undergo surgery to remove all enlarged lymph nodes and to maximally debulk the tumor. Depending on the tumor volume, this is followed by adjuvant radiation and chemotherapy or hormone therapy.

Uterine Carcinoma

Uterine sarcomas are not officially staged with the FIGO system for corpus lesions. They are classified as either pure, being of only one mesodermal element; or mixed, with malignant mesodermal and malignant epithelial components (i.e., carcinosarcoma). Mixed mesodermal tumors have both, an epithelial and a stromal component and can be homologous or heterologous. Homologous types have a native stromal component such as a muscle; heterologous types are consistent with rhabdomyosarcoma, chondrosarcoma, liposarcoma, or neuroendocrine differentiation. Heterologous tumors are much more aggressive. Müllerian adenosarcomas consist of a benign epithelial element, usually a fibrosarcoma or endometrial sarcoma, and rarely heterologous elements.

Uterine Sarcomas

FIGO Staging for Carcinoma of the Corpus Uteri

Stage IA G123	Tumor limited to the endometrium
Stage IB G123	Invasion to less than one-half of the myometrium
Stage IC G123	Invasion to more than one-half of the myometrium
Stage IIA G123	Endocervical glandular involvement only
Stage IIB G123	Cervical stromal invasion
Stage IIIA G123	Tumor invasion of serosa and/or adnexa, and/or positive peritoneal cytology
Stage IIIB G123	Vaginal metastases
Stage IIIC G123	Metastases to pelvic and/or paraaortic lymph nodes
Stage IVA G123	Tumor invasion of bladder and/or bowel mucosa
Stage IVB	Distant metastases including intra-abdominal and/or inguinal lymph nodes

Histopathology: Degree of Differentiation

Cases of carcinoma of the corpus should be classified (or graded) according to the degree of histologic differentiation, as follows:

- G1 = 5% or less of a nonsquamous or nonmorular solid growth pattern
- G2 = 6% to 50% of a nonsquamous or nonmorular solid growth pattern
- G3 = more than 50% of a nonsquamous or nonmorular solid growth pattern

Notes on Pathologic Grading

1. Notable nuclear atypia, inappropriate for the architectural grade, raises the grade of a grade 1 or grade 2 tumor by 1.
2. In serous adenocarcinomas, clear cell adenocarcinomas, and squamous cell carcinomas, nuclear grading takes precedence.
3. Adenocarcinomas with squamous differentiation are graded according to the nuclear grade of the glandular component.

Rules Related to Staging

1. Because of the surgical staging of corpus cancer, procedures previously used for the determination of stages, such as the findings from fractional D&C to differentiate between stage I and stage II, are no longer applicable.
2. It is appreciated that there may be a small number of patients with corpus cancer who might be treated primarily with radiation therapy. If that is the case, the clinical staging adopted by FIGO in 1971 would still apply, but designation of that staging system would be noted.
3. Ideally, the width of the myometrium should be measured along with the width of tumor invasion.

Adapted from International Federation of Gynecology and Obstetrics. Staging classifications and clinical practice guidelines for gynaecologic cancers. *Int J Gynecol Obstet.* 2000;70:207–312.

Endometrial stromal sarcomas are tumor cells resembling that of the stroma surrounding proliferative endometrium. Low-grade lesions have fewer than 10 mitoses per 10 high-power field while high-grade lesions have more than 10 mitoses per 10 high-power field. High-grade lesions frequently are found in postmenopausal patients and are usually estrogen and progesterone receptor negative.

Leiomyosarcomas are uterine smooth muscle tumors. Tumors are evaluated histologically from mitoses per 10 high-power field. Fewer than 5 mitoses per 10 high-power field indicates a benign lesion; 5–9 mitoses per 10 high-power field, an intermediate lesion; and more than 10 mitoses per 10 high-power field, aggressive lesions that frequently recur.

Although there is no official staging, the FIGO system for corpus carcinoma is frequently used. Metastasis occurs by direct extension and lymphatic and hematogenous spread. Surgical treatment of uterine sarcomas is type 1 extrafascial hysterectomy and bilateral salpingo-oophorectomy. In young patients with leiomyosarcomas, ovarian preservation is at times maintained. Additional surgical staging such as lymphadenectomy and omentectomy has not proved efficacious in increasing survival. Studies of adjuvant radiation chemotherapy have demonstrated mixed results in patients with sarcomas.

Classification of Uterine Sarcomas

- I. Pure sarcomas
 - (a) Pure homologous
 1. Angiosarcoma
 2. Fibrosarcoma
 3. Leiomyosarcoma
 4. Stromal sarcoma
 - (b) Pure heterologous
 1. Chondrosarcoma
 2. Liposarcoma
 3. Osteogenic sarcoma
 4. Rhabdomyosarcoma
- II. Mixed sarcomas
 - (a) Mixed homologous
 - (b) Mixed heterologous
 - (c) Mixed homologous and heterologous
- III. Malignant mixed müllerian tumors
 - (a) Malignant mixed müllerian tumor, homologous type: Carcinoma plus one or more of the homologous sarcomas listed in IA
 - (b) Malignant mixed müllerian tumor, heterologous type: Carcinoma plus one or more of the heterologous sarcomas listed in IB; homologous sarcoma(s) may also be present
- IV. Sarcoma, unclassified
- V. Malignant lymphoma

Epithelial Ovarian Carcinomas

In the United States, approximately 21,550 new epithelial carcinomas, with 14,600 deaths, are expected to occur in 2009. Ovarian carcinoma, as endometrial carcinoma, is surgically staged in accordance with the criteria of the FIGO system. Surgical staging includes removal of all peritoneal fluid from the cul-de-sac, which is then submitted for cytologic evaluation. If no fluid is present, peritoneal washings obtained with normal saline solution are collected for cytologic evaluation. The anterior and the posterior cul-de-sac, pericolic gutters, epigastrium, and hemidiaphragms should be sampled. The latter specimens are sent separately. After obtaining the abdominal washings, the abdomen should be thoroughly evaluated for transcoelomic spread of ovarian carcinoma. The diaphragms as well as the liver, spleen, and viscera are palpated. The small intestines should be exteriorized, and the entire length, as well as the large intestine should be examined. Areas suspicious for carcinoma should be excised and sent to the pathology laboratory for histologic evaluation. If no gross tumor is present in the omentum, an infracolic omentectomy is performed. The greater omentum adherent to the transverse colon is excised. Retroperitoneal spaces are evaluated for nodal enlargement, pelvic lymph nodes are sampled, and periaortic lymphadenectomy to the level of the renal veins is performed. Random peritoneal biopsy specimens are taken for staging ovarian lesions that are macroscopically confined to the ovaries. Ovarian tumors with metastasis are surgically debulked. Optimal cytoreduction (debulking) has been attained when each piece of tissue is less than 2 cm in diameter. Survival, however, continues to improve if cytoreduction is done for tumor volume less than 5 mm.

Early stage IA, grade 1 tumors in women who desire to preserve fertility can be treated with unilateral oophorectomy. The uterus and the contralateral ovary are preserved to permit future childbearing. It is controversial whether stage IA, grade 1 lesions require complete staging, which would increase the risk for adhesions. Stage IA and IB, grade 2 and 3, and stage IC carcinomas are treated with total abdominal hysterectomy, bilateral salpingo-oophorectomy, and surgical staging. Stage IA, grade 1 tumors do not require chemotherapy. The remaining stage I carcinomas are treated with four to six courses of chemotherapy.

Stages II, III, and IV tumors are managed similarly, with the ultimate goal to remove all macroscopic disease. Cytoreduction markedly increases response to adjuvant chemotherapy and improves survival. Intestinal resection and splenectomy are indicated if a bowel obstruction or pending obstruction is present or if resection will permit optimal debulking of tumor to less than 2 cm. With the recent advent of the ultrasonic surgical aspirator, the need for a diaphragm resection has become infrequent. The ultrasonic surgical aspirator has also permitted the surgeons to electively remove tumor from the abdominal viscera, thereby decrease the need for resection. All, stages II, III, and IV carcinomas are treated with six courses of chemotherapy. The combination of agents, most active is cisplatin plus paclitaxel.

Second-Look Laparotomy

All disease greater than stage IA, grade 1 requires adjuvant chemotherapy. Second-look laparotomy is advocated for advanced ovarian carcinoma in patients who undergo adjuvant chemotherapy and have no evidence of disease on completion of the initial therapy. CT or MRI of the abdomen and pelvis is performed to rule out the

FIGO Staging for Carcinoma of the Ovary

Staging of ovarian carcinoma is based on the findings at clinical examination and by surgical exploration. The histologic findings are to be considered in the staging, as are the cytologic findings, as far as effusions are concerned. It is desirable that a biopsy be taken from suspicious areas outside the pelvis.

Stage I	Growth limited to the ovaries.
Stage IA	Growth limited to one ovary; no ascites present, containing malignant cells. No tumor on the external surface; capsule intact.
Stage IB	Growth limited to both ovaries; no ascites present containing malignant cells. No tumor on the external surfaces; capsules intact.
Stage IC ^a	Tumor classified as either stage IA or IB, but with tumor on the surface of one or both the ovaries; or with ruptured capsule(s); or with ascites containing malignant cells present or with positive peritoneal washings.
Stage II	Growth involving one or both ovaries, with pelvic extension.
Stage IIA	Extension and/or metastases to the uterus and/or tubes.
Stage IIB	Extension to other pelvic tissues.
Stage IIC ^a	Tumor either stage IIA or IIB but with tumor on the surface of one or both the ovaries; or with capsule(s) ruptured; or with ascites containing malignant cells present or with positive peritoneal washings.
Stage III	Tumor involving one or both the ovaries with peritoneal implants outside the pelvis and/or positive retroperitoneal or inguinal nodes. Superficial liver metastasis equals stage III. Tumor is limited to the true pelvis but with histologically proven malignant extension to small bowel or omentum.
Stage IIIA	Tumor grossly limited to the true pelvis with negative nodes but with histologically confirmed microscopic seeding of abdominal peritoneal surfaces.
Stage IIIB	Tumor of one or both the ovaries with histologically confirmed implants of abdominal peritoneal surfaces, none exceeding 2 cm in diameter; nodes are negative.
Stage IIIC	Abdominal implants greater than 2 cm in diameter and/or positive retroperitoneal or inguinal nodes.
Stage IV	Growth involving one or both the ovaries, with distant metastases. If pleural effusion is present, there must be positive cytologic findings to allot a case to stage IV. Parenchymal liver metastasis equals stage IV.

From International Federation of Gynecology and Obstetrics. Staging classifications and clinical practice guidelines for gynaecologic cancers. *Int J Gynecol Obstet.* 2000;70:207–312.

^a To evaluate the impact of the different criteria for allotting cases to stage IC or IIC, on prognosis, it would be of value to know whether the rupture of the capsule was spontaneous or caused by the surgeon, and if the source of malignant cells detected was peritoneal washings or ascites.

presence of persistent disease. CA-125, if elevated at diagnosis can provide a measure of response. Markedly elevated levels at the completion of therapy or increased levels during initial chemotherapy are indicative of persistent disease or poor response. Second-look laparotomy entails performing a laparotomy and evaluating all coelomic peritoneal surfaces for gross disease. If any gross tumor is present, attempts are made to resect the remaining tumor, and adjuvant chemotherapy is continued. If no tumor is identified macroscopically, peritoneal biopsy specimens are obtained from all surfaces, including the anterior and posterior cul-de-sacs, lateral pelvic sidewalls, pericolic gutters, anterior abdominal wall, and abdominal pelvis and hemidiaphragms, and the infragastric omentum is excised. Representative samplings of the peritoneal and bowel adhesions are sent to the pathology laboratory for histologic evaluation. If no disease is present, then pelvic and periaortic lymph node sampling is performed. Any enlarged nodes are excised and sent for histologic evaluation. Ovarian carcinoma will recur by 5 years in 40–50% of the patients in whom second-look laparotomy yielded normal findings. A national collaborative group study (Gynecologic Oncology Group) is randomizing patients to observation vs. p32 therapy. It is hoped that p32 will destroy microscopic disease not identified at second-look laparotomy. In patients with positive findings or recurrent disease, topotecan, etoposide, or hexamethameline, in descending order, are administered as single agents.

Second-look laparoscopy has become increasingly common. It is strongly recommended that open laparoscopy be performed because of the nature of the ovarian carcinoma. If laparoscopic findings are positive, all attempts are made to remove the remaining disease via laparoscopy or laparotomy. If there is no evidence of disease at laparoscopy, laparotomy is recommended for thorough evaluation of the peritoneal cavity, including palpation of the peritoneal surfaces, to assist in identifying persistent disease.

Vulvar Carcinoma

Vulvar carcinoma is uncommon, accounting for less than 5% of all gynecologic malignancies. In 2009, it is estimated that there will be 3,580 new cases and 900 deaths from this malignancy.

The use of radical procedures to treat vulvar carcinoma has decreased markedly during the past decade. Attempts are made to perform radical hemivulvectomies and unilateral inguinal femoral lymph node dissections through separate incisions, rather than en bloc resection of the vulva and lymph nodes. Of importance is the depth of invasion as well as the width of the lesion. Lesions of less than 1 mm of invasion and 2 cm in width can be treated conservatively with wide local radical excision and no inguinal lymph node dissection. With less than 1 mm of invasion, risk of inguinal lymph node metastasis is essentially zero. T1 lesions of less than 2 cm with invasion of more than 1 mm should be treated with radical vulvectomy. If the tumor is a lateralizing lesion, hemivulvectomy is appropriate, preferably with 2 cm tumor margins. Attempts should be made to spare the clitoris, urethra, and anal sphincter. Ipsilateral inguinal femoral lymph dissection should be performed, and if suspect nodes are positive for metastasis at frozen-section analysis, contralateral lymph node dissection is required. The Gynecologic Oncology Group has shown that

FIGO Staging of Vulvar Carcinoma

Stage 0	Carcinoma in situ, intraepithelial carcinoma
TIS	
Stage I	Tumor confined to the vulva and/or perineum – 2 cm or less
T1 N0 M0	in greatest dimension, no nodal metastasis
Stage II	Tumor confined to the vulva and/or perineum – more than
T2 N0 M0	2 cm in greatest dimension, no nodal metastasis
Stage III	Tumor of any size with...
T3 N0 M0	(1) Adjacent spread to the lower urethra and/or the vagina or
T3 N1 M0	the anus, and/or...
T1 N1 M0	(2) Unilateral regional lymph node metastasis
T2 N1 M0	
Stage IVA	Tumor invades any of the following:
T1 N2 M0	upper urethra, bladder mucosa, rectal mucosa, pelvic
T2 N2 M0	bone, and/or bilateral regional node metastasis
T3 N2 M0	
T4 any N M0	
Stage IVB	
Any T	Any distant metastasis including pelvic lymph nodes
Any N M1	

TNM Classification of Carcinoma of the Vulva (FIGO)

<i>T</i>	<i>Primary tumor</i>
TIS	Preinvasive carcinoma (carcinoma in situ)
T1	Tumor confined to the vulva and/or perineum – 2 cm or less in greatest dimension
T2	Tumor confined to the vulva and/or perineum – more than 2 cm in greatest dimension
T3	Tumor of any size with adjacent spread to the urethra and/or vagina and/or to the anus
T4	Tumor of any size infiltrating the bladder mucosa and/or the rectal mucosa, including the upper part of the urethral mucosa and/or fixed to the bone
<i>N</i>	<i>Regional lymph nodes</i>
N0	No lymph node metastasis
N1	Unilateral regional lymph node metastasis
N2	Bilateral regional lymph node metastasis
<i>M</i>	<i>Distant metastasis</i>
M0	No clinical metastasis
M1	Distant metastasis (including pelvic lymph node metastasis)

From International Federation of Gynecology and Obstetrics. Staging classifications and clinical practice guidelines for gynaecologic cancers. Int J Gynecol Obstet. 2000;70:207–312.

pelvic lymphadenectomy in patients with positive inguinal femoral lymph nodes was not superior to pelvic irradiation. T2 and early T3 lesions are surgically treated with a radical vulvectomy and bilateral inguinal femoral lymph node dissection. Two methods are available for performing this technique. The first, traditional method which was initially described by Way, involves en bloc resection. The second, preferred method, involves three separate incisions: the radical vulvectomy with attempts to spare the urethra and the anus and two additional groin incisions below the inguinal ligament for inguinal lymph node dissection. Separate groin incisions should not be used in patients with large midline or clitoral lesions. In patients with T4 lesions and lesions that appear to be invading the rectum or proximal urethra, a combination of chemotherapy and tele-therapy is used to shrink the tumor and permit more conservative surgical resection of the tumor.

Surgical Applications

Simple Extrascial Total Abdominal Hysterectomy With or Without Bilateral Salpingo- oophorectomy

Exploratory laparotomy is performed through a midline or transverse incision. Kelly clamps are utilized to clamp the cornial areas of the uterus, which decreases the theoretical risk for transtubal migration of tumor cells in the presence of an endometrial lesion.

Two atraumatic Kelly clamps placed on the cornial region enable the surgeon to elevate the uterus and place traction on it. The round ligament is identified, grasped with a Kelly clamp, and ligated distally. The round ligament contains Sampson's

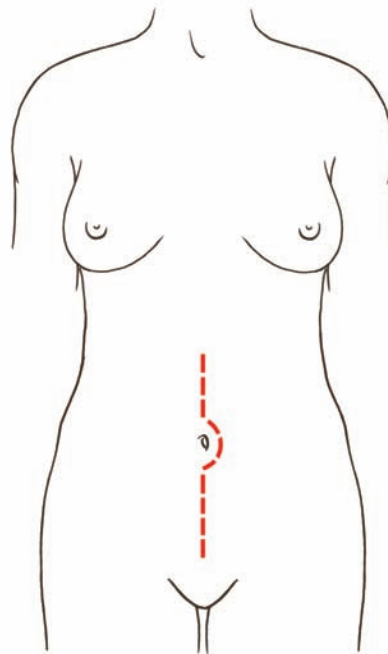


Figure 14.8

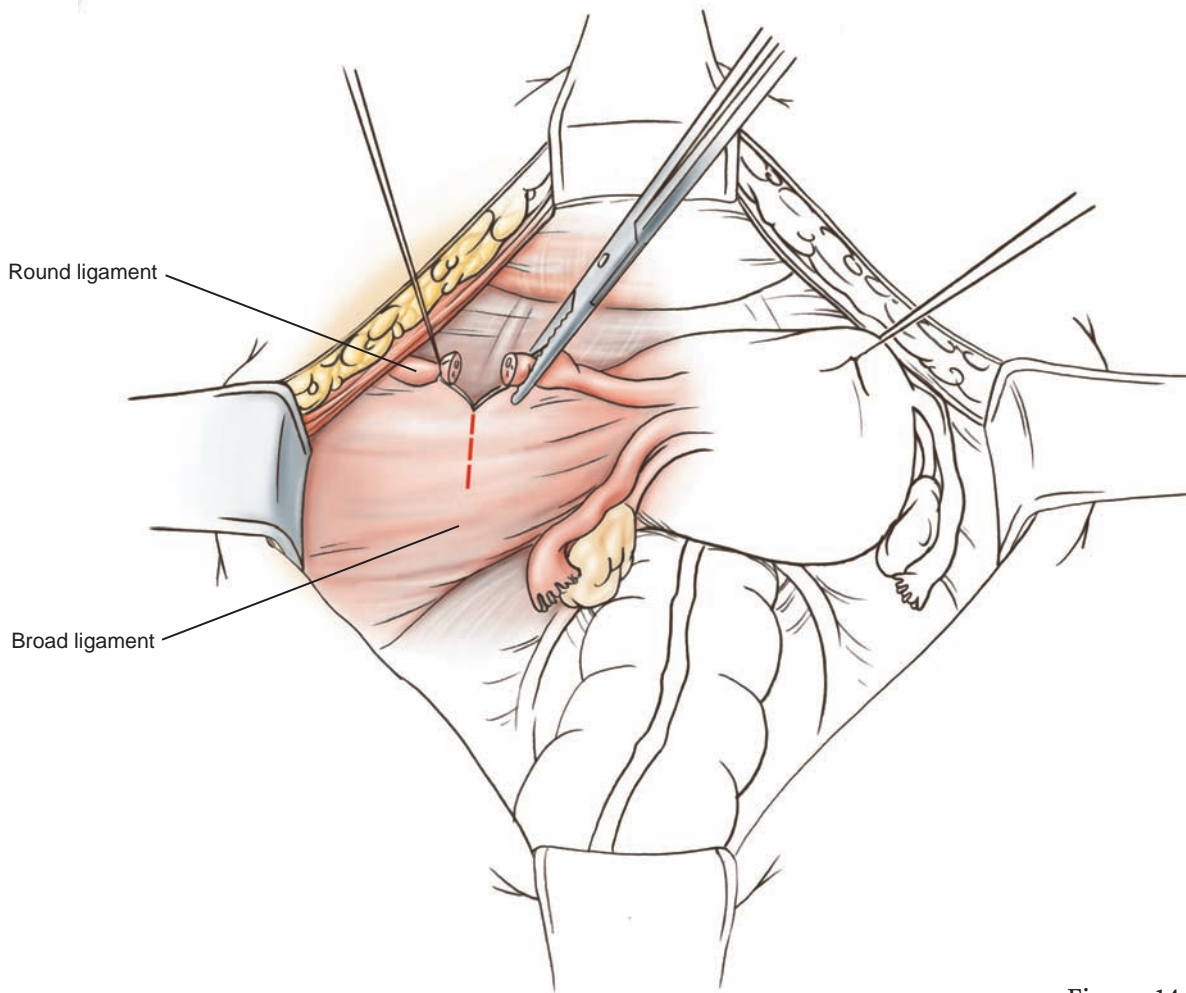


Figure 14.9

artery, which can produce postoperative bleeding if the pedicle is not ligated with a Metzenbaum scissors or cautery. The posterior leaf of the broad ligament is then incised. Pelvic vessels, including the infundibular pelvic ligament, the common iliac, hypergastric, and external iliac vessels, and the ureter, are identified. The infundibular pelvic ligament is isolated in the medial leaf of the peritoneum and sharply incised throughout its entire length from the pelvic brim to the uterus. It is then double clamped and ligated with 0 Vicryl suture. If the ovaries are to be conserved, the utero-ovarian (suspensory) ligaments, adjacent to the uterus are clamped and ligated. The ovaries are then suspended out of the pelvis to prevent adherence to the cuff and placed outside the potential radiation field.

The anterior cul-de-sac bladder peritoneum is grasped with atraumatic forceps and sharply incised. The vesicovaginal space is then sharply incised, with tension placed medially to avoid the lateral vascular bladder pillars. If no extrauterine disease is present, sharp dissection of the peritoneal reflection of the posterior cul-de-sac is not required. If additional mobilization is required, the peritoneum is sharply incised and the rectovaginal plane is sharply and bluntly dissected. The vesicovaginal and rectovaginal planes are avascular planes of the pelvis.

Figure 14.10

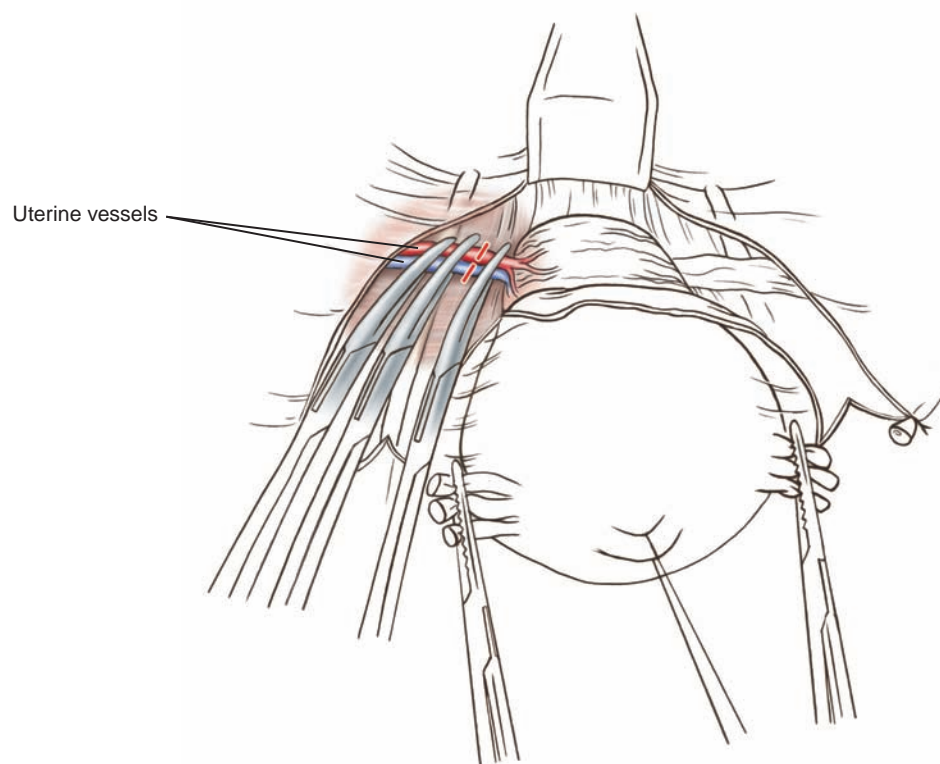
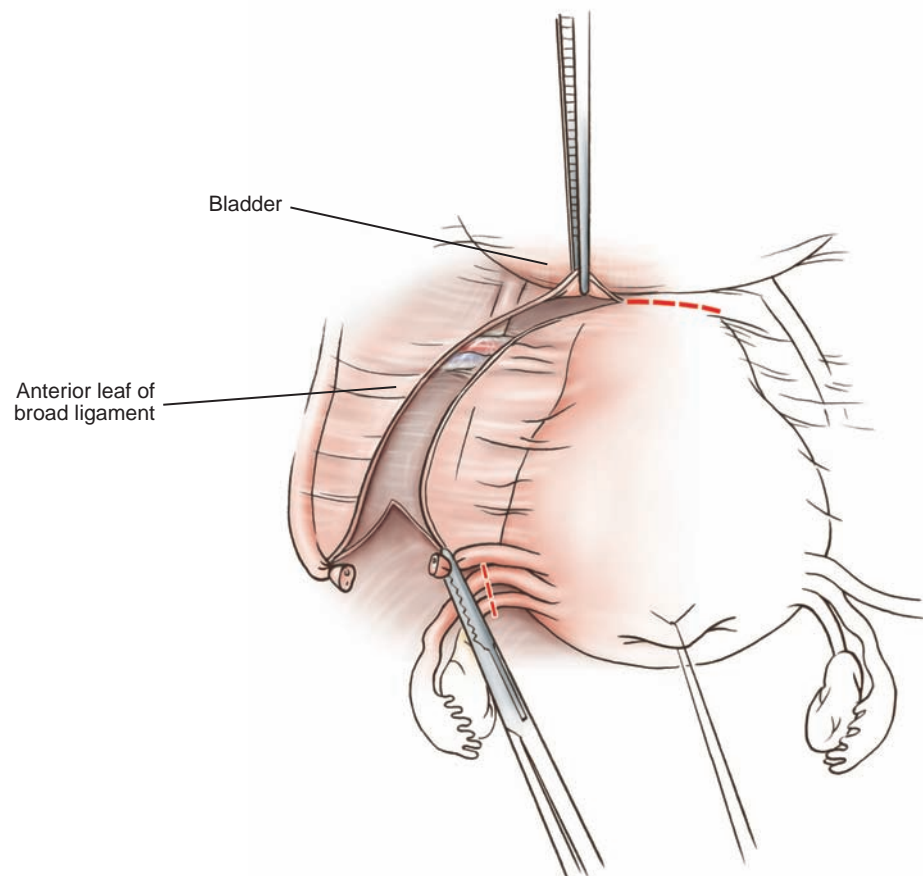


Figure 14.11

The uterus is now freely mobile. The uterine vessels can be seen adjacent to the cervix and the uterus, with the ureter coursing under the uterine artery to its insertion in the bladder. Each artery is approximately 10 cm long, and the ureters are 30 cm long. The uterine vessels are then doubly clamped and ligated at the level of the internal os. A third clamp is used distally to prevent backbleeding from the uterine specimen. Uterosacral ligaments are easily identifiable and palpated at this time. The pubovesical cervical fascia is part of the endopelvic fascia, which surrounds and supports the cervix. This pubovesical fascia becomes contiguous with the cardinal and broad ligaments, extending to the lateral pelvic sidewall. In patients with malignancy, this fascia is left intact during hysterectomy. Atraumatic hysterectomy clamps are used to clamp the cardinal ligaments to the level of the external os. Each pedicle is suture ligated at the level of the external os, and a curved clamp, that includes the vaginal apex and the uterosacral ligament, is placed. Transfixion stitches are used to assist in vault suspension by the attachment of the vaginal cuff to the uterosacral ligament. Alternatively, the vagina can be entered and the specimen, sharply excised. Ochsner clamps are used to secure the vaginal margins. Angle sutures are placed in a figure-of-eight fashion including the vaginal apex and uterosacral ligaments. The remainder of the vaginal cuff is closed with interrupted sutures. In the past, it was customary to suture the vaginal edges for hemostasis and leave the cuff open, but with the present availability of closed drainage systems and antibiotics, this is no longer required.

Laparoscopy was initially used to assist in performing a difficult vaginal hysterectomy, and also enabled vaginal removal of the adnexa. Surgeons have returned to using the supracervical hysterectomy via a laparoscopic approach. After ligation of the vessels and cardinal ligaments, the uterus is morcellized. The morcellized fragments are then extracted through the trocar site. A supracervical hysterectomy is rarely indicated for gynecologic malignancies. A laparoscopy-assisted hysterectomy and bilateral salpingo-oophorectomy is an accepted substitute for abdominal or vaginal hysterectomy in the treatment of stage I and II carcinoma of the endometrium, or stage IA carcinoma of the cervix. A pelvic and periaortic node dissection can also be performed laparoscopically. Recent studies have shown similar nodal counts in appropriately selected laparoscopic patients.

Robotic surgery is growing in popularity among Gynecologic Oncologists. Radical hysterectomy and pelvic node dissections (for cervical cancer) as well as hysterectomy, node dissection, omentectomy and tumor debulking for early uterine and ovarian cancer, are routinely performed in some practices. During the next several years, this technique may become the desired approach among patients and surgeons.

Piver et al. identified five classes of extended hysterectomy for cervical carcinoma. Type I hysterectomy is an extrafascial, simple hysterectomy. In type II, or modified radical hysterectomy, described by Wertheim, the medial 50% of the cardinal ligament and uterosacral ligaments are excised. Type III hysterectomy includes the removal of most of the uterosacral and cardinal ligaments and the upper third of the vagina. Type IV, or extended radical hysterectomy, includes excision of the

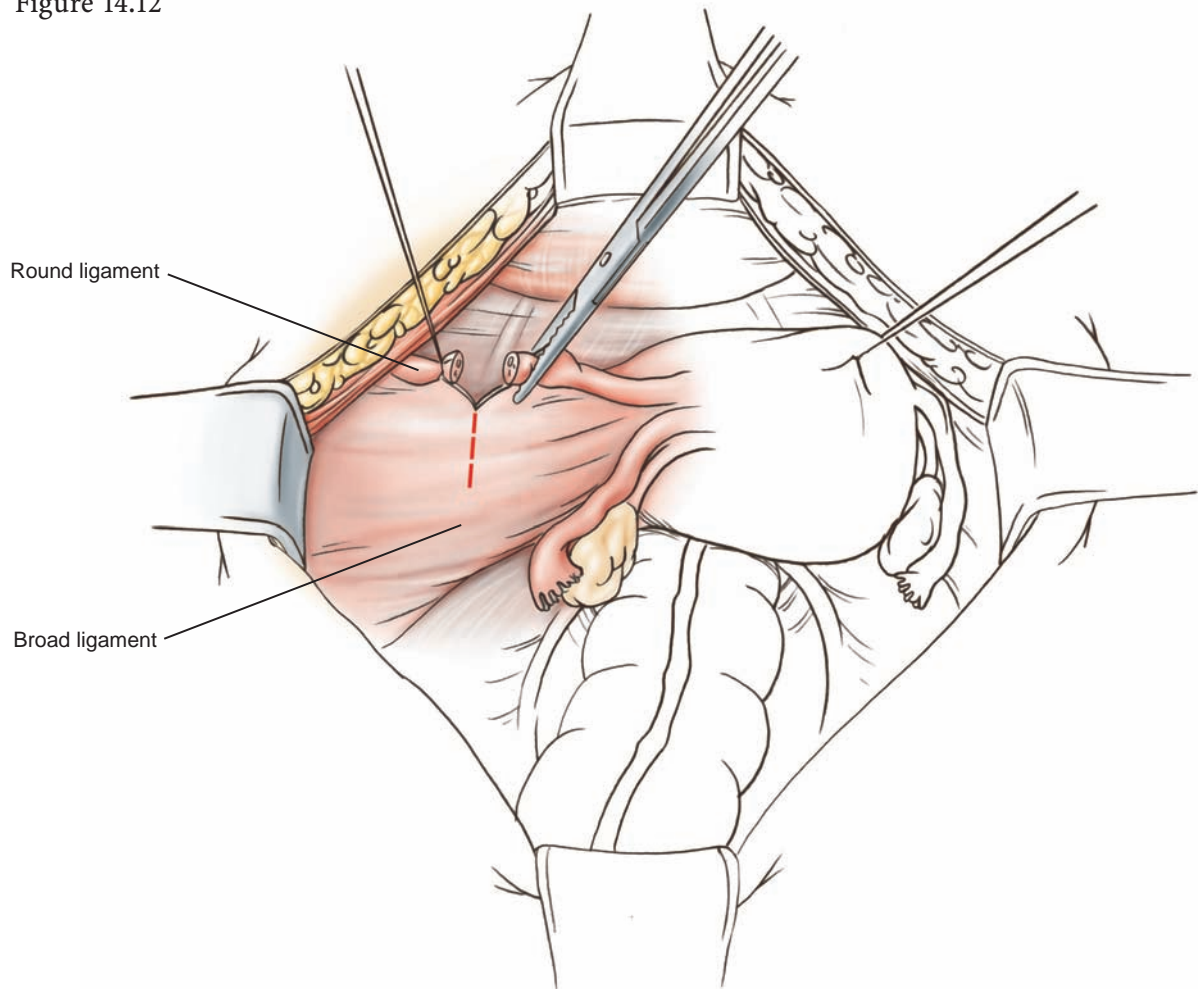
Laparoscopic Hysterectomy

Radical Hysterectomy

periurethral tissue, superior vesical artery, and up to 75% of the vagina. Type V, or partial exenteration, includes removal of the distal ureter and the bladder. This technique is rarely used because stage IV carcinomas are most properly treated with definitive radiation therapy. Stage IA2 carcinoma of the cervix with an invasion of more than 3 mm below the basement membrane and/or lymph vascular involvement, stage IB carcinoma of the cervix, and early stage IA carcinoma of the cervix with an extension to the upper third of the vagina, are all treated with type II or III radical hysterectomy.

The patient is placed in a modified dorsal supine lithotomy position, with the legs in Allen stirrups. The abdomen, perineum, and vagina are prepared to make sterile and draped, and a urethral Foley catheter is placed in the bladder. An abdominal wall incision is made; either a vertical midline, Maylard, or Cherney incision. Upon entering the peritoneal cavity, the peritoneum is inspected for tumor infiltration. The upper abdomen, including the diaphragm, the liver, the spleen, the periaortic and pelvic lymph nodes, are palpated to ensure that no areas suspicious for metastasis are present. The abdominal visceral contents are then packed out of the pelvis with a Balfour retractor or Buckwalter retractor. The fundus is grasped with a Lahey

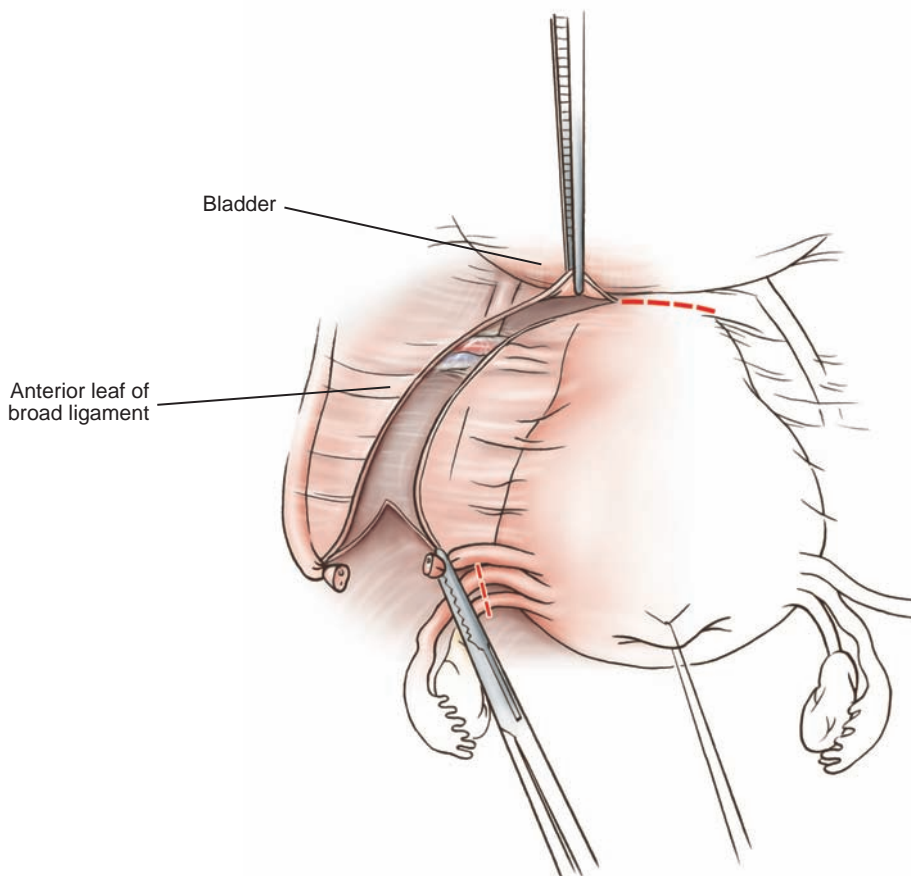
Figure 14.12



thyroid clamp to permit traction of the uterus and cardinal ligaments. Two philosophies exist regarding the order of performing an extended abdominal hysterectomy (radical) and bilateral pelvic lymph node dissection. Some gynecologic oncologists prefer to perform a pelvic lymph node dissection with frozen-section evaluation prior to extended hysterectomy. In the absence of suspect lymph nodes, the author prefers to perform the hysterectomy, then pelvic lymph node dissection. If multiple lymph nodes are microscopically positive, adjuvant radiation therapy is required. With tension on the uterus, the round ligament is grasped distally and ligated with 0 Vicryl suture. The proximal limb is either clipped or suture ligated.

Round ligaments are then incised and the incision is extended cephalad. This permits identification of the common iliac, the external iliac, and the hypogastric vessels and the ureter. If the patient is older than 40 years, the ovaries are frequently not preserved and an oophorectomy is performed. After the infundibulopelvic ligament is identified medially, the peritoneum is sharply incised distally to the uterine vessels. This thoroughly isolates the adnexa and the infundibulopelvic ligament, which includes the uterine artery and veins. The infundibulopelvic ligament is then doubly clamped and ligated with 0 Vicryl suture. The proximal ligation may be a double 0 Vicryl tie or a single 0 Vicryl tie, followed by a 0 Vicryl suture tie distal to the free tie. The peritoneum overlying the bladder is sharply incised.

Figure 14.13



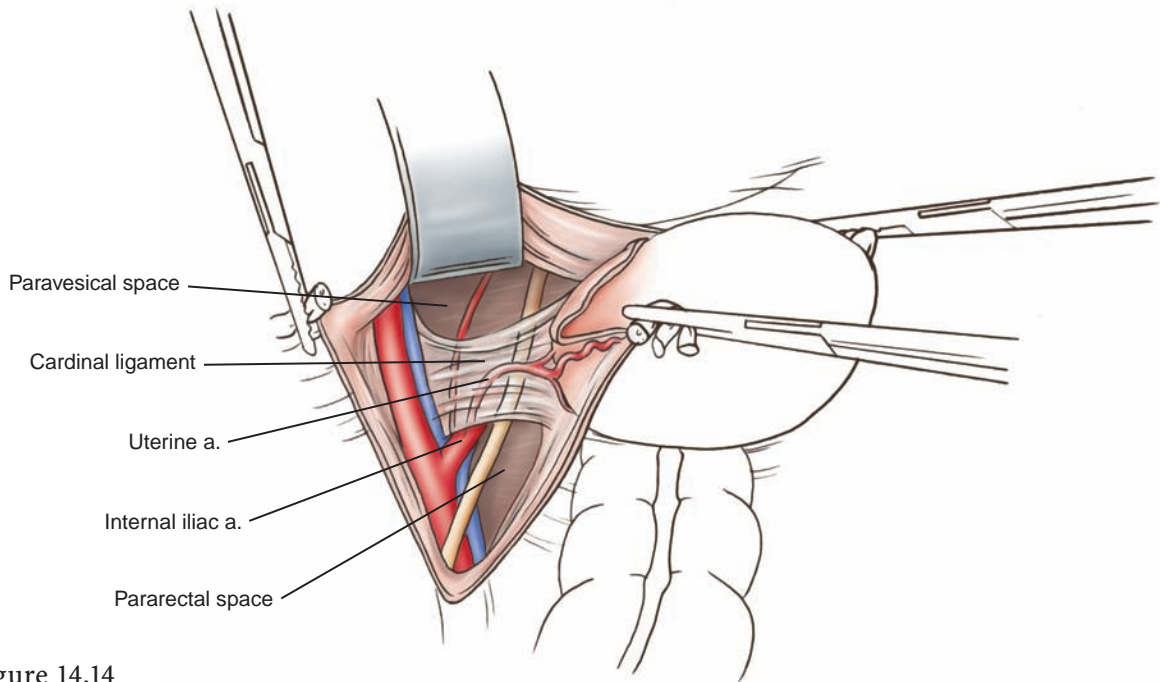


Figure 14.14

The anterior leaf of the broad ligament is lifted along the vesicouterine peritoneal fold, and the vesicovaginal space is dissected sharply, with the bladder mobilized anteriorly. This space is avascular. Attempts should be made to dissect in the midline and to avoid perforating the vessels present in the bladder pillars, laterally.

Two additional avascular spaces are then dissected free: The paravesical space, which is bordered medially by the obliterated artery, laterally by the obturator internus muscle, posteriorly by the cardinal ligament, and anteriorly by the pubic symphysis and the pararectal space, which is bordered medially by the rectum, laterally by the hypogastric artery, anteriorly by the cardinal ligament, and posteriorly by the sacrum.

By placing the index finger and the middle finger in the perirectal space, the surgeon can palpate the lateral extent of the cardinal ligament or web. Nodularity or tumor is a contraindication to type II or III hysterectomy. Cardinal ligaments contain branches of the internal iliac vein and the sympathetic nerve fibers to the bladder superiorly and parasympathetic nerve fibers, inferiorly. The pelvic lymph nodes are inspected again. If the dissection is performed prior to hysterectomy, the lymph node dissection is performed at this point.

During an extended hysterectomy, the uterine artery is identified at its origin on the anterior division of the hypogastric artery. Frequently, the superior vesical artery requires dissection from the cardinal ligament to assist in isolating the uterine artery. The artery is then clamped and ligated bilaterally at its origin. Clamping the distal pedicle of the uterine artery affords the ability to have additional traction. The ureter is then sharply dissected from the medial peritoneum. Additional traction may be

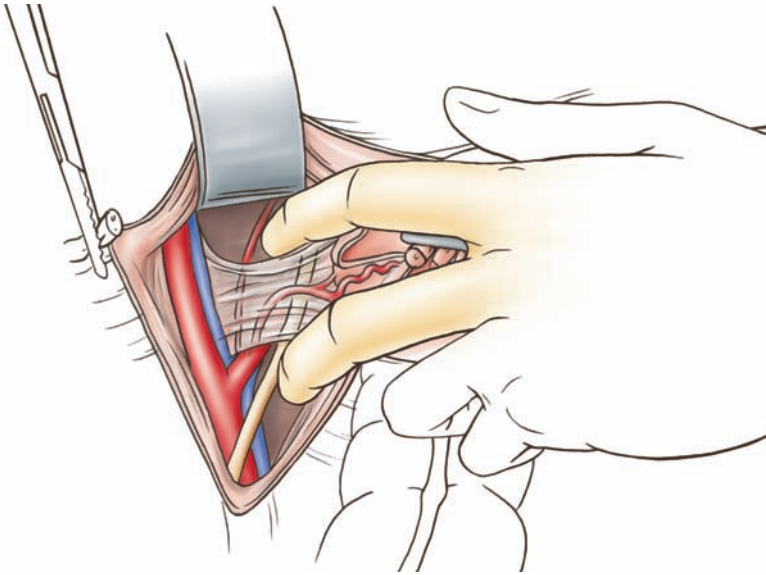


Figure 14.15

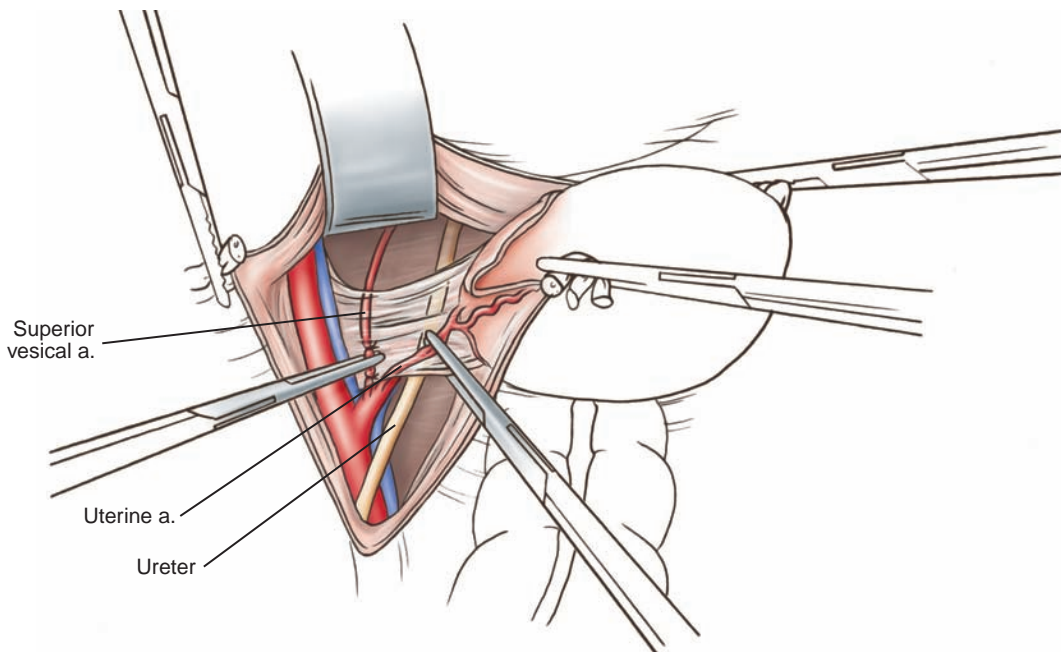


Figure 14.16

obtained with atraumatic forceps. The filmy adhesions around the ureter are sharply incised.

The cardinal ligament engulfs the uterine artery and the ureter. A procedure called “untunneling” the ureter is then performed. With traction on the uterine artery, the ureter is sharply dissected free of the web to its insertion in the uterus. The ureter is freed with a combination of sharp and blunt dissection of the tunnel with a right-angle clamp. Reinhoff-type clamps are used to clamp the roof of the tunnel. This should be done in several steps, ligating each pedicle. The remainder of the roof at the tunnel is the anterior vesicouterine ligament, which is also incised.

Figure 14.17

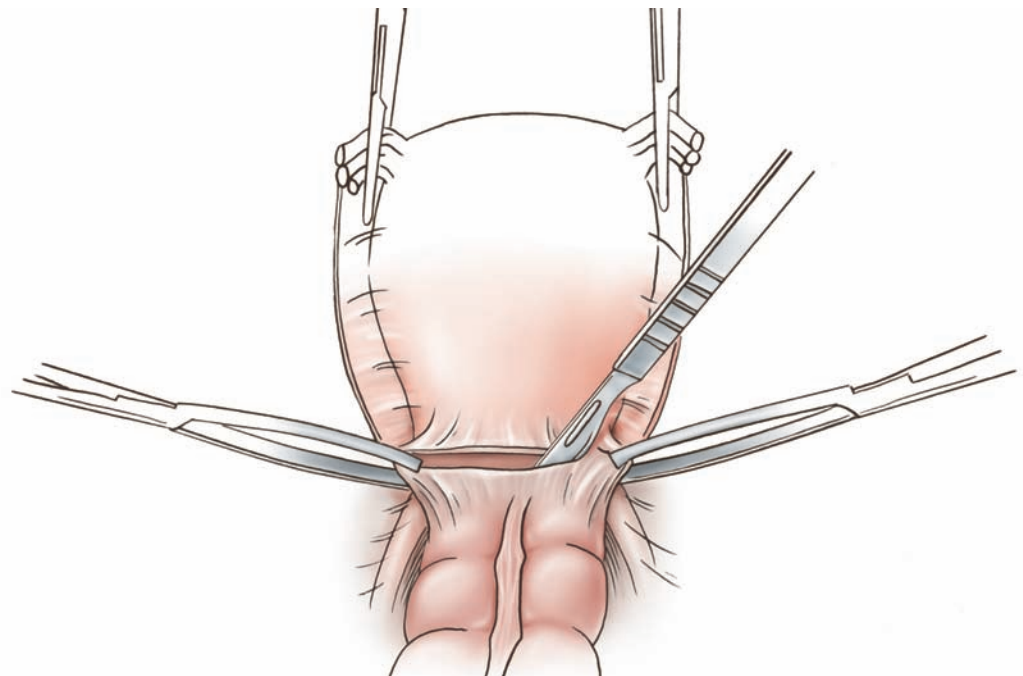
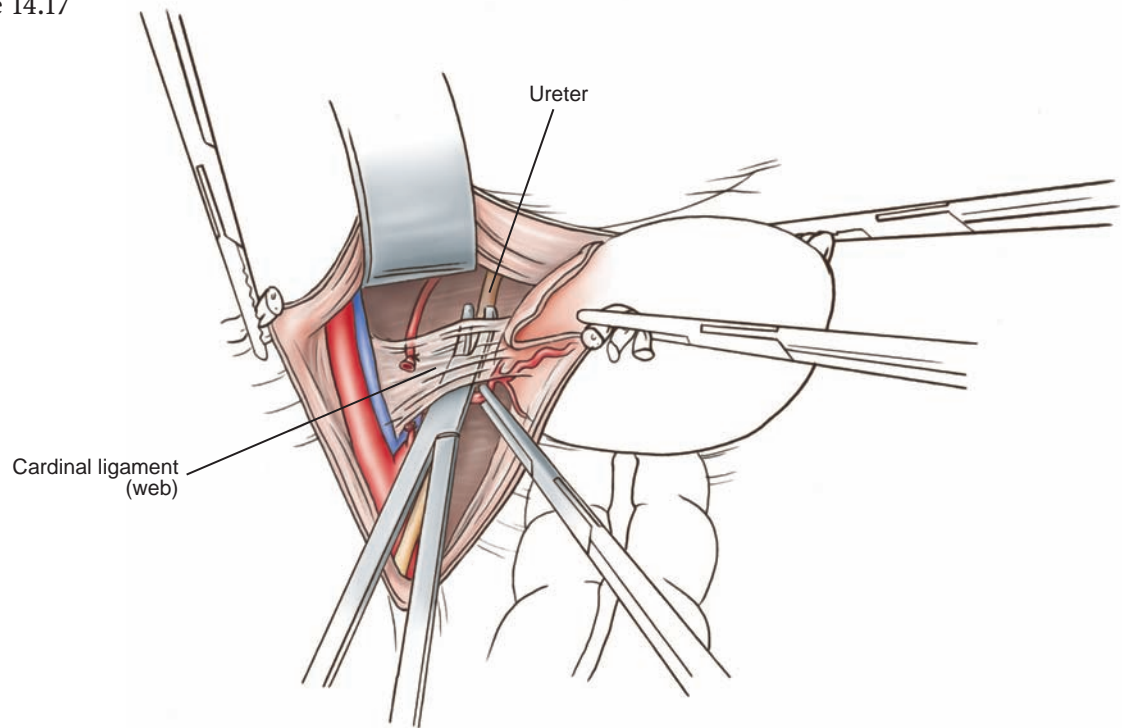


Figure 14.18

The uterus is retracted caudad and medially. A fourth avascular plane of the pelvis, the rectovaginal space, is dissected.

The peritoneal reflection of the rectum and the uterus is grasped with two Allis clamps and retracted cephalad. The peritoneum is then sharply incised and the rectovaginal space is dissected.

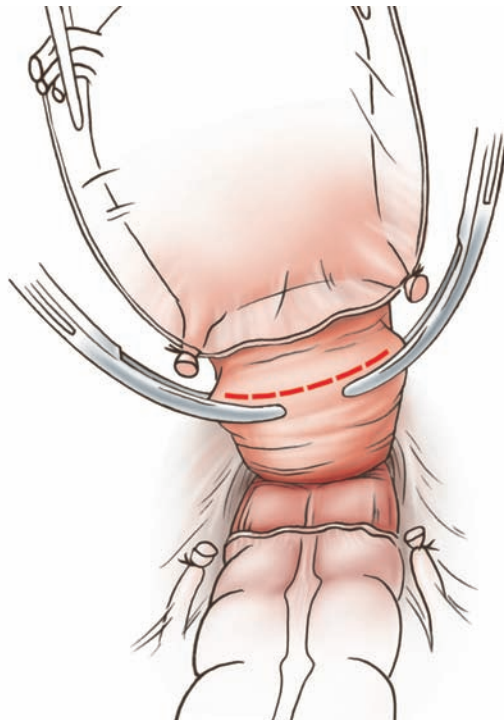


Figure 14.19

Parametria, cardinal ligaments, uterosacral ligament, and vagina can now be freely palpated and the extent of tumor can be evaluated. In type II hysterectomy, the ureter is retracted laterally and 50% of the cardinal ligament is excised. Parametrial clamps such as Wertheim clamps are used in this procedure. It is recommended that a transfixion stitch be placed on the pedicles. This procedure is then repeated on the uterosacral ligament.

The procedure is completed bilaterally. The vaginal tube is isolated and excised up to one third, in a type III hysterectomy. The majority of the cardinal ligament and the uterosacral ligament is excised. Interrupted sutures are used to close the vaginal cuff. One complication of this surgery is febrile morbidity in 25–50% of patients. Blood loss is frequently less than 1 L. Retrovaginal or vesicovaginal fistula occurs in approximately 1–2% of patients. As with any laparotomy for invasive malignancy, pulmonary embolism and small bowel obstruction occur in 1–2% of patients. A late complication is bladder dysfunction, secondary to incising the sympathetic and parasympathetic nerves coursing through the uterosacral and cardinal ligaments. Bladder sensitivity is markedly diminished and as a result, the patient is unable to initiate voiding. Management includes bladder drainage by one of the three methods. In the first method, an indwelling suprapubic or transurethral catheter is placed intraoperatively, and removed after the patient has demonstrated resolution of bladder dysfunction. The method preferred by the author is intermittent catheterization. If postvoiding residual urine is more than 150 mL, the patient is taught to perform intermittent catheterization and discharged with instructions to catheterize herself/himself every 4–6 h prior to the resumption of micturition. On resumption of micturition, the patient should collect postvoiding residual urine until the volume is less

than 100 mL. In patients who have difficulty in identifying the urethra, gentian violet or methylene blue is used to paint the urethral orifice to guide the patient in catheterization. Lymphocysts may develop and can be followed up expectantly or drained under ultrasound guidance.

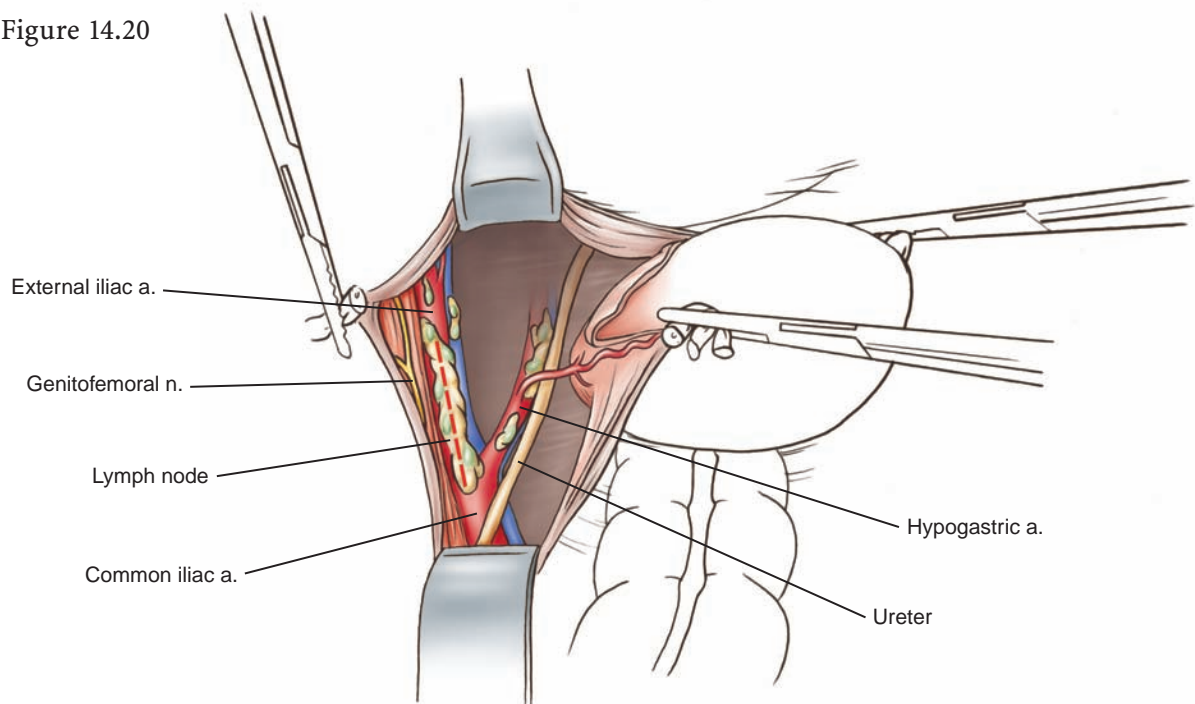
Extended, or type II or type III, radical hysterectomies have been attempted laparoscopically, but the procedure is controversial among gynecologic oncologists. Many believe that dissection via laparoscopy is not extensive enough. The combination of laparoscopy and radical vaginal hysterectomy (Schauta type) did not gain popularity in the United States until laparoscopic pelvic lymphadenectomy was accepted. The initial dissection is performed laparoscopically, and the procedure is completed via a vaginal approach. During the past decade, several centers have performed radical trachelectomy and lymph node dissection for early cervical cancer. This procedure results in low fertility and high miscarriage rate. Very few surgeons have significant experience to decrease complications.

Pelvic Lymphadenectomy

Pelvic lymphadenectomy is performed prior to, or after radical hysterectomy. Stage IA, IB, and IIA carcinomas of the cervix, and stage IIA and IIB carcinomas of the endometrium, can be treated with radical (extended) hysterectomy and bilateral pelvic lymph node dissection with periaortic lymph node evaluation. Pelvic lymphadenectomy is routinely performed in endometrial cancer staging.

The round ligament is ligated and incised. This permits the surgeon to incise the lateral leaf of the peritoneum towards, and above the bifurcation of the common iliac artery. A Deaver retractor is used to expose the majority of the common iliac artery cephalad. A small Richardson retractor is used distally to assist in exposing

Figure 14.20



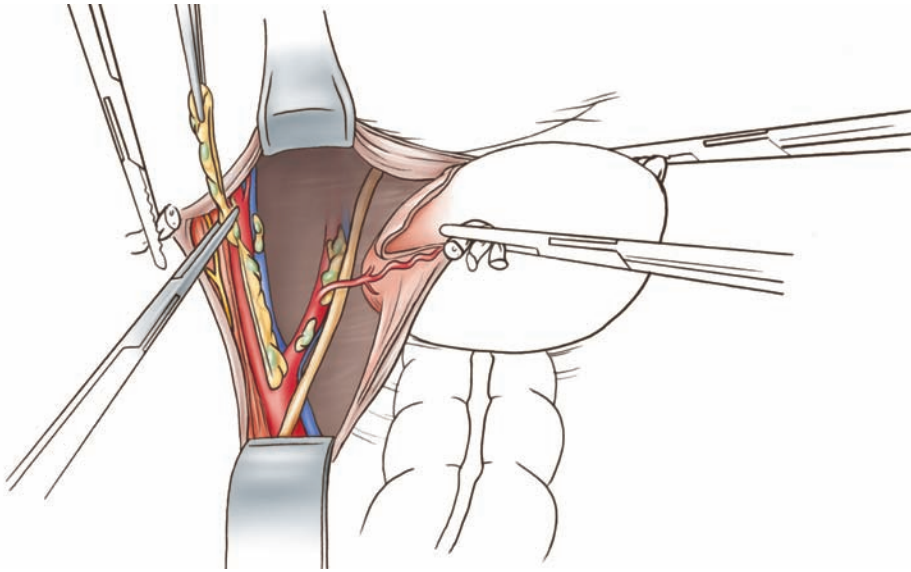


Figure 14.21

the inferior epigastric vessels. On entering the retroperitoneal space, the ureter and the hypogastric, external iliac, and the common iliac vessels are identified. At the bifurcation of the common iliac chain, the external iliac node is divided into lateral and medial portions.

The lateral chain is stripped free from the artery, along the artery to the circumflex iliac vein. Hemoclips may be placed along the length of the proximal and distal pedicles.

The medial chain is then dissected. It is important to note that the genitofemoral nerve courses along the psoas muscle and can be injured if care is not taken to spare this nerve. The hypogastric lymph nodes are also dissected, and clips are placed caudad and cephalad. Tension is then placed on the obturator space and the obturator lymph nodes. Special attention must be taken not to injure the external iliac vein. The iliac vein is retracted laterally with a vein retractor.

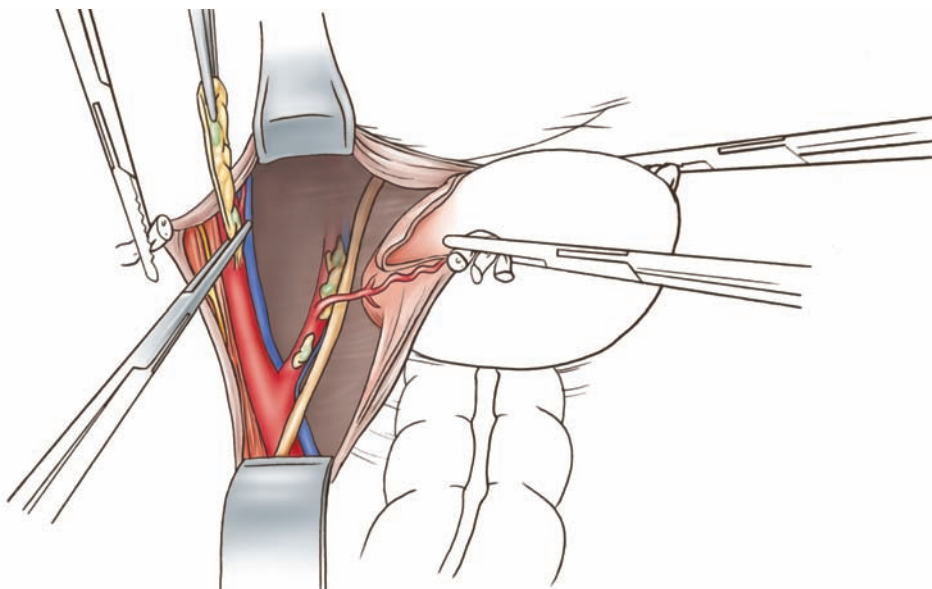


Figure 14.22

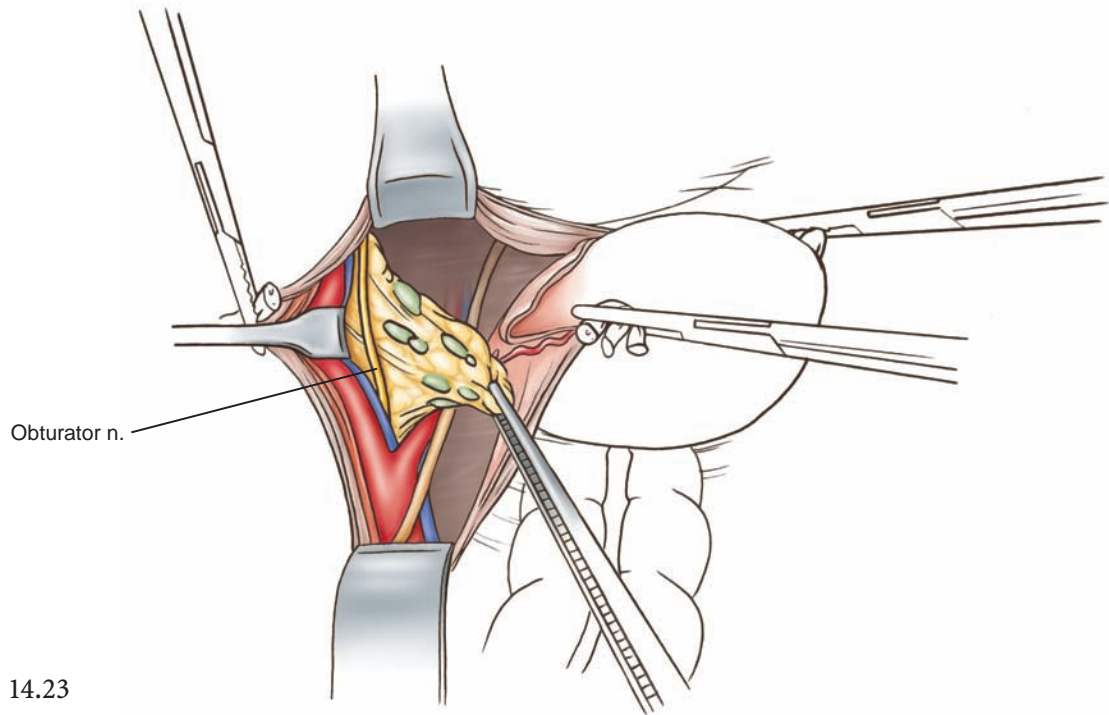


Figure 14.23

The lymphatic tissue and fat in the obturator space are gently teased, and the obturator nerve is identified before excising or clipping any tissue. If the obturator nerve is incised, a plexus of vessels can be seen posterior to the obturator nerve. Careful dissection will assist in avoiding these vessels. Damage to the obturator nerve results in the inability to adduct the thighs. The nerve should be repaired with 4–0 Vicryl interrupted sutures. Physical therapy is frequently required for complete rehabilitation. The obturator artery and vein are usually dorsal to the obturator nerve. In approximately 10% of patients, an aberrant vein arises from the external iliac vein.

Pelvic lymph node dissections can be performed laparoscopically without difficulty. The common iliac, external and hypogastric lymph nodes, are exposed after making an incision in the lateral leaf of the peritoneum. An obturator lymph node resection is performed similar to that of laparotomy. Prior to excising the nodes, it is imperative to identify the obturator nerve. Laparoscopic vein retractors are used to assist in reflecting the hypogastric vein laterally.

Periaortic Lymph Node Dissection

There are two approaches for periaortic lymph node dissection. In early stage cervical carcinoma, large periaortic lymph nodes should be biopsied and sent for frozen-section analysis. If the results are negative, the radical hysterectomy (extended hysterectomy) should proceed. It is controversial whether periaortic lymph node dissection should be performed in early cervical carcinoma, if the pelvic lymph nodes test negative. Traditionally, early cervical carcinoma and endometrial carcinoma was treated with a limited periaortic lymph node dissection, approximately 2.5 cm above the inferior mesenteric artery. Two approaches are taken. In one, an incision

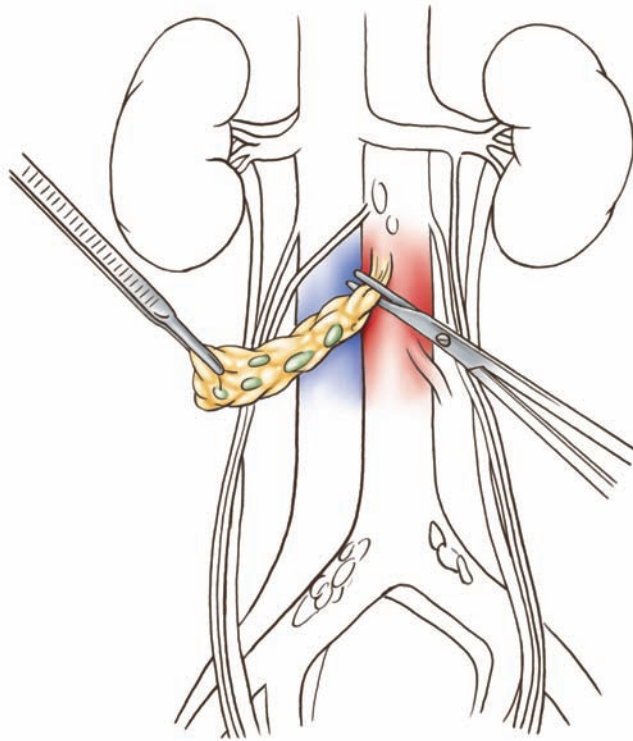


Figure 14.24

is made lateral to the ascending colon, the retroperitoneal space is entered, and the bowel is reflected medially.

An alternative method, which is preferred by the author in most patients, is to exteriorize the small bowel medially, and enter the retroperitoneum by incising the medial peritoneal reflection over the mesenteric vessels, vena cava, and aorta. A Deaver retractor is used cephalad, the ureter is identified bilaterally, and a lymph node dissection is performed starting at the bifurcation of the aorta and extending, approximately 2.5 cm above the inferior mesenteric artery for endometrial and cervical carcinoma, and to the renal veins for ovarian carcinoma. Ligation clips are used during this procedure to decrease the possibility of losing a perforating vessel. It should be noted that the left and right ovarian arteries have their origin on the aorta below the superior mesenteric artery and the renal vessels. The right ovarian vein empties directly into the inferior vena cava, and the left ovarian vein enters into the left renal vein, prior to emptying into the inferior vena cava. When performing a lymph node dissection, the pericaval and periaortic lymph nodes are removed. It is imperative that the lymph nodes on the right and left sides of the vena cava are excised and sent to the pathology laboratory for histologic evaluation. If the ureters are not identified bilaterally, the surgeon is at a risk of ligating and incising the ureter. Occasionally, during an extensive lymph node dissection, as a result of marked fibrosis or enlarged lymph nodes, the inferior mesenteric artery might not be identified and ligated. The inferior hemorrhoidal vessels and the superior mesenteric artery via the marginal artery of Drummond provide collateral circulation to the bowel that was dependent on the inferior mesenteric artery.

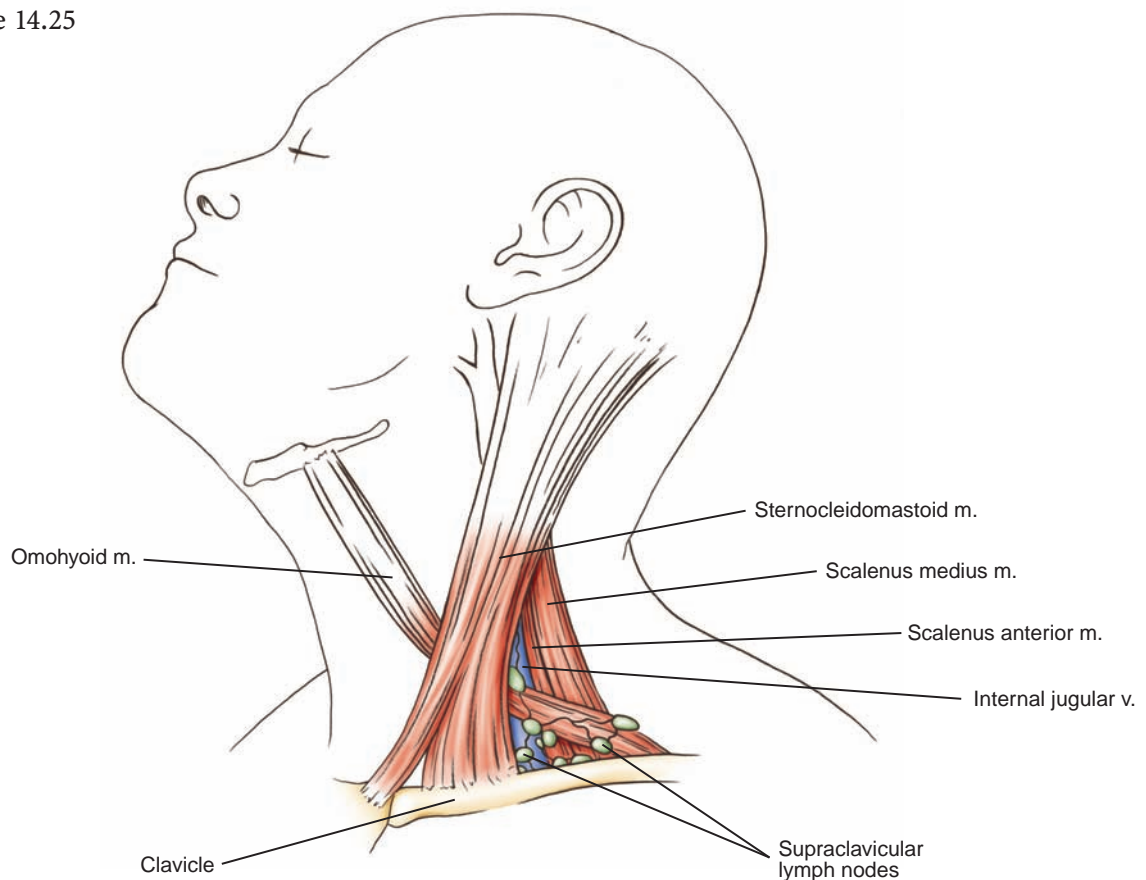
Laparoscopic periaortic lymphadenectomy can be performed with minimal difficulty to the level of the inferior mesenteric artery. Extensive dissection to the level of the renal vessels is difficult and should be attempted only by surgeons with significant laparoscopic experience. It is imperative that the laparoscopic surgeon is prepared to deal with the potential complications inherent in excising periaortic lymph nodes.

Supraclavicular Lymph Node Biopsy

In patients with cervical cancer with positive periaortic lymph nodes, 5–30% will have positive supraclavicular (scalene) lymph nodes. If a lymph node is palpable, needle aspiration can be performed, thereby averting the necessity for excisional biopsy. If no enlarged lymph nodes are palpated, a supraclavicular lymph node biopsy is performed. An incision is made transversely, 1–2 cm above and parallel to the clavicle. After incising the subcutaneous tissue,, a scalene fat pad containing lymph nodes is identified and resected.

The anatomic landmarks include the clavicle inferiorly, the omohyoid muscle laterally and posteriorly, and the sternocleidomastoid muscle medially. The triangle consists of the scalenus anterior and medius muscles. Injury can occur if attention is not paid to the adjacent structures such as the internal jugular vein, posterior to the scalenus medius muscle, which lies beyond the internal carotid artery, beyond the scalenus muscle. The phrenic nerve courses through the subclavicular triangle, frequently on the surface of the scalenus muscles. Damage to the phrenic nerve decreases

Figure 14.25



diaphragm movement. In addition to these adjacent structures, injury to the thoracic duct or lung can occur, and complications include chylothorax or pneumothorax, respectively.

In the staging of ovarian cancer, omentectomy is required, even if no gross tumor is present. In the presence of a gross disease debulking may require infracolic and supracolic omentectomy. Omentectomy is also indicated in endometrial papillary serous carcinoma.

The omentectomy begins at the hepatic flexure of the colon. Initially, the omentum is dissected free from the transverse colon with a cautery or Metzenbaum scissors. Vascular pedicles are ligated with free ties, ligation clips, or the CO₂ Power L.D.S. stapler (U.S. Surgical Corp., Norwalk, Conn.). The lesser sac is exposed during this procedure. If a supracolic omentectomy is required, the omental branches of the gastric artery are ligated, as described previously. The dissection is carried out to the level of the splenic hilum, with the gastroepiploic artery left intact to supply

Omentectomy

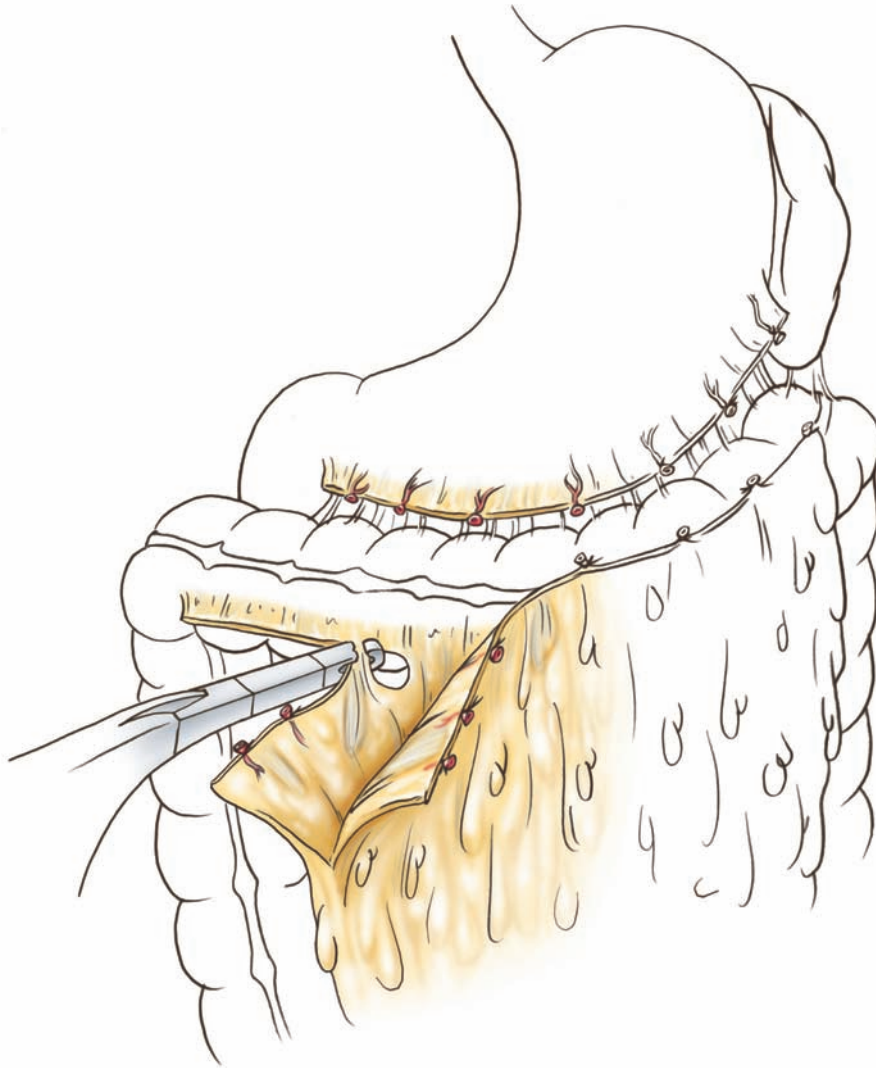


Figure 14.26

blood to the greater curvature of the stomach. A nasogastric tube should be in place postoperatively.

Laparoscopic resection of the omentum can be performed with a combination of laparoscopic ligation clips through a 10–12-mm port, and cautery.

Radical Vulvectomy With Inguinal Femoral Lymphadenectomy

The patient is placed supine with the legs in candy cane or moveable stirrups. The abdomen and the perineum are prepared and draped. A groin incision is made approximately 2 cm above the inguinal ligament and carried down to the aponeurosis of the external oblique muscles.

The skin flap is then mobilized, preserving Camper's fascia. It should be noted that the incision is carried from the anterosuperior iliac spine across the mons to the contralateral anterosuperior iliac spine. A combination of cautery and sharp dissection with the Metzenbaum scissors is utilized. The superficial lymph nodes are removed. Each inguinal ligament is then identified. Lymph nodes at the inguinal

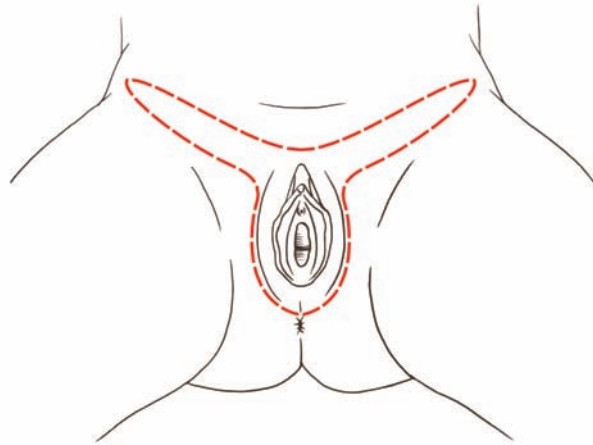


Figure 14.27

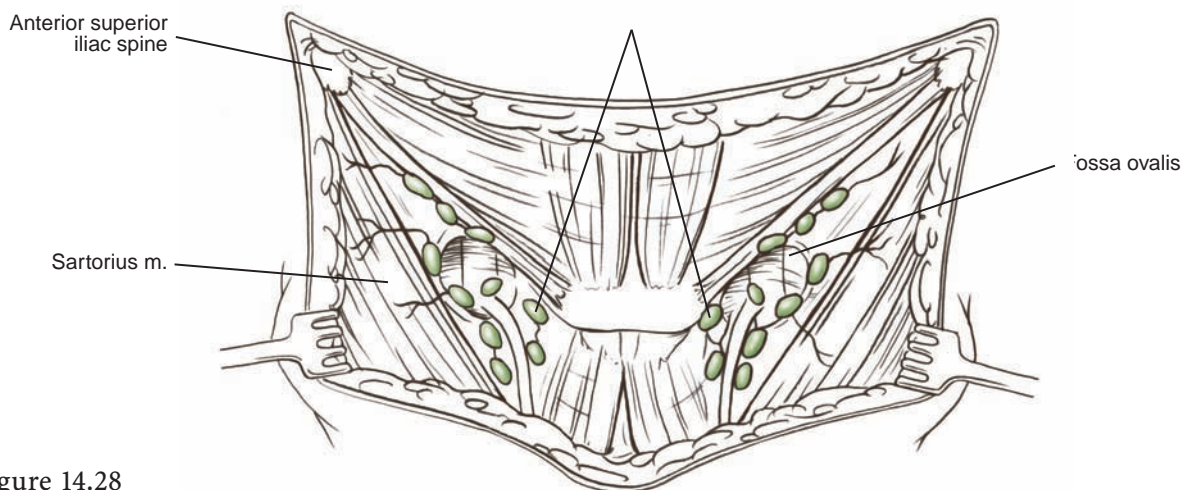


Figure 14.28

ring, that is, Cloquet's, Rosenmüller's, and sentinel lymph nodes, are frequently sent separately for histologic evaluation; if positive, deep lymph nodes are sampled in all cases. The saphenous vein can be identified at this time. The vein has been traditionally doubly clamped and incised, then ligated with 2-0 suture. Attempts are now made not to sacrifice this vessel. It is believed that by preserving the saphenous vein, venostasis will be decreased, and hence leg edema, postoperatively.

At this point the surgeon can identify all of the inguinal structures. The mnemonic navel (nerve, artery, vein, empty space, lymphatics) is used to assist in identification of the femoral and the lymphatic vessels. Approximately, 1–2 cm above the origin of the saphenous vein is the circumflex artery. The adductor longus muscle is identified below the saphenous vein. This muscle and the area around the saphenous vein are stripped of all lymphatic tissue. The fascia lata is split with approximal femoral vein. Femoral lymph nodes are situated medial to the femoral vein within the opening of the fascia ovalis. Sentinel node biopsy can also be used in vulvar malignancies.

The lymphatic tissue is sharply dissected free and sent to the pathology laboratory for histologic evaluation. Sartorius muscle can now be identified laterally.

To protect the femoral vessel, it is transected at its insertion with a cautery and transposed over the femoral artery and vein. If the fascia can be sutured closed there is no need to perform this maneuver. In 50–90% of en bloc resections primary closure results in wound breakdown. Sartorius muscle transposition will protect the vessels and the nerve during granulation. It is controversial whether this is required when using a transverse rectus abdominis musculocutaneous (TRAM) flap or gracilis flap to cover the vulvectomy and lymph node defects, because these myocutaneous flaps bring additional muscle into the field to protect the vessels. On completion of the lymph node dissection, the vulvar and vaginal incisions are marked with a marking pen. Metzenbaum scissors and a cautery are used to dissect the specimen down to

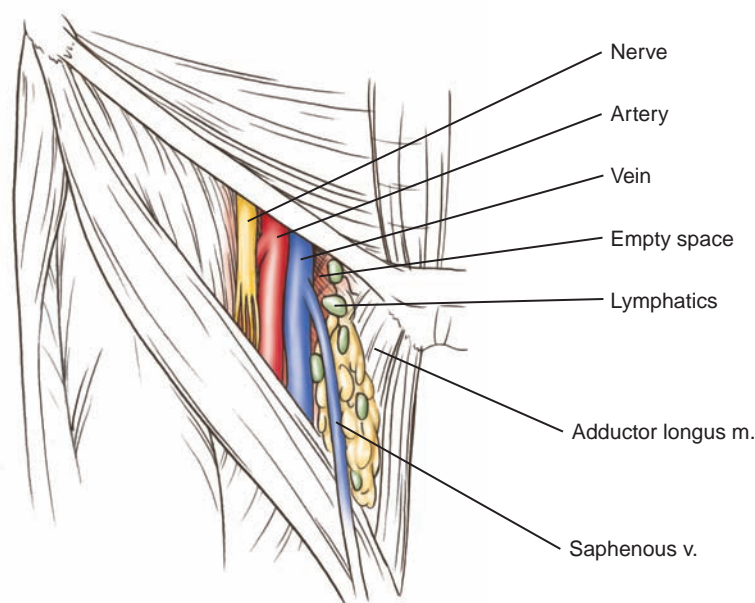


Figure 14.29

Figure 14.30

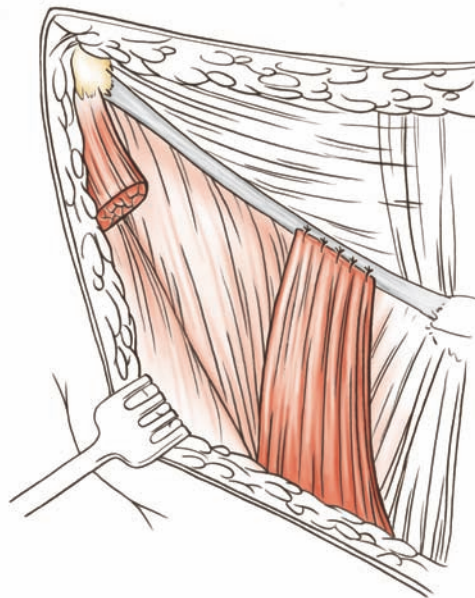
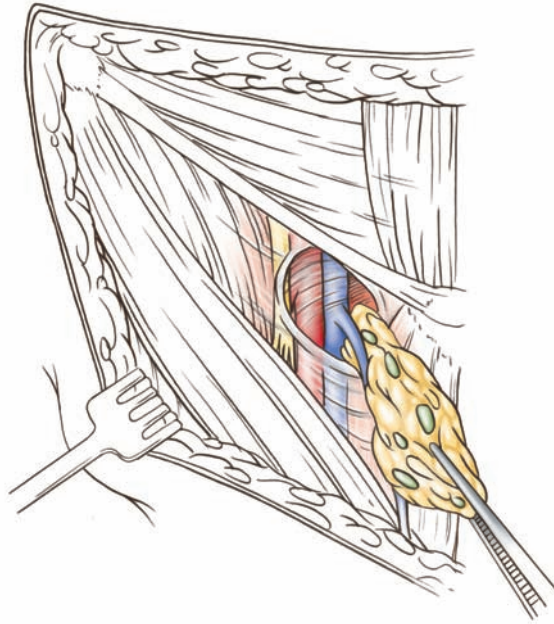


Figure 14.31

the urogenital diaphragm. The pudendal artery and vein are identified, clamped, and ligated. Superiorly at the clitoris, careful attention must be placed so as not to clamp the proximal urethra. A catheter is placed into the bladder. The dorsal bundle and the clitoral vessels are isolated and clamped with a Kocher clamp. The specimen is then incised and a 0 absorbable suture is placed. The specimen is dissected off the pubic periosteum and adducted fascia. Laterally, the incision is made in the labiocrural fold or 2 cm from the lesion. This incision is dissected down to the fascia of the urogenital diaphragm. The ischiocavernosus muscles can then be transected. Posteriorly, it is

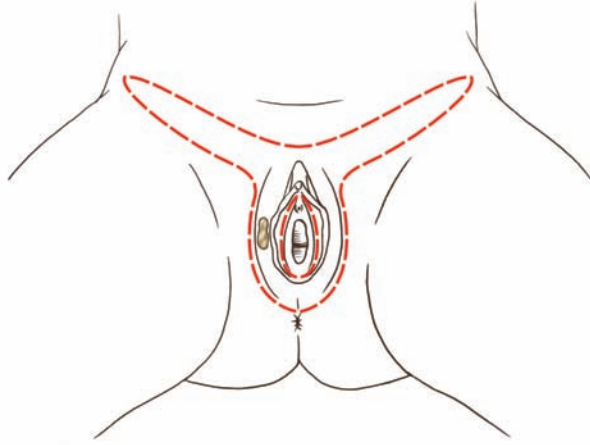


Figure 14.32

imperative that the vulva and the distal vagina are sharply dissected from the rectum. A medial margin of the vulvar specimen is then incised with a No. 10 blade and sent to the pathology laboratory for histologic evaluation. Although 2-cm margins are attempted, the specimen is sent for frozen-section evaluation of the lateral and the medial margins of tumor resection.

The pathologist should also be made aware that the en bloc vulvar specimen includes the superficial lymph nodes in the mons tissue. This en bloc resection is frequently called the rabbit or longhorn incision. Although one can mobilize the adjacent tissue and primarily close it, the author has found the use of tram or gracilis flaps to be advantageous in decreasing wound separation and breakdown. The three incisions, however, can be closed primarily if vulvar resection is not extensive.

Two closed suction drains are placed in the groin and the vulvar region. Both sides of the groins are incised and the mons is left intact. The vulva or hemivulvectomy incisions are made separately.

Hemivulvectomies are used in small isolated lesions. Radiation therapy has been used as a neoadjuvant therapy in patients with advanced disease who would otherwise require pelvic exenteration. Radiation therapy is usually administered with

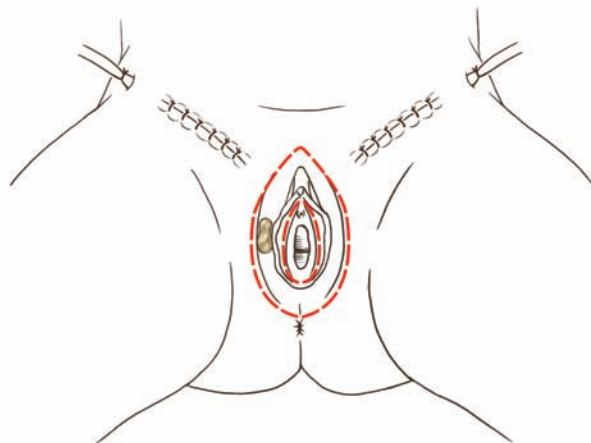
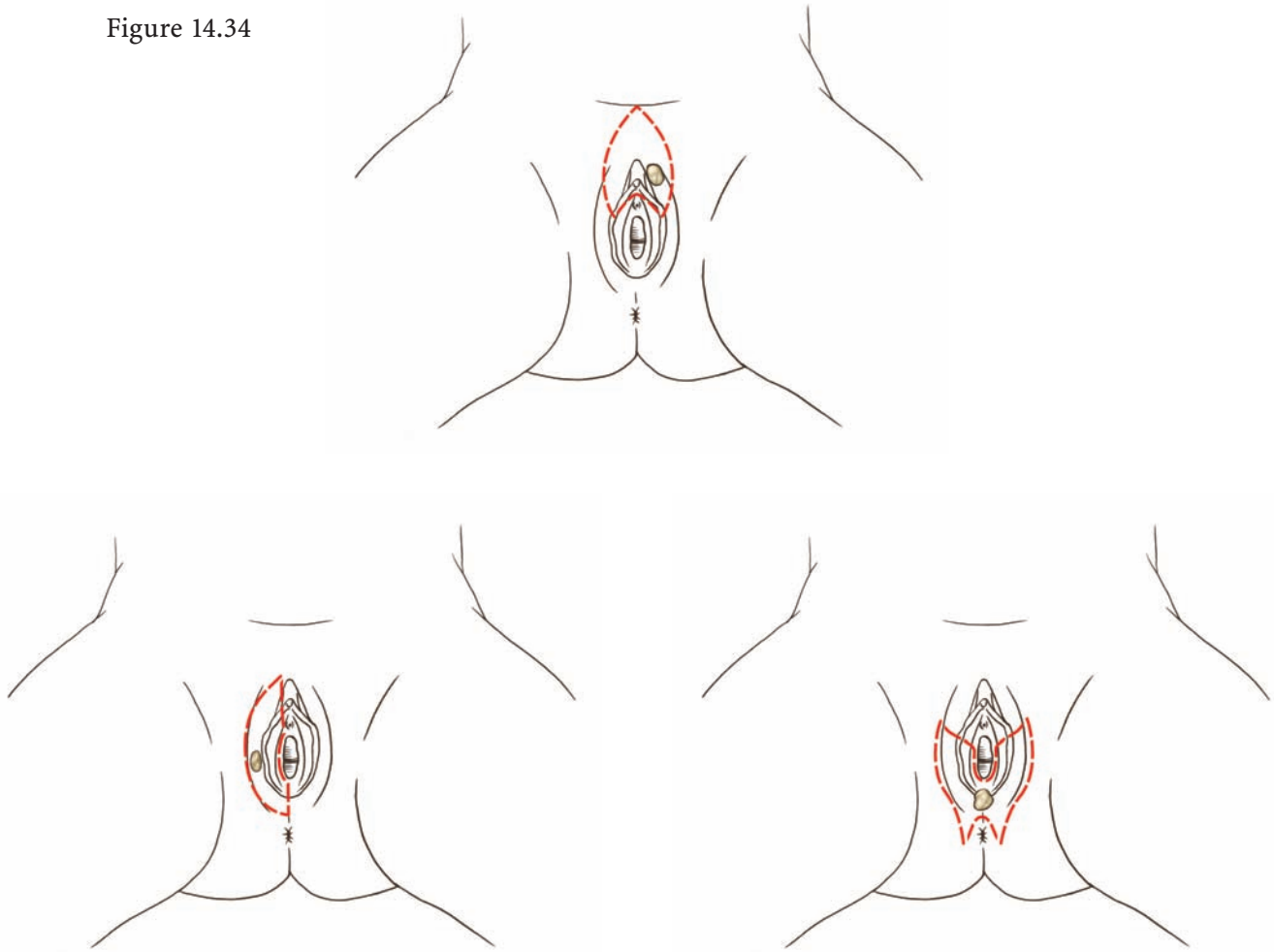


Figure 14.33

Figure 14.34



chemotherapy, such as cisplatin, 5-FU, and myomycin-C. With the combination of chemotherapy and radiation, the lesion can be shrunk to a size that permits conservative therapy rather than total pelvic exenteration. Adjuvant pelvic radiation therapy is used when two or more ipsilateral inguinal lymph nodes are positive for cancer. Additional indications may be tumors with margins less than 5 mm and women who are not medically able to undergo inguinal lymph node dissection. Lymph node metastasis is the most important prognostic feature in vulvar cancer, followed by tumor ploidy and size.

Anatomic Basis of Complications

- Major**
- Major suture placement through bladder and vagina results in vesicovaginal fistula.
 - Extensive devascularization and dissection of the ureter results in ureterovaginal fistula.

- Ureteral ligation can occur if the vessels and the ureter are not identified during hysterectomy or lymph node dissection.
- Extensive inguinal femoral lymph node dissection can result in lymphadenectomy of the leg.
- Bladder atony results from denervation during radical hysterectomy.
- Obturator injury during pelvic lymphadenectomy can result in difficulty adducting thighs, even after repair.
- Injury to the genitofemoral nerve results in anesthesia to the medial thigh and lateral labia.
- Injury to the femoral cutaneous nerve results in anesthesia over the anterior thigh.

Minor

Key References

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This chapter provides an extensive review of the proper instrumentation required for the ease and safe conduct of any laparoscopic procedure. The laparoscopic surgeon should be familiar with a number of instruments for performing laparoscopic surgery.

DeLancey JOL. Surgical anatomy of the female pelvis. In: Rock JA, Jones HW III, editors. *TeLinde's operative gynecology*. 10th ed. Philadelphia, PA: Lippincott-Raven; 2008. p. 63–94

This chapter provides an extensive review of pelvic anatomy. In addition to comprehensive coverage of the pelvic viscera, vessels, nerves, and lymphatic vessels, Dr. DeLancey introduces the surgeon to the musculature of the pelvis.

Griffiths CT, Silverstone A, Tobias J, et al (editors). *Gynecologic oncology*. London: Mosby-Wolfe; 1977

This book reviews the treatment of gynecologic malignancies. In addition, the etiology, epidemiology, pathologic presentation, and staging are discussed.

Hoffman MS, Cavanagh D. Malignancies of the vulva. In: Rock JA, Jones HW III, editors. *TeLinde's operative gynecology*. 10th edn. Philadelphia, PA: Lippincott-Raven; 2008. p. 1331–84

This chapter is a thorough analysis of the surgical treatment of vulvar malignancies and the data supporting it. This is a classic text in gynecologic surgery.

Nezhat F, Mahdavi A, Pejovic T. Laparoscopic procedures. In: Bieber EJ, Sanfilippo SJ, Horowitz IR, editors. *Clinical gynecology*. 1st ed. Philadelphia, PA: Churchill Livingstone, Elsevier; 2006. p. 549–68

Diagnostic laparoscopy is the most commonly performed laparoscopic gynecologic procedure. This chapter reviews procedures indicated for infertility, pelvic pain, pelvic inflammatory disease and suspected pelvic mass or ectopic pregnancy.

Thompson JD, Warshaw JS. Hysterectomy. In: Rock JA, Jones HW III, editors. *TeLinde's operative gynecology*. 10th ed. Philadelphia, PA: Lippincott-Raven; 2008. p. 771–854

Most gynecologic surgeons read about the simple hysterectomy for the first time in this text. This chapter keeps the tradition alive with its discussion and illustrations of abdominal and vaginal hysterectomies.

Wheless CR Jr. *Atlas of pelvic surgery*. 2nd ed. Philadelphia: Lea and Febiger; 1988

This surgical atlas is a must for the surgeon interested in pelvic surgery. Each procedure is illustrated in stepwise fashion.

Suggested Readings

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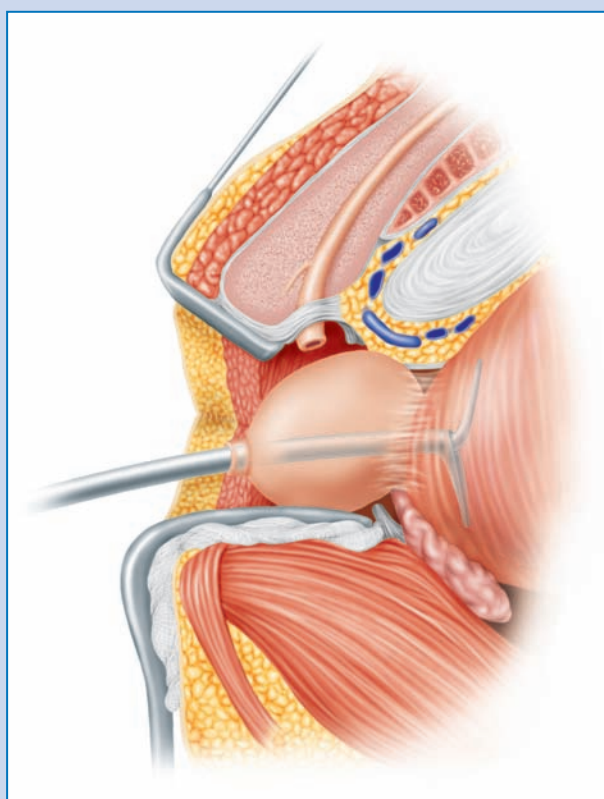
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Male Genital System

John G. Pattaras,
Fray F. Marshall,
Peter T. Nieh



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Introduction

Cancer surgery of the male genital system has changed dramatically over the last decade. With increasing comfort and advancements in laparoscopy, urologic oncology has seen that a majority of intra-abdominal and retroperitoneal surgeries are performed skillfully in a minimally invasive fashion. Robotics has recently filtered into the urologic world by offering the advantages of three-dimensional and high-definition endoscopic acuity, dissection and reconstruction. Excluding skin cancer, prostate cancer continues to be the most common malignancy amongst men and the second leading cause of cancer related death in men, in the United States. Testis cancer incidence is slowly rising, may be contributed to by environmental causes such as pesticide exposure. Penile cancer has been, and remains a very rare entity in the United States.

Prostate Gland

The prostate has been described as a walnut sized gland with, the base fused to the bladder, the apex to the pubic bone, and the urethra running through it. The complexities of prostate cancer surgery have never been truly appreciated by non-urologists. It is a genital gland that surrounds a vital urinary structure, the urethra, and is itself surrounded by vital structures such as the rectum and erectile nerves. Removing the cancerous gland in its entirety, then reconstructing the vesico-urethral anastomosis with respect to urinary continence and the preservation of erectile function has always been the key. It is estimated that almost 192,280 men will be newly diagnosed with prostate cancer in 2009 with about 27,360 deaths. The estimated chance of being diagnosed with prostate cancer is 1 in 6 during the male's lifetime, with only 1 in 35 succumbing to the disease. Treatment options for locally confined disease still focus on surgery and radiation, with ablative options such as cryotherapy showing promise.

Anatomy The anatomy of the prostate gland is surgically challenging because of its location deep in the pelvis and in close proximity to critically important structures. The prostate is located posterior to the pubic bone and inferior to the bladder where it rests upon the rectum and a sling of pelvic musculature, collectively known as the pelvic floor.

Structures such as, the rectum, external urethral sphincter, neurovascular bundles, bladder neck, and dorsal venous complex, make extirpation of the prostate gland challenging. Histologically, the prostate is composed of an outer fibro-muscular layer surrounding the outermost peripheral zone. The inner zones known as the peripheral, transitional, and central, are composed of stromal and glandular tissues. The prostate is divided into well-defined zonal anatomy which is clearly seen during

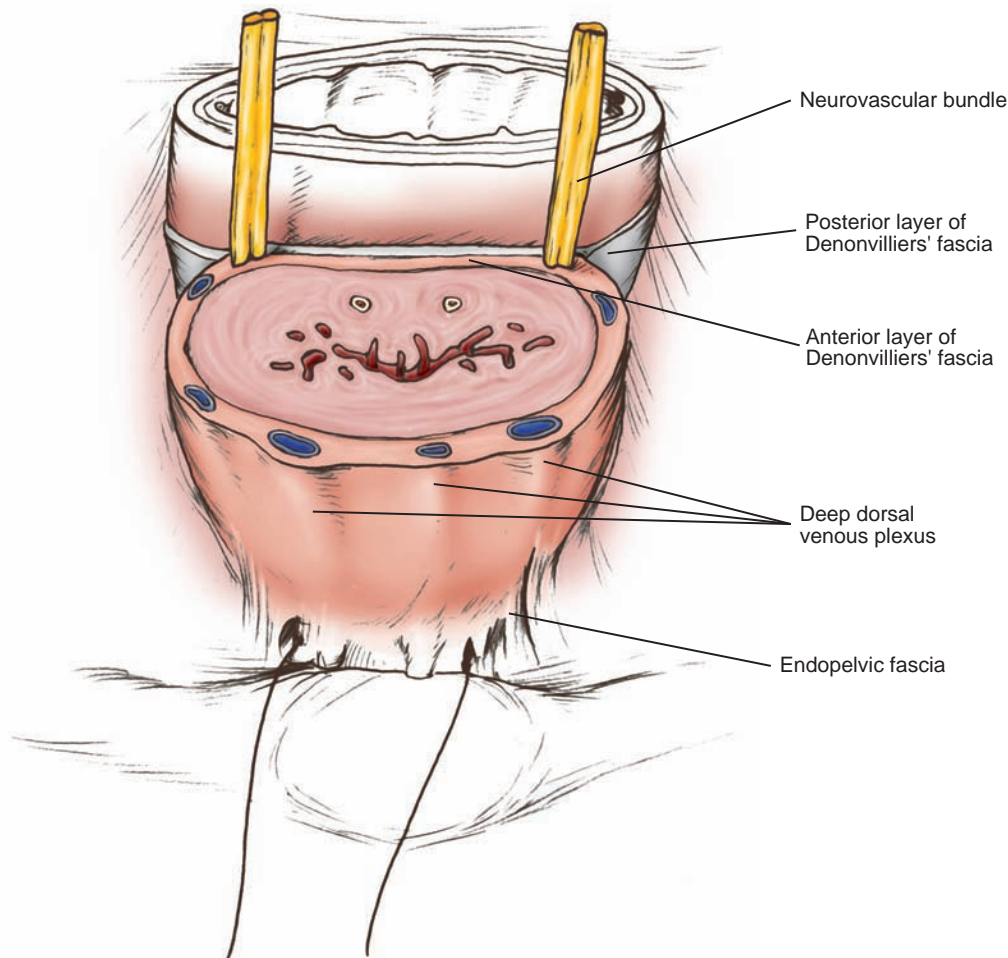


Figure 15.1

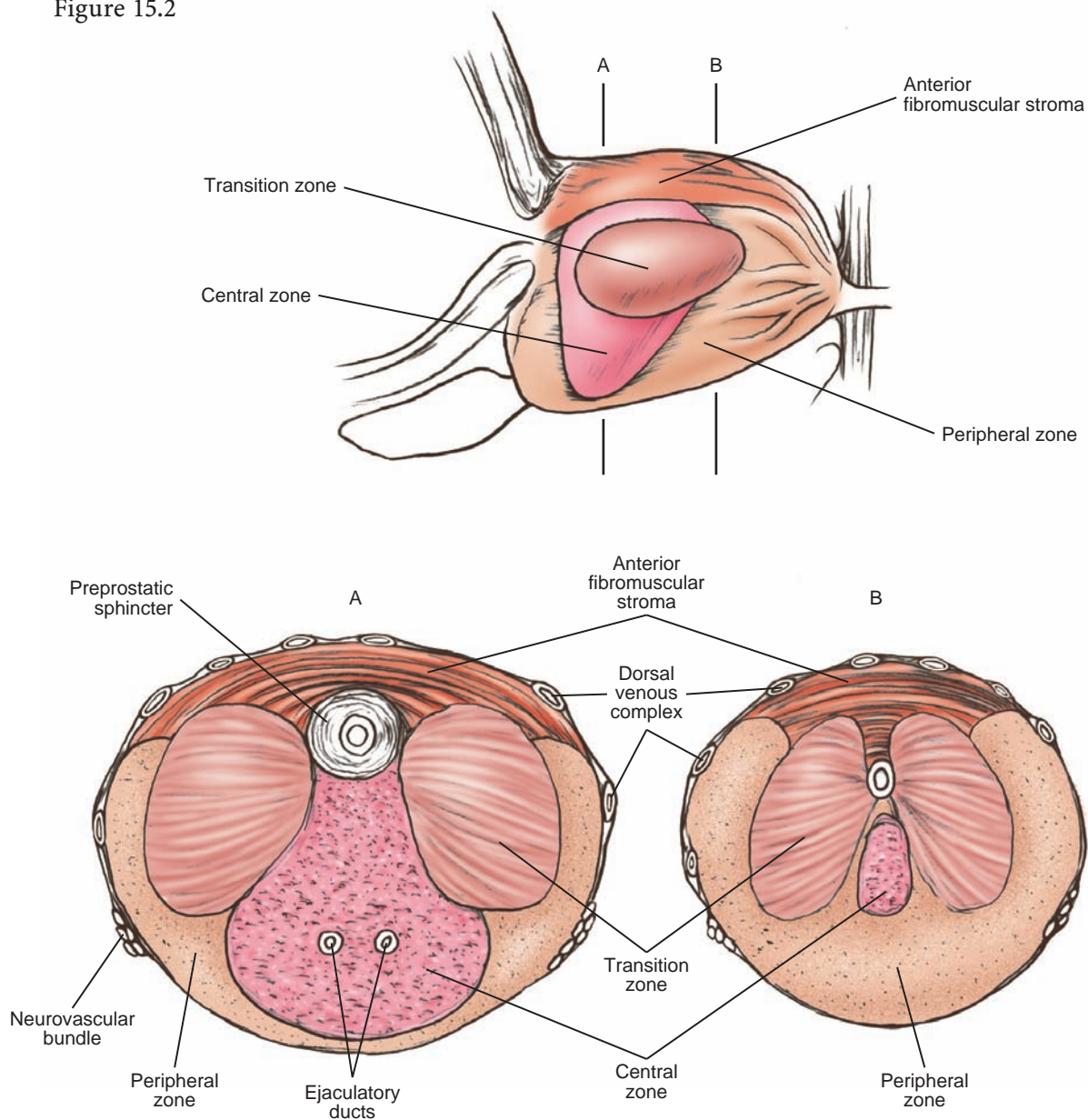
ultrasonography. The zones correspond to histologic anatomy, and are important for the pathogenesis of prostatic diseases. The peripheral zone contains the true prostatic glands, wherein greater than 90% of prostate cancers arise. The transition zone correlates to the periurethral glands, where the benign prostate hyperplasia (BPH) and urinary obstruction develops, while the central zone is the tissue surrounding the ejaculatory ducts making up most of the base.

The vascular supply to the prostate is derived from the anterior division of the internal iliac artery which forms the inferior vesical artery and subsequently branches to the prostate. The primary vasculature enters the base of the prostate near the bladder neck and then extends with variability, towards the apex of the gland. The neurovascular bundle which supplies the innervation to the cavernosal erectile bodies, runs along the posterior-lateral border of the prostate, starting at the base and working anteriorly to lie more lateral towards the apex.

The bundle runs between the anterior and the posterior layers of Denonvilliers' fascia.

The lymphatic drainage from the prostate, starts within the prostate and culminates into the lymphatics, exiting the prostate via the apex and the base of the gland. The lymphatic channels empty into the region of the obturator nodes lying alongside the obturator artery and nerve, located between the internal and external

Figure 15.2



iliac vessels. Lymphatic drainage continues along the common iliac vessels towards the retroperitoneum.

Surgical Applications

Transrectal Ultrasound Guided Needle Biopsy

Prostate cancer screening remains a controversial topic. With the advent of serum prostate specific antigen (PSA) testing, the incidence of prostate biopsies has increased, with a corresponding increase in the detection of asymptomatic and impalpable T1c carcinoma. Transrectal ultrasound guided needle biopsy (TRUS) remains the mainstay

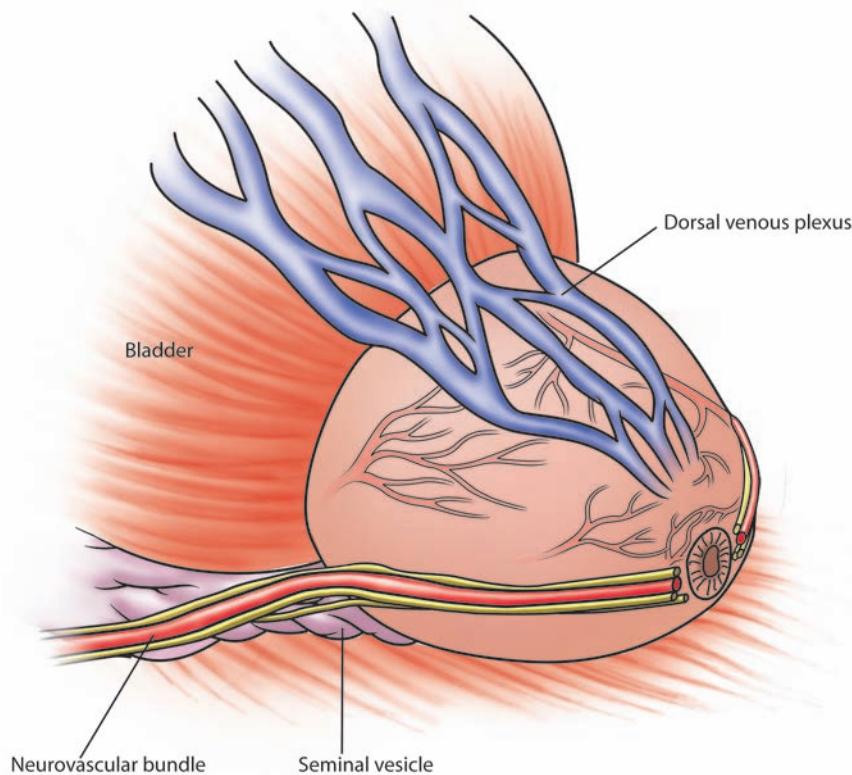


Figure 15.3

means of prostate cancer detection. For patients with either an abnormal digital rectal exam or an elevated PSA, transrectal ultrasonography is performed for several reasons. Biplanar ultrasonography can give relatively accurate measurements of the prostate gland, whereas digital rectal examination may grossly underestimate the gland size. Ultrasonography may also detect impalpable hypoechoic lesions which necessitate biopsy. Preparation for TRUS is simple. All patients should be off any anticoagulants and refrain from aspirin or NSAID's for a period of 10–14 days. A quinolone antibiotic as well as enema is taken 1–2 h prior to biopsy. The procedure is routinely performed under local anesthesia. In the last few years, it has become more common to administer a combination of intrarectal and periprostatic anesthesia to the patient. The intrarectal block is usually in the form of injected 2% lidocaine jelly solution. The periprostatic block is administered under ultrasound guidance by using a long spinal needle to infiltrate the junction of the prostate base and seminal vesicles, usually with 5 mL of 1% lidocaine on each side. This reduces the discomfort of the rectal probe and the biopsy needle to a negligible extent during the procedure. While in the past, sextant specimens were the standard for TRUS prostate biopsies without anesthesia, at present, 12–20 specimens are routinely obtained with much less discomfort.

Under ultrasound evaluation, the prostate is visualized in transverse and sagittal planes. It is in these planes that the zonal anatomy of the prostate is seen. The zones

include the peripheral, transition and central zones. These correspond to the peripheral prostatic glands and stroma, the periurethral glands and centrally, the tissue surround the ejaculatory ducts. Biopsies are performed using 17–18-gauge core sampling needles. The areas for biopsy are clearly visualized on ultrasonography and include mainly the peripheral zone, and any abnormal findings which is suggestive of malignancy. The base (nearest to the bladder), mid and apex of the prostate are sampled on both sides. Some urologists routinely obtain transition zone biopsies especially when the patient's elevated PSA does not correlate with gland size and ultrasound findings. The specimens are sent off in separate containers matching the biopsy site in order to properly map any positive findings. Although these small sample sizes may not correlate with the degree of prostate cancer found on surgical removal, mapping may be useful for the guidance of ablative procedures such as the placement of the radiation seeds or cryoablative therapy. Currently, there is an increased interest in focused prostate cancer therapy because traditional radiologic imaging is rarely helpful in pinpointing the affected area, and gland sparing techniques may have less morbidity and a better quality of life.

Pelvic Lymph Node Dissection

In the pre-PSA era, the pelvic lymph node dissection (PLND) was required to detect extraprostatic disease that occurred in 30% of patients undergoing radical prostatectomy. However, today, newly diagnosed prostate cancers are far more likely to be organ confined, and PLND is limited to patients who are at a risk for node involvement, such as PSA >10, Gleason score ≥ 8 , and suspected seminal vesicle invasion (T3).

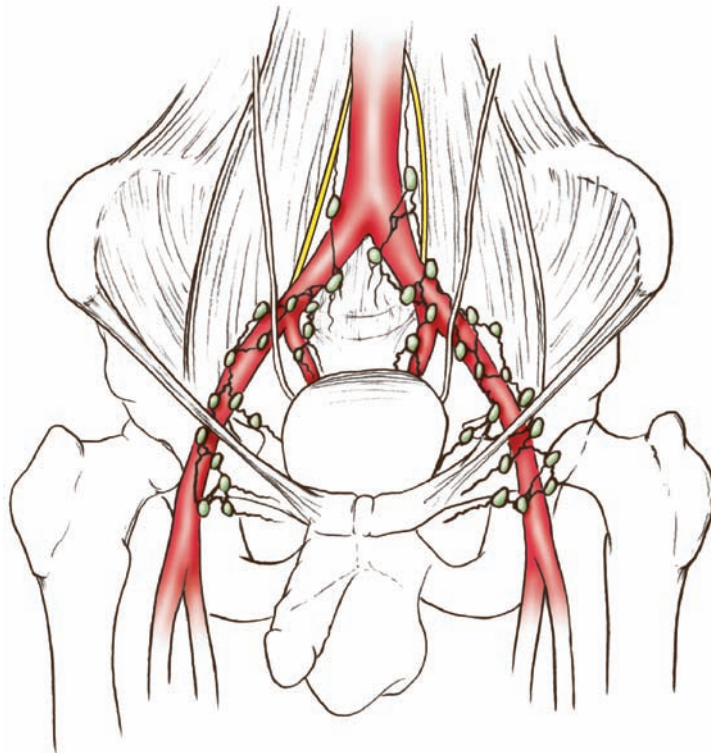


Figure 15.4

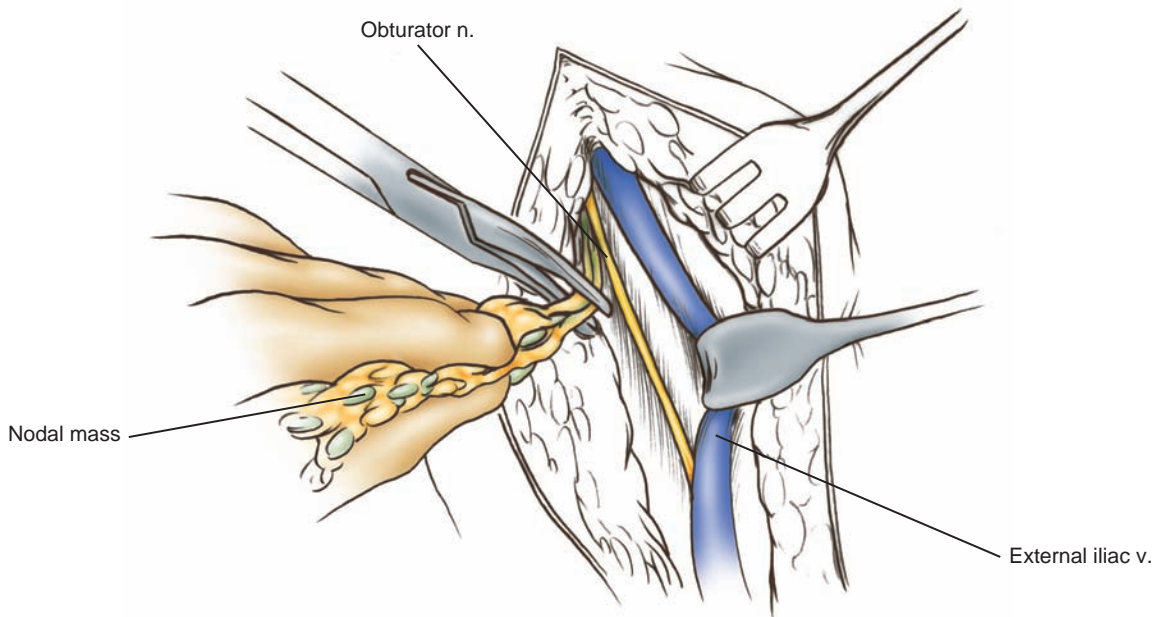


Figure 15.5

The pelvic nodes dissection may be performed either by open or laparoscopic technique, or either by intraperitoneal or extraperitoneal approach. The typical PLND for prostate cancer is usually limited to the nodes within the obturator fossa. While this is still considered as the primary landing site for metastatic disease, skip metastases may occur, even to the presacral nodes. The extent of node dissection is often modified to minimize lower extremity edema by limiting the lateral margin to the medial aspect of the external iliac artery. The other margins are: distally – Cooper’s ligament, proximally – the common iliac bifurcation, and posteromedially – the internal iliac artery.

The dissection starts along the external iliac artery, opening the adventitia from the common iliac bifurcation to the crossing circumflex iliac vein from the external iliac vein. The adventitia over the external iliac vein is also incised. The adipose/nodal tissue is teased away from each vessel and the body wall with gentle blunt dissection. Lymphatics and venous branches should be clipped. With a vein retractor elevating the iliac vein, the obturator nerve is isolated and preserved. The nerve is readily palpable, coursing like a bow string along the deep pelvic sidewall, and a gentle plucking of the nerve elicits the “obturator kick.” The node packet is clipped or ligated at the distal margin at Cooper’s ligament and along the obturator internus, and at the proximal margin at the common iliac bifurcation.

Not much has changed with the radical retropubic prostatectomy (RP) procedure over the last decade. It is the standard of surgical care for patients necessitating pelvic node dissection and has distinct advantages for nerve-sparing erectile preservation. The open procedure is performed with the patient in a supine position and mildly flexed on the surgical table. Some surgeons still prefer a dorsal lithotomy position to allow perineal access. A midline infra-umbilical incision is made down to the

Radical Retropubic Prostatectomy

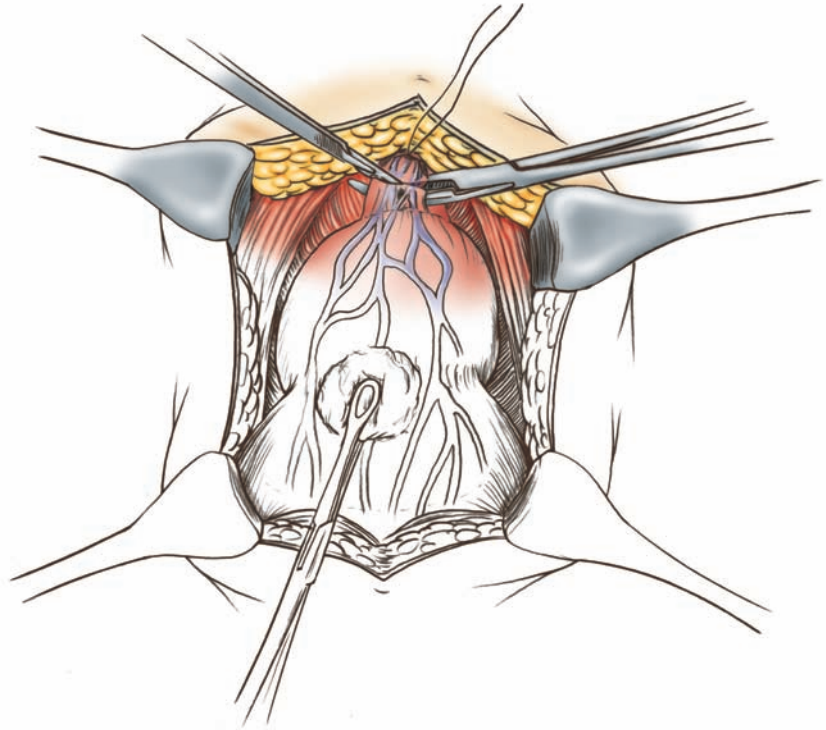


Figure 15.6

extraperitoneal space. In attempts to limit morbidity, urologists adept to RP, commonly utilize only a mini-laparotomy incision which is 7–8 cm long. A Foley catheter is placed sterilely on the field to decompress and identify the bladder. Extraperitoneal space which allows access to the anterior and lateral surfaces of the prostate, is created. Lymph node dissection, if necessary is usually performed at this step, prior to prostatectomy.

Dissection and visualization of the endopelvic fascia and pubo-prostatic ligament are enabled by defatting the prostate surfaces. Sharp or cautery dissection of the endopelvic fascia is performed to obtain access to the prostatic apex and dorsal venous plexus (DVP) of the penis. Although there are differences in the techniques to ligate the dorsal vein, it usually involves sharp dissection of the pubo-prostatic ligaments and right angle ligation of the DVP with absorbable suture. The DVP is divided to expose the prostate apex. The anterior surface of the urethra is now dissected.

If a nerve sparing approach is considered, only the urethra is dissected and the periurethral tissue is spared. At this point, the erectile nerves run along the 3 and 9 o'clock surface of the urethra. The periprostatic tissue is then sharply divided in a retrograde fashion high on the antero-lateral surface of the prostate apex. The dissection is performed to the base or the prostate-vesical junction. The erectile neurovascular bundles drop to the 5 and 7 o'clock position at the base of the prostate.

With the urethra dissected circumferentially, the prostate is swept retrograde allowing a greater length of visible urethra. A large right angle clamp is commonly placed beneath the urethra and the anterior surface is sharply cut exposing the catheter. The catheter is delivered through the incision, clamped and cut distally keeping

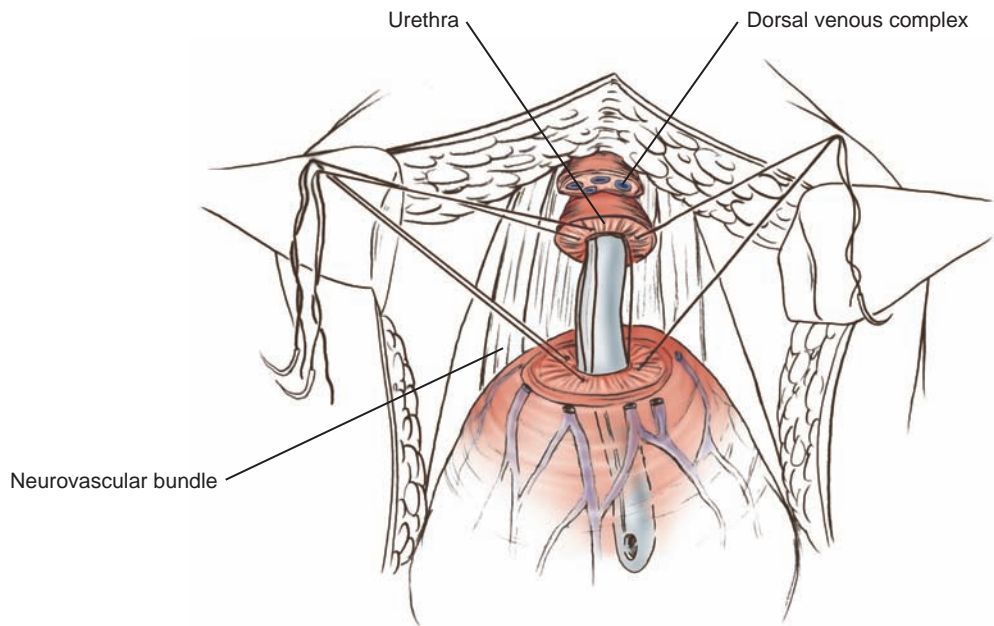


Figure 15.7

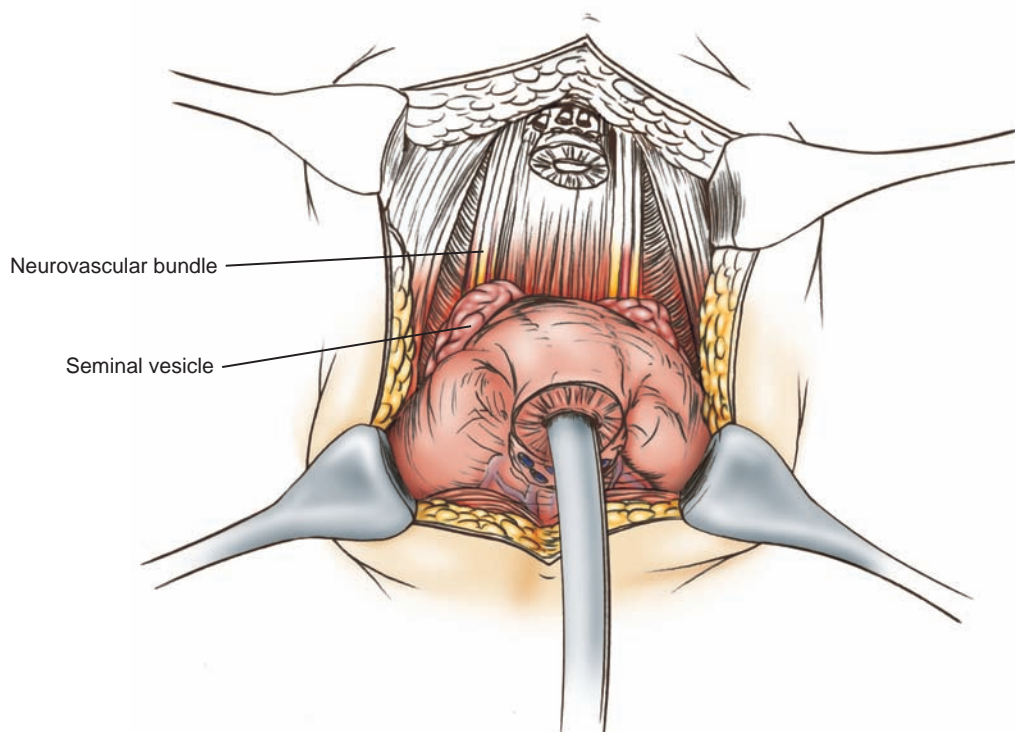


Figure 15.8

the balloon inflated. Some surgeons place urethral sutures at this juncture prior to completely releasing the urethra. The posterior urethra is then sharply divided thereby allowing access to the recto-urethralis tissue. This is sharply divided and allows finger access to the plain between the prostate and perirectal fat. The sulcus of the prostate can be bluntly dissected off the rectum till Denonvilliers fascia is

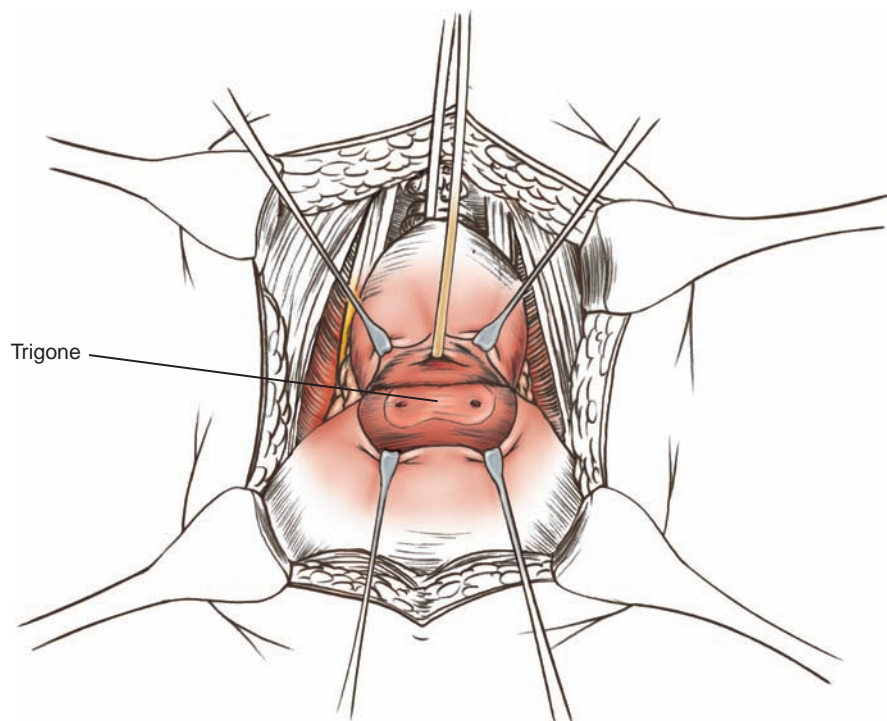
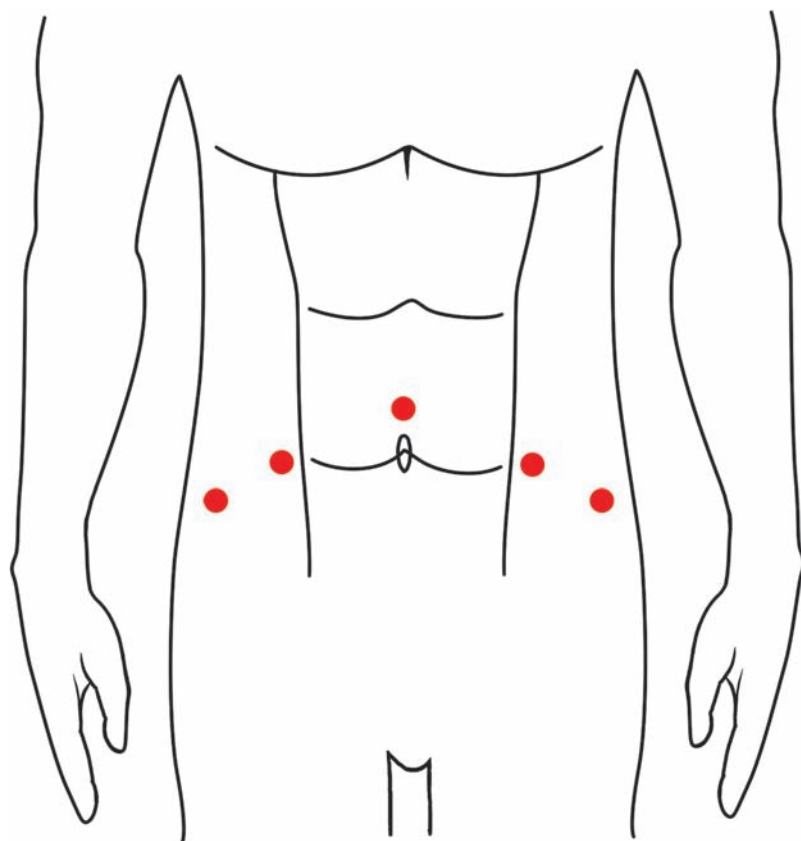


Figure 15.9



Trocar configuration for
robotic prostatectomy

Figure 15.10

reached. Apical attachments of the prostate can be sharply incised or ligated up to the base. The prostate is lifted up and Denonvilliers' fascia is incised. The pedicles of the prostatic base, which are branches of the internal iliac and inferior vesical arteries are then ligated. The seminal vesicles and the ampulla of the vas deferens are reached and divided. Care must be maintained not to injure the neuro-vascular bundles which run along the tips of the seminal vesicles.

The bladder neck is divided and the prostate specimen is removed.

Depending on the size of the remaining bladder neck and the surgeon's preference, the bladder neck can be reapproximated to accommodate a large bore catheter. The urethral orifices are also inspected if possible. The reanastomosis of the vesico-urethral junction is one of the most challenging aspects of the operation. Eversion of the bladder neck urothelium is commonly performed. Five to six absorbable sutures are placed through the urethral stump to the everted bladder neck. A silicone based Foley catheter is passed per urethra and placed in the bladder, after placing the posterior sutures. The anterior sutures complete the anastomosis and only then are all the sutures tied down while gentle traction on the catheter is performed. Inspection and drain placement completes the surgery.

The momentum exuded by robotic surgery over the field of urology was unpredicted. Minimally invasive surgery has always been an influence in the field of urology, starting with the transurethral resection of prostate (TURP) and ever expanding with the laparoscopic nephrectomy. Since the introduction of the daVinci robot (Intuitive Surgical, Sunnyvale, CA, USA), the number of robotic prostatectomies has sky-rocketed. In 2000, only 36 robotic prostatectomies were reported. By 2006 the estimate was over 30,000. In 2009, it is estimated that 80% of radical prostatectomies will be performed robotically in the U.S. The technology allows all the advantages of open RP such as wide excision, nerve dissection and access for pelvic node dissection. Although this technology is still not definitely proven to be superior to its open counterpart, marketing and patient demand has driven its numbers to almost double yearly since 2000. Recent data suggests that continence and erectile preservation are equal if not better than open RP. Though pure laparoscopic prostatectomy has been successfully and safely performed in thousands of patients, it was only after the introduction of the daVinci, that the novice to experienced laparoscopist, could have minimally invasive access to the prostate. The daVinci's three-dimensional (and now high definition) vision and degrees of dexterity allow for superior oncologic evaluation and more meticulous reconstruction.

The procedure is very similar to its open counterpart except that it is performed in an antegrade fashion. The patient is positioned in a low lithotomy or spilt leg fashion, then fastened to the table with a cocooned bean bag, or padded and taped, to allow placement in a steep Trendelenburg position. Laparoscopic access is performed in a traditional intraperitoneal fashion by the scrubbed surgical assistant. Five to six trocars are placed in a horizontal fashion. The newer daVinci S has four operating arms (1 camera and 3 working units) controlled at a remote console. The surgeon sits at the console and operates the robotic arms by finger control, a touch panel and foot

Robotic Prostatectomy

controls. Once the trocars are secured, the robot is driven in towards the patient and docked to the trocars.

The first step allows access to the preperitoneal space and this is accomplished by dissecting and dropping the bladder. Once in the retropubic space, the procedure of identifying and cleaning off the endopelvic fascia and puboprostatic ligaments, are similar to its open counterpart. The endopelvic fascia is opened, the puboprostatics are incised, and the DVP is sutured and ligated.

The robotic technique employs an antegrade approach by incising the junction between the prostatic base through the entire bladder neck. The urethral catheter is deflated but left in the prostatic urethra for upward and lateral manipulation of the prostate. The seminal vesicles and the ampulla of the vas deferens are dissected and ligated achieving a plane under the prostatic base. Denonvillier's fascia is incised which lifts the prostate off the rectal wall. The nerve sparing approach is achieved by creating a veil between the neuro-vascular bundle and the prostate capsule. The combination of 3-dimensional acuity and the fine motions of the robotic arms is felt to provide a level of dissection that atraumatically preserves the neurovascular bundle. After the bilateral bundles are freed, the base pedicles are ligated and the posteriolateral attachments are sharply incised.

The prostate is retracted superiorly, creating tension on the urethra which is then carefully incised. The catheter is then pulled back and the prostate specimen is removed from its place and set aside to be bagged and removed at the end of the procedure. The urethral vesical anastomosis is completed with robotic intracorporeal suturing. Most robotic urologists use two sutures tied to one another, and start a running anastomosis at the six o'clock position and work upwards from each side over a new urethral catheter. The robotic anastomosis is more easily performed and water tight, than either pure laparoscopic or open techniques. This has led some surgeons to remove the urethral catheters, days earlier than in the past.

Perineal Prostatectomy

Despite the popularity of the open, and now the robot-assisted RP, the perineal prostatectomy has been a time-tested yet underutilized, procedure. This approach is particularly useful in patients with morbid obesity, prior laparoscopic hernia surgery, (where the mesh creates a densely fibrotic barrier to the retropubic space), failed retropubic procedure, and following multiple abdominal procedures that limit retropubic access, such as femoral-femoral bypass vascular grafts, or pelvic phlegmon from inflammatory bowel disease. The main contraindications would be a large prostate volume (over 50–60 mls) and spinal problems that would be aggravated by lithotomy positioning. Patients have minimal discomfort from this incision, and length of stay is usually less than 24 h.

The patient is placed in the exaggerated lithotomy position, carefully supporting the sacral area with folded gelpad, and using padded leg supports to get the perineum, almost horizontal. A curved Lowsley retractor is placed to immobilize the prostate.

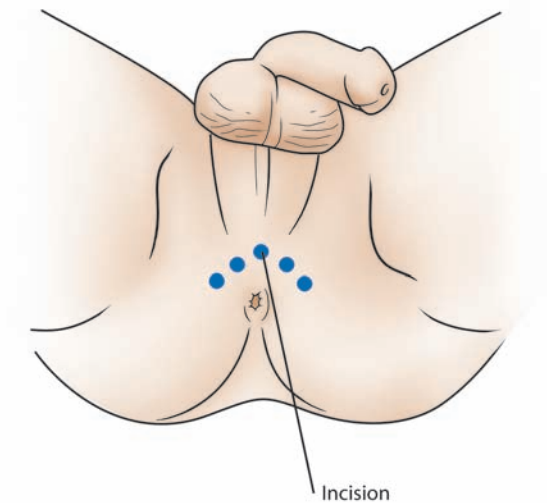


Figure 15.11

An O'Connor rectal drape is helpful to allow digital inspection during critical parts of the rectal wall dissection. An inverted U incision is performed medial to the ischial tuberosities. The ischiorectal fossa is entered and the central tendon is separated from the anterior rectal wall and divided.

Dissection on the shiny anterior wall of rectum is carried up to, and through the rectourethralis musculature, aiming for the prostatic apex/urethra. The white layer of posterior Denonvillier's fascia is exposed, dropping the rectum posteriorly, and displaying the posterior prostate. A nerve-sparing procedure may be performed by dissecting the neurovascular bundles laterally.

At the base of the prostate, the fascia is opened near the midline, and the vasa deferentia and the seminal vesicles are dissected free, being sure to clip the artery to the seminal vesicle.

The vascular pedicles lateral to the seminal vesicles are ligated and divided. Next, the urethra at the prostatic apex is isolated using a right angle clamp beneath the dorsal vein complex, and the urethra is transected. A straight Young retractor replaces the Lowsley retractor through the prostate to provide posterior traction, to clean off anterior attachments between the prostate and the bladder neck.

Either a bladder neck peel procedure or guillotine opening of the bladder neck may be performed. The bladder neck is matured with 4-0 monocril sutures, and the

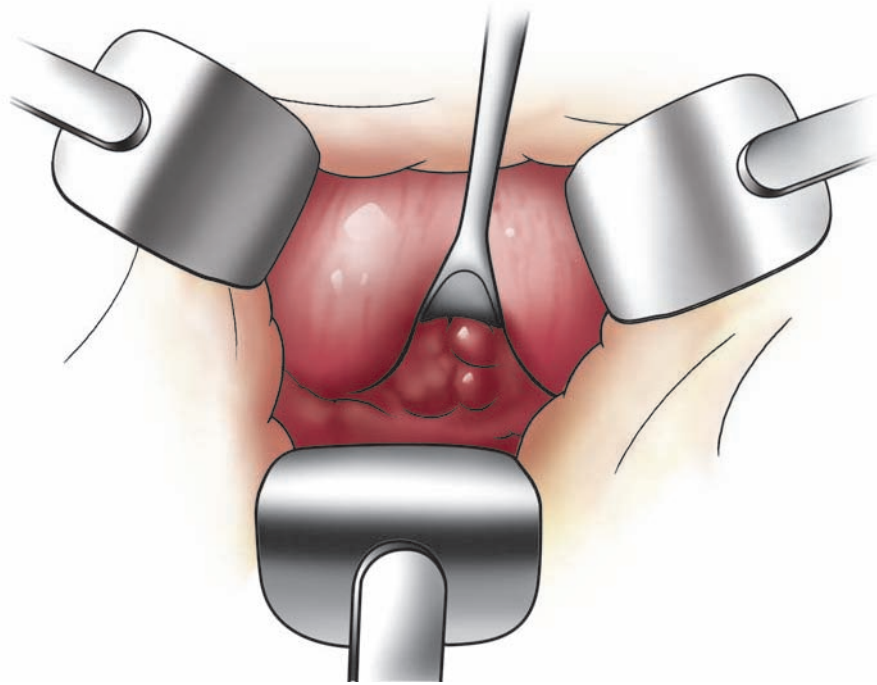


Figure 15.12

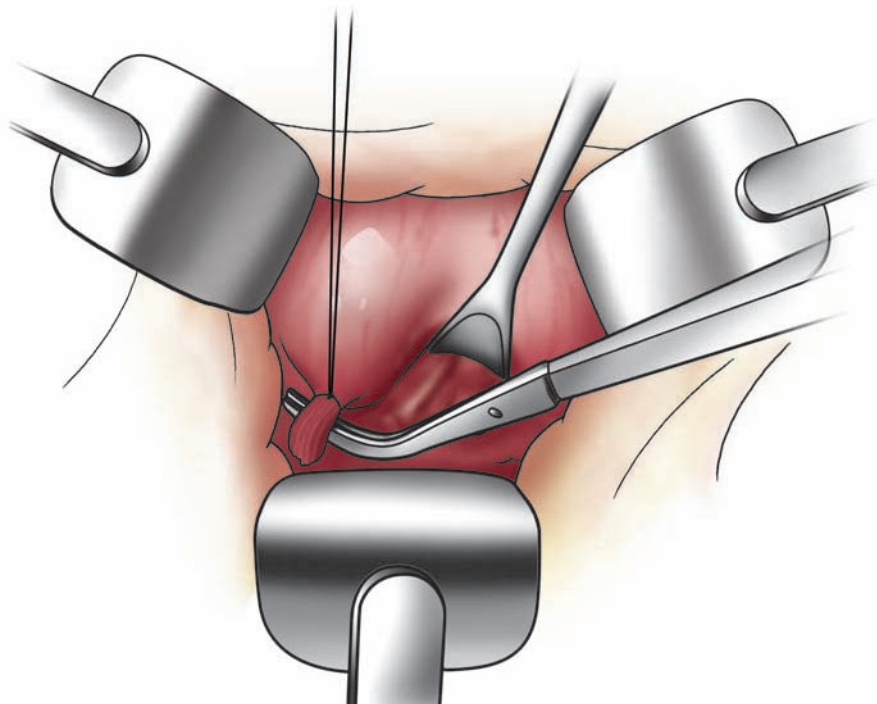


Figure 15.13

opening should be tailored with 2-0 vicryl in a tennis-racquet type closure, if necessary.

A grooved urethral sound or foley catheter is passed for the placement of 2-0 monocryl sutures, starting with the 10 and 2 o'clock positions. Once these two sutures are placed through the corresponding positions at the bladder neck and tied, an

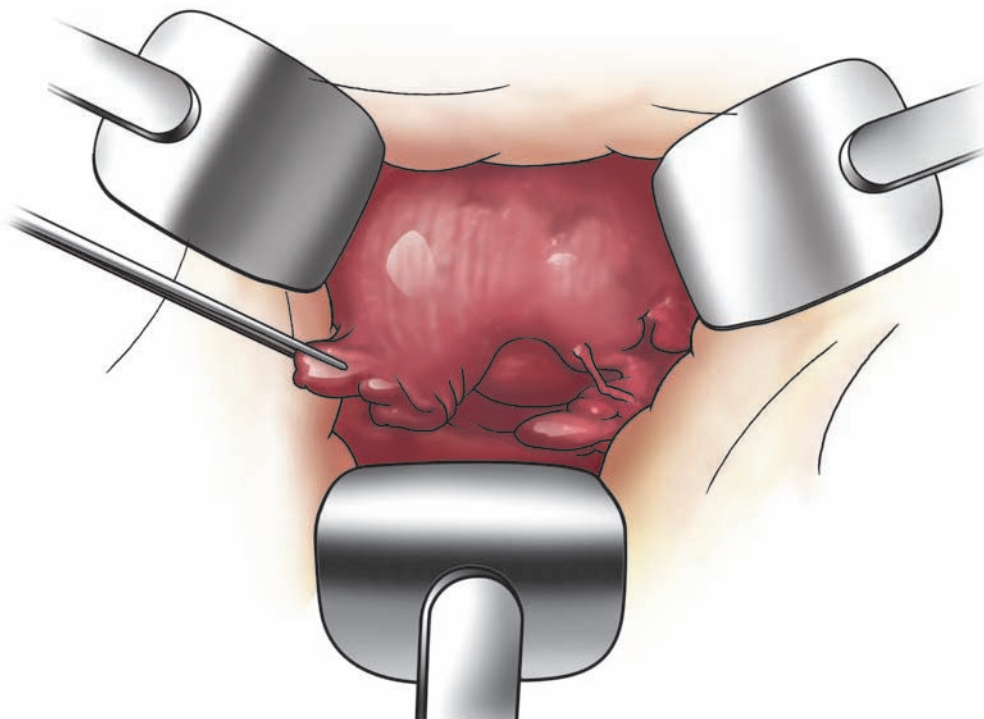


Figure 15.14

18–20 Fr foley catheter is placed. The remaining 2–0 monocryl sutures are placed at 3, 5, 7 and 9 o'clock positions to complete the vesicourethral anastomosis. A Penrose drain is not necessary, unless there is concern for urinary leak. The central tendon is reapproximated with 2–0 Vicryl, and the incision is closed with a subcuticular 4–0 monocryl. The catheter is removed about 10 days following surgery.

Testis

Testicular carcinoma is one of the rarest yet most curable malignancies faced by the urologists. For just over eight thousand new cases expected in 2008, only 380 deaths are anticipated in the United States. It remains the most common solid malignancy in men between the ages of 18–40 years. Testicular cancer is one of the few urologic malignancies in which, surgery, chemotherapy, and radiation, are all potentially curable therapies depending on the specific pathologic subtype and staging.

The testes are the paired male reproductive organs which lie within the scrotum. Embryologically, the testis begins its differentiation as a retroperitoneal organ which descends through the abdominal wall to lie within the scrotum, separated by a central septum. As the testis passes through the abdominal wall and the inguinal canal, it

Anatomy

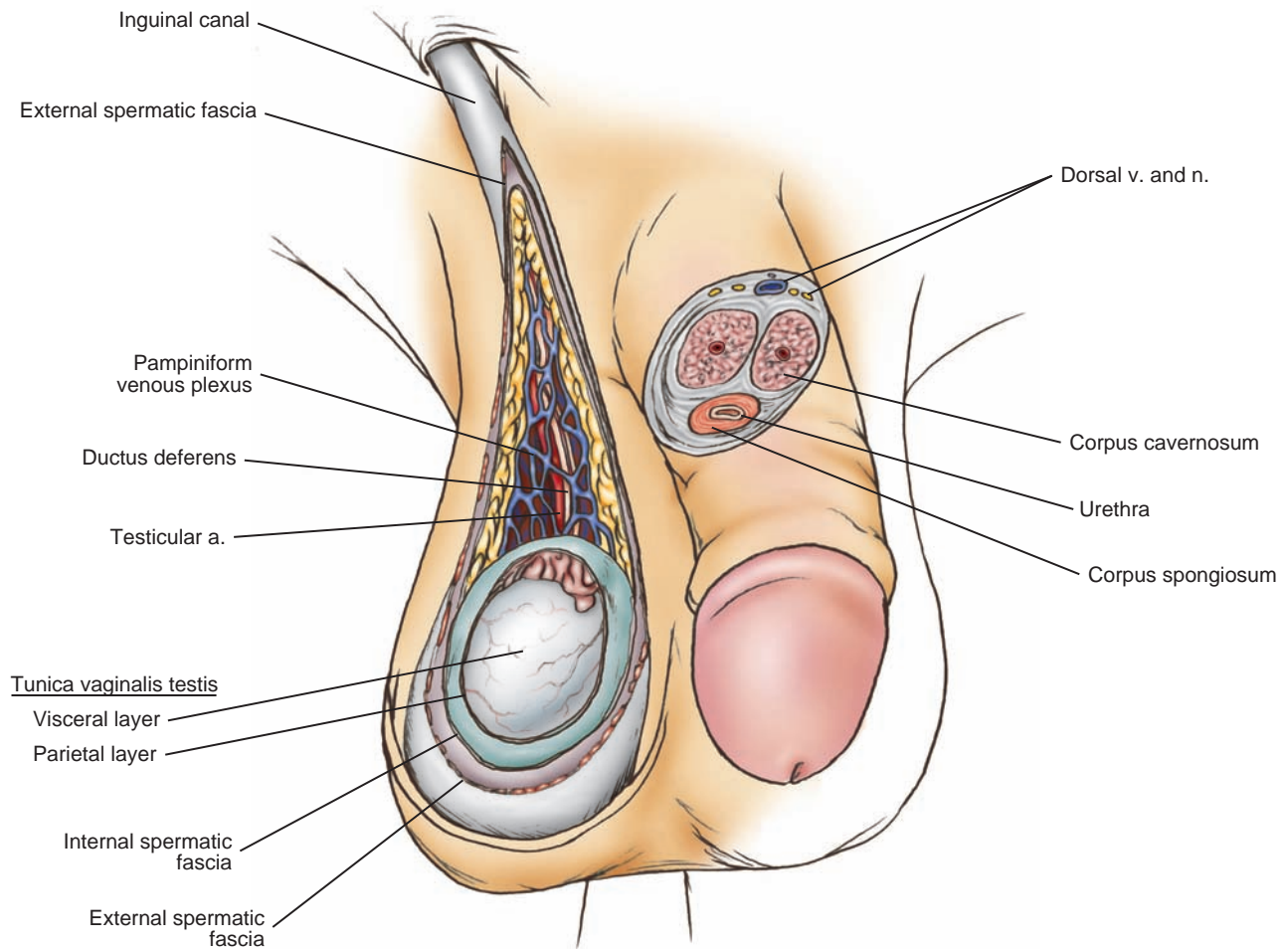


Figure 15.15

acquires the various layers forming the scrotum. The layers are known as the internal spermatic fascia, cremasteric muscle and external spermatic fascia.

The vascular supply to the testes is derived from its embryological origin near the great vessels. The internal spermatic arteries originate from the aorta just below the renal arteries. As they proceed within the retroperitoneum into the pelvis, they freely anastomose with the vasal and the cremasteric arteries before exiting the external inguinal canal and entering into the testis. The venous return differs in that, the right spermatic vein directly enters the vena cava just below the renal vein and the left spermatic vein drains into the left renal vein which then drains into the vena cava. This indirect pathway is the presumptive cause of left sided varicoceles.

The testis lymphatic drainage parallels the vascular supply into the retroperitoneum via the spermatic cord.

The lymph node landing pattern follows a right to left pattern. From observations made by Donahue et al., the retroperitoneal drainage of each testis has been extensively mapped. The right testis drains predominately into the interaortocaval nodes, with significant drainage to the paracaval nodes below the renal hilum. There is a small but significant number of early metastases to the left para-aortic nodes. The left testis drains predominately into the para-aortic nodes (including the nodal

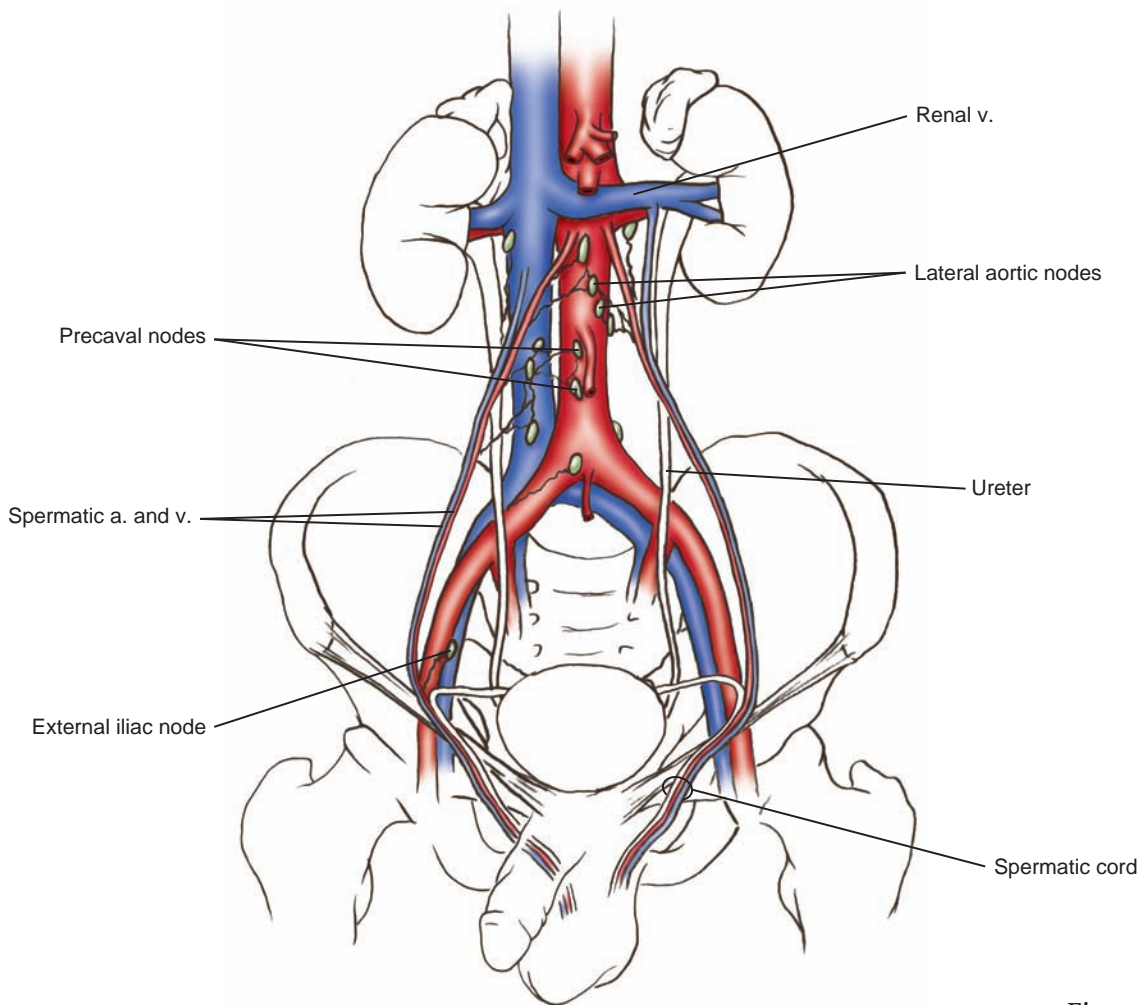


Figure 15.16

tissue above the renal hilum) and there is some significant drainage into the inter-aortocaval nodes. In the left side, unlike the right side, there is relatively no drainage or associated early metastases in the para-caval region.

Surgical Applications

A radical orchiectomy should always be performed via an inguinal rather than scrotal approach due to the fact that the lymphatic drainage of the testes is into the retroperitoneum. High ligation of the spermatic cord is necessary to remove all of the possibly affected tissues out of the scrotum and the inguinal region. The surgical approach begins by positioning the patient for inguinal and scrotal access. After an incision which is overlying the external ring of the inguinal canal, proximal and distal dissection of the cord is performed. Once the cord is dissected and mobilized, a penrose drain is passed under the cord. The inguinal canal is opened

Radical Orchiectomy

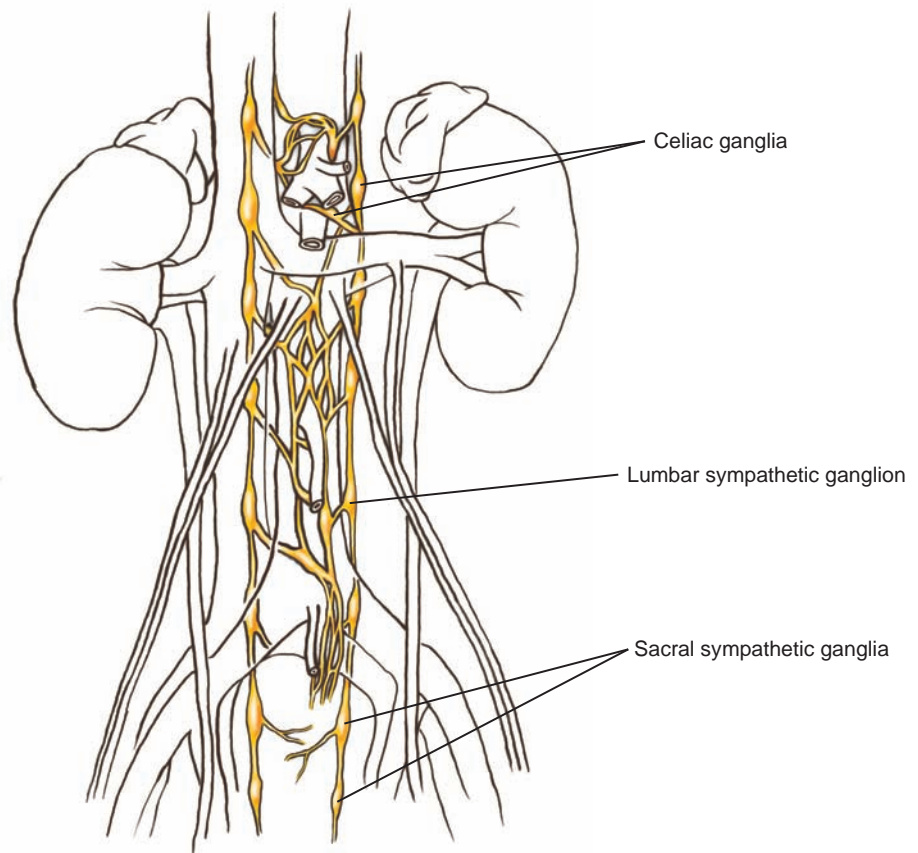


Figure 15.17

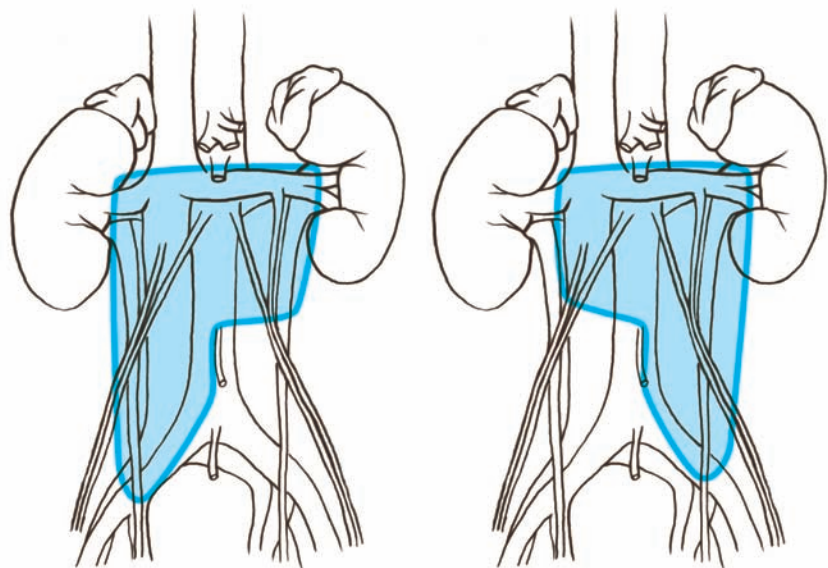


Figure 15.18

and the ilio-inguinal nerve is dissected free from the remaining cord. The penrose is then double passed, excluding the nerve proximally, and around the cord, tightly limiting vascular and lymphatic outflow. The spermatic cord is bluntly dissected into the scrotum freeing up any attachments. The testis with the tumor is then delivered

through the inguinal incision. At this point, high proximal ligation of the cord is performed and the specimen is removed. The remaining stump of the spermatic cord is then sutured ligated with a long tail of nonabsorbable visible suture such as silk or Prolene (Ethicon, Cincinnati OH, USA). Once ligated, the cord is manually pushed up into the retroperitoneum for possible identification during future retroperitoneal lymph node dissection. The canal and the incision are closed appropriately.

Retroperitoneal lymph node dissection (RPLND) is one of the few surgical procedures where lymph node removal is considered as diagnostic and curative in urologic oncology. Templates have been developed for nonseminomatous germ cell tumors which are at high-risk for recurrence disease. Templates minimize the surgical field and also lessen, the chances of sacral nerve damage and the likelihood of retrograde ejaculation. With extensive knowledge of the testes drainage patterns, modified RPLND templates have been determined to spare the morbidity of bilateral sympathetic nerve damage. Sparing one of the sympathetic chains allows unilateral innervation

Retroperitoneal Lymph Node Dissection

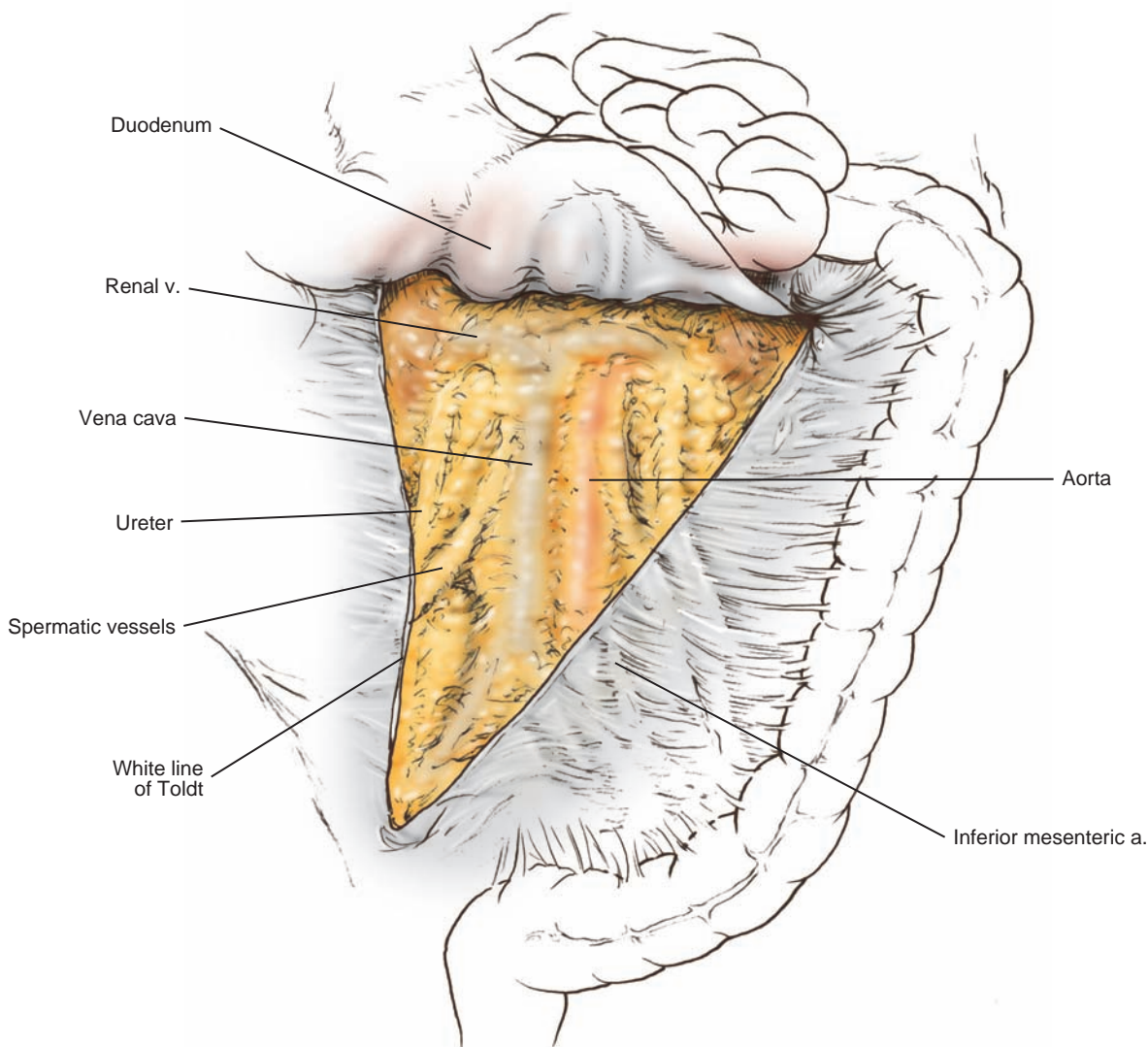


Figure 15.19

for the preservation of competent ejaculatory function. Damage to both the right and the left sympathetic chains may lead to retrograde ejaculation and secondary infertility. In template dissections, the lateral border consists of the ipsilateral ureter, the superior border is the ipsilateral renal vein, and the inferior margin is the end of the ipsilateral spermatic cord and the bifurcation of the common iliac artery on the contralateral side. If there is any radiologic evidence of a bulky nodal disease, a complete RPLND should be performed.

Commonly, an open RPLND is performed via an extended midline incision from xiphoid to symphysis. The entire small bowel and right colon are mobilized after incising the white line of Toldt and freeing the ligament of Treitz. With the bowel contents placed in bowel bags to keep moist and warm, the great vessels are identified.

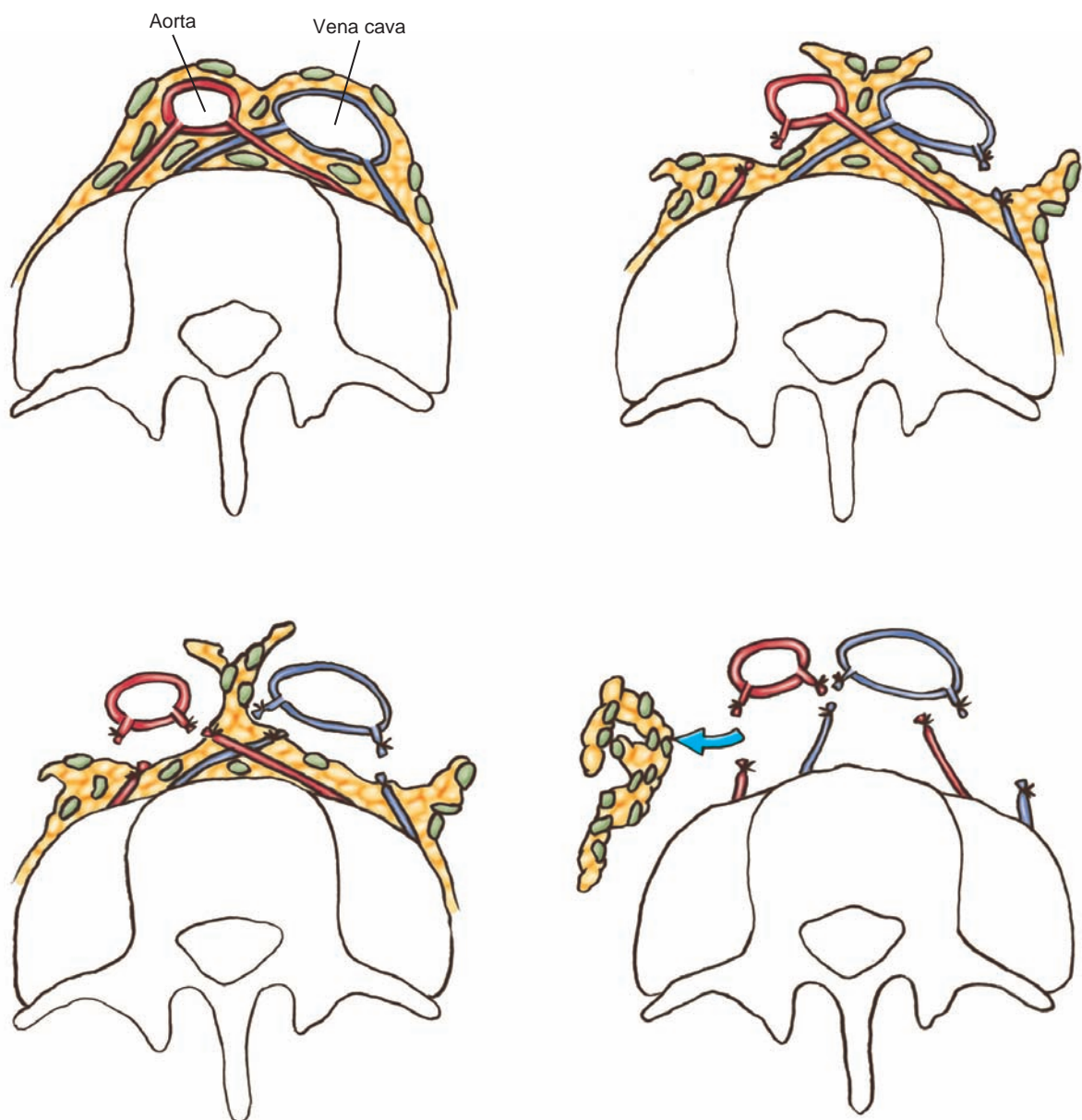


Figure 15.20

The dissection is begun on the anterolateral surface of the great vessel, dividing the fatty-lymphatic tissue and rolling it medially and laterally. This is commonly referred to as a “Split and Roll” technique. The right template includes complete specimens from below the bilateral renal veins superiorly, the right ureter laterally, medial to and not below the inferior mesenteric artery then along the common iliac artery. The entire peri-caval, intra-aortic and superior para-aortic nodes are removed. Tissues which lie below and lateral to the inferior mesenteric artery is spared to preserve the sympathetic chain. The left template starts at the renal veins and contains the left ureter as the lateral border. Tissues above the inferior mesenteric artery is removed bilaterally including pericaval and intra-aortocaval packets. The entire para-aortic nodes including those that are down and along the left common iliac artery is cleaned off.

Complications from RPLND involve vascular, lymphatic and neurologic structures. Bleeding is kept to a minimal level in virgin dissections. If care is taken in the dissection at the bifurcations of the common iliac vessels, a nerve sparing technique will minimize the risk of retrograde ejaculation. Banking semen for future fertility is recommended for all the patients. Postchemotherapy residual masses are significant challenges, and one must be prepared for significant blood loss or removal of an organ which has been invaded (nephrectomy is not uncommon).

In the field of minimally invasive urologic oncology, there is no other operation like the laparoscopic RPLND that can minimize morbidity of usually young healthy males. Laparoscopic RPLND has been controversial in that, certain initial series did not duplicate open surgical oncologic principles. Specifically, intraaortocaval and retrocaval dissections were limited, secondary to experience. As urologic oncology has embraced more complicated renal surgery, familiarity in and around the great vessels allows exact duplication of its open counterpart with decreased blood loss and quicker recovery time. Indications for laparoscopic RPLND usually are unilateral template dissections such as high-risk nonseminomatous germ cell tumors without prior chemotherapy. With experience, postchemotherapy and bilateral procedures have been performed but with great risk and morbidity. In a series of template dissections, lymph node packets can be removed by two to three specimen bags via 12-mm port sites. Typically 4–5 trocars are necessary and a transperitoneal access is standard. Utilizing a harmonic scalpel for dissection and newer fibrin glues has minimized blood loss. The combination of mostly younger healthy patients and laparoscopic techniques has made this, once morbid, procedure into an overnight stay.

Laparoscopic RPLND

Penis

Carcinoma of the penis is rare and associated with poor hygiene, unretractable foreskin (phimosis) and human papilloma viral infection. Penile cancers limited to the foreskin may be treated with circumcision, with excellent cosmetic results. However,

many of these cancers involve the glans or corporal bodies, and more radical, or disfiguring surgery is necessary for cure. Chronic infection, sometimes with gross purulence, is often associated with penile carcinoma. Thus, aggressive antibiotic therapy prior to surgery is recommended. Inguinal adenopathy may resolve with treatment if this is purely inflammatory; or improve if this is metastatic, to diminish the risk of local vascular invasion which may have disastrous outcomes

Surgical Anatomy Topography

The penis consists of the paired corporal bodies, the urethra, and the head or glans. The corporal bodies consist of spongy erectile tissue (corpora cavernosum) surrounded by a double tough layer of connective tissue (Buck's fascia or tunica albuginea). The proximal penis is split and each body fixed to the ischiopubic ramus. The body is the fused portion of the corporal bodies with the urethra beneath, and the glans is the distal extension of the corpus spongiosum. The urethra is surrounded by a delicate layer of erectile tissue (corpus spongiosum), which is in direct continuity with the glans penis distally, and is adherent dorsally to the distal corporal bodies.

Figure 15.21

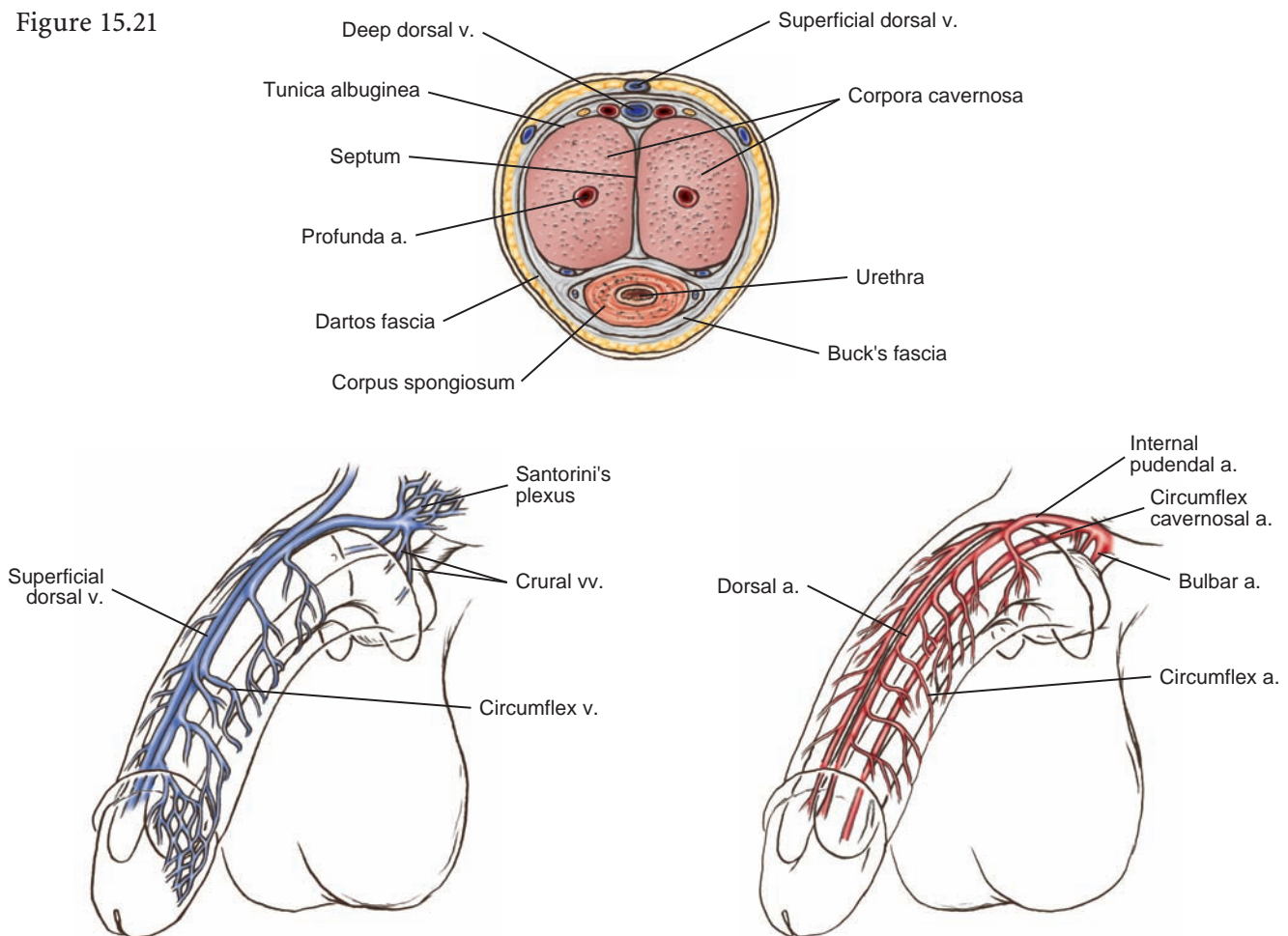
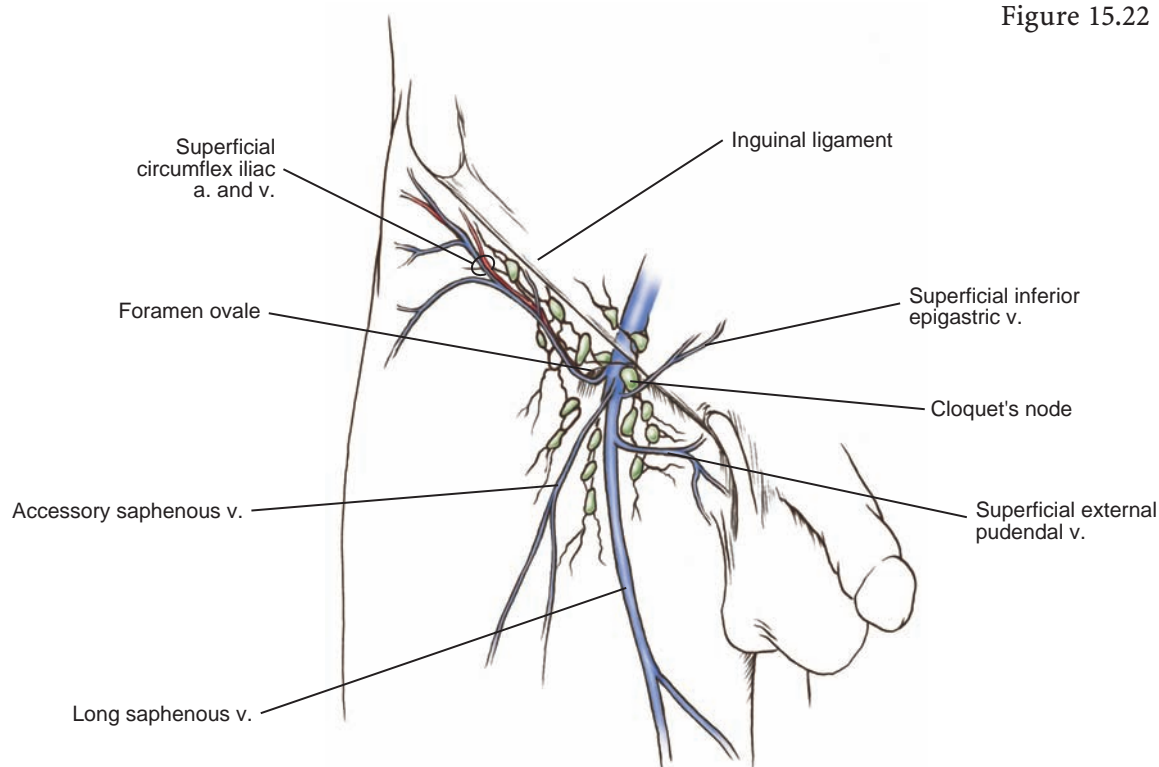


Figure 15.22



The penile blood supply is via the pudendal artery, which in turn arises from the internal iliac (hypogastric) artery. The three terminal branches of the pudendal artery are the deep penile artery, which feeds the corpora cavernosa through the dorsal and cavernosal artery; and the bulbar and urethral arteries, which perfuse the corpus spongiosum. The pudendal artery travels on the undersurface of the pubic ramus in Alcock's canal, and may be injured by direct trauma such as a straddle injury or chronic injury from older style bicycle seats.

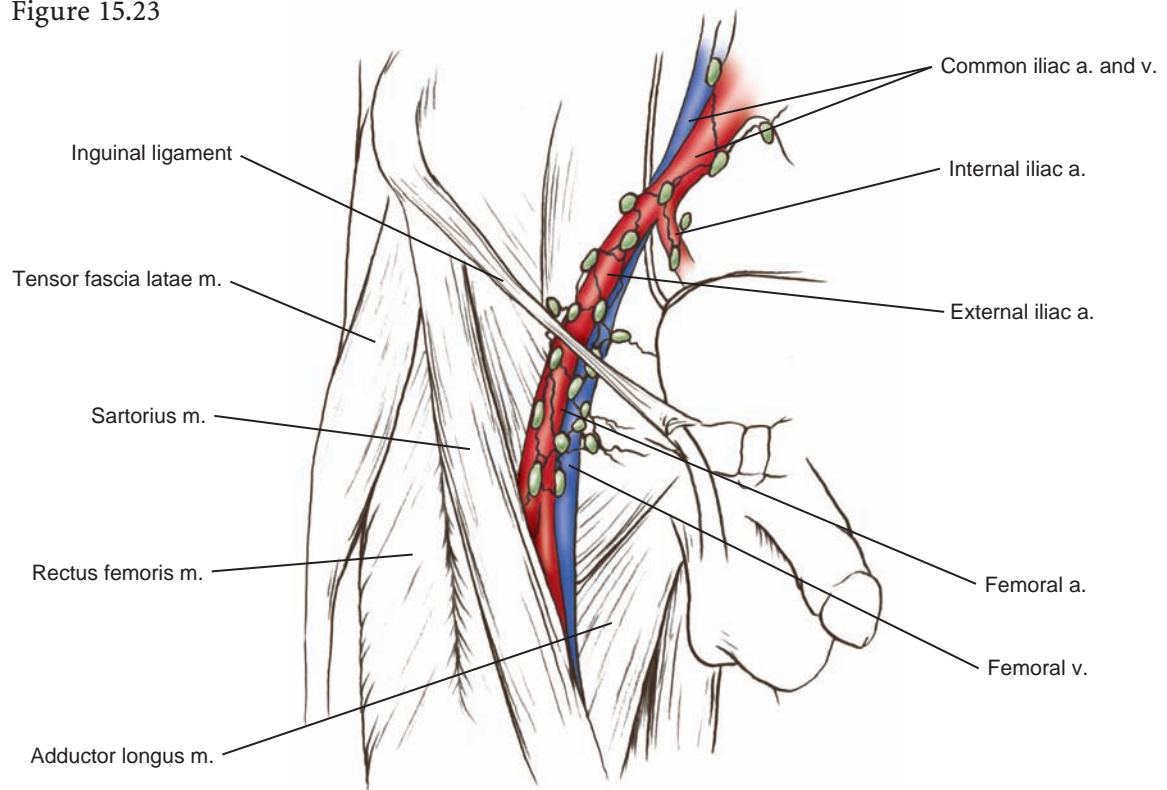
The venous drainage of the penis consists of superficial, intermediate, and deep venous systems.

The superficial system (superficial dorsal vein) drains the skin and the subcutaneous tissue. The intermediate system (lateral and circumflex veins) drains the corpora cavernosa into the deep dorsal vein, and then into the dorsal vein complex (Santorini's plexus) beneath the pubic symphysis.

The deep system (bulbar draining corpus spongiosum, crural and cavernosal draining corpora cavernosa, and internal pudendal) also feeds into the dorsal vein complex. The generous venous tributaries into the dorsal vein complex may result in troublesome bleeding during radical RP or following pelvic fracture.

The penile nerves for erectile function come from the pararectal area, along the lateral-posterior aspect of the prostate and prostate apex, then travel around the lateral aspect of the corporal bodies at the penile base, to lie just off the midline in the dorsal aspect of the penile shaft.

Figure 15.23



The lymphatic drainage of the penile skin/foreskin is to the superficial inguinal nodes, then to the deep inguinal nodes and then to the external iliac nodes in the pelvis. The lymphatic drainage of the glans may be to the superficial inguinal lymph nodes, or directly to either the deep inguinal nodes or the external iliac nodes.

Surgical Applications

Total Radical Penectomy

When the lesion is sizeable, involving the bulk of distal penis, a total penectomy is necessary. At surgery, after the preparation of the penis, the fungating/necrotic lesion may be covered with sterile adhesive wrap or part of a surgical glove to limit contamination of the operative site. An elliptical incision is performed at the penile base.

The corporal bodies are detached from the inferior aspect of the pubic rami. The bulbar urethra is mobilized from the corporal bodies, and transected. The corporal bodies are transected and oversewn with 2-0 Vicryl. The urethral stump is spatulated, and brought through the perineum beneath the scrotum, where the urethrostomy is created with interrupted 3-0 Vicryl sutures. The defect at the former penile base is vigorously irrigated and closed with interrupted suture. A penrose drain may be used if there is concern with potential infection.

Figure 15.24

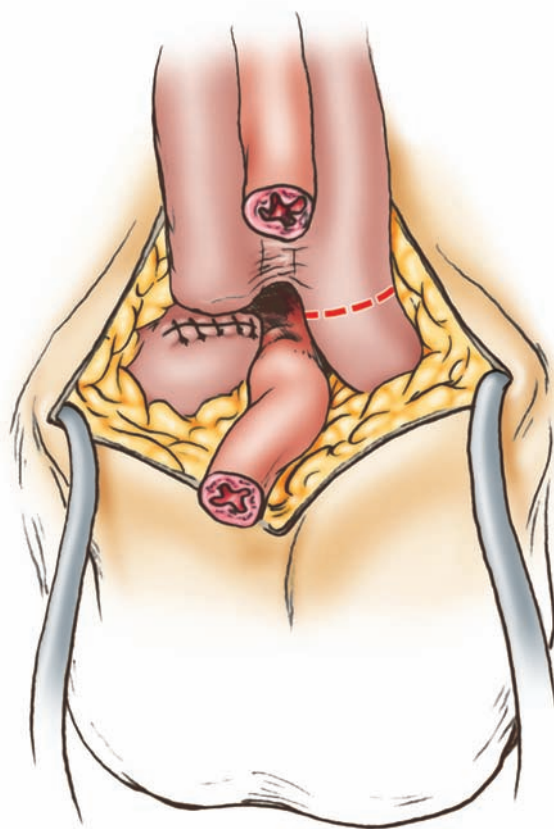
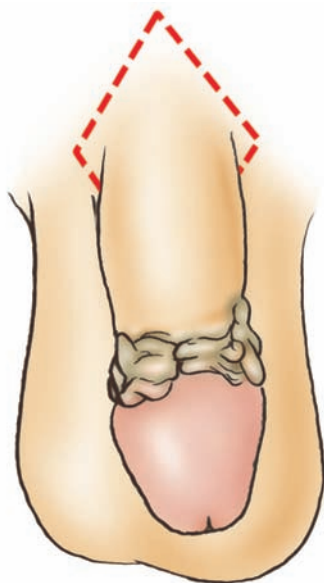


Figure 15.25

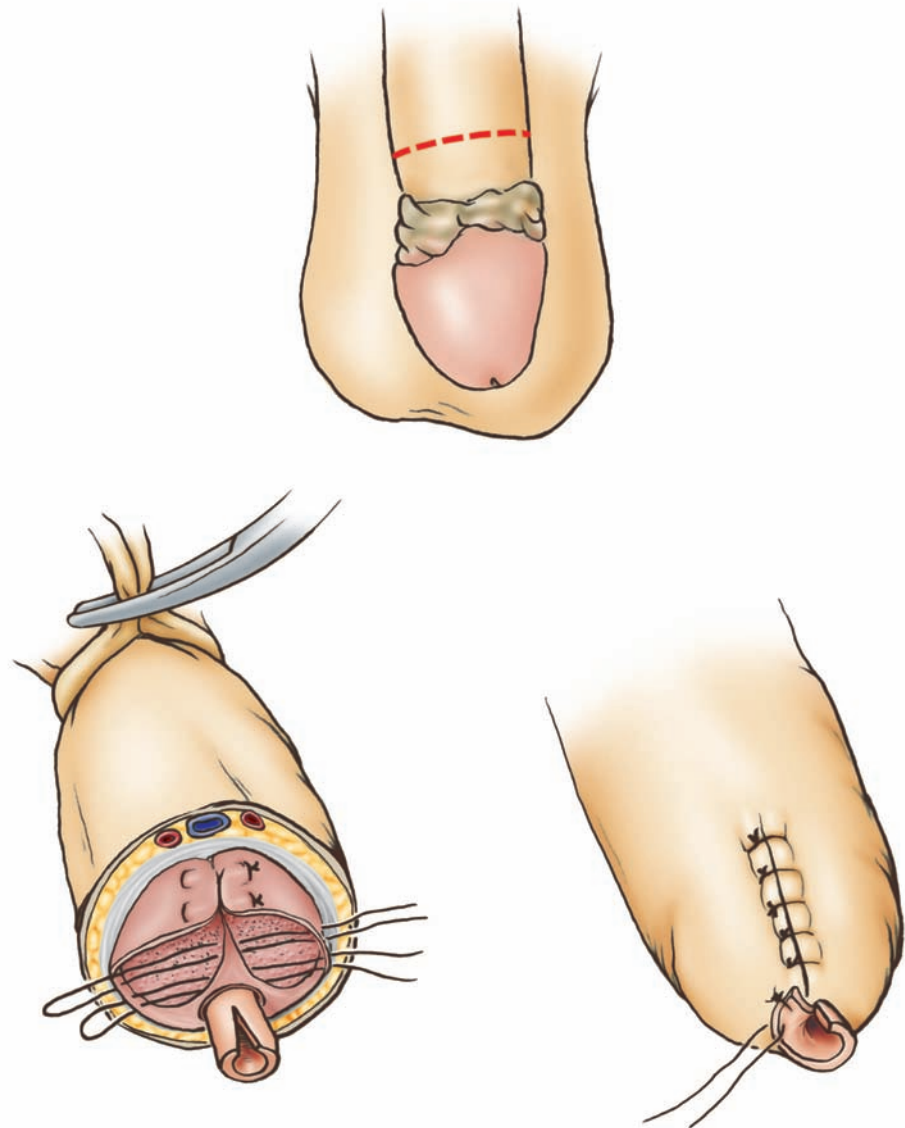


Figure 15.26

Partial Penectomy

When the penile lesion is small and distal, a partial penectomy may be performed. A circumscribing incision is made on the shaft, 2 cm from the proximal edge of the tumor. The corporal bodies are exposed proximally another 2 cm. The urethra is separated from the corporal bodies. The corporal bodies are transected, and the ends are oversewn with 2-0 Vicryl.

The urethra is divided and spatulated, and the urethrostomy is performed at the ventral aspect of the skin closure.

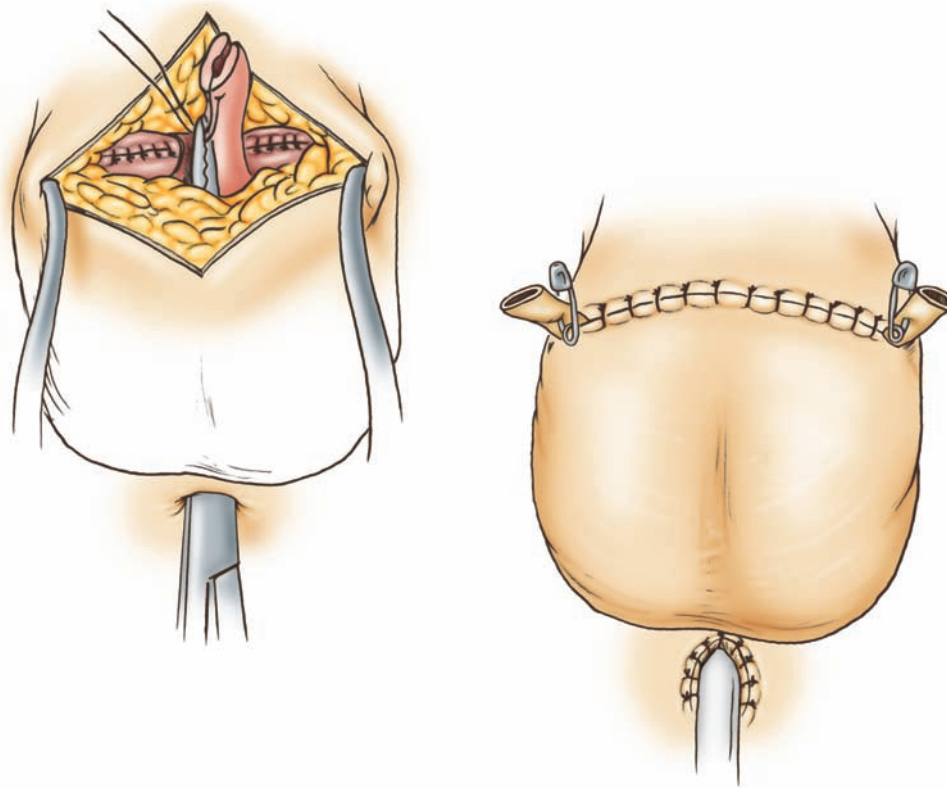


Figure 15.27

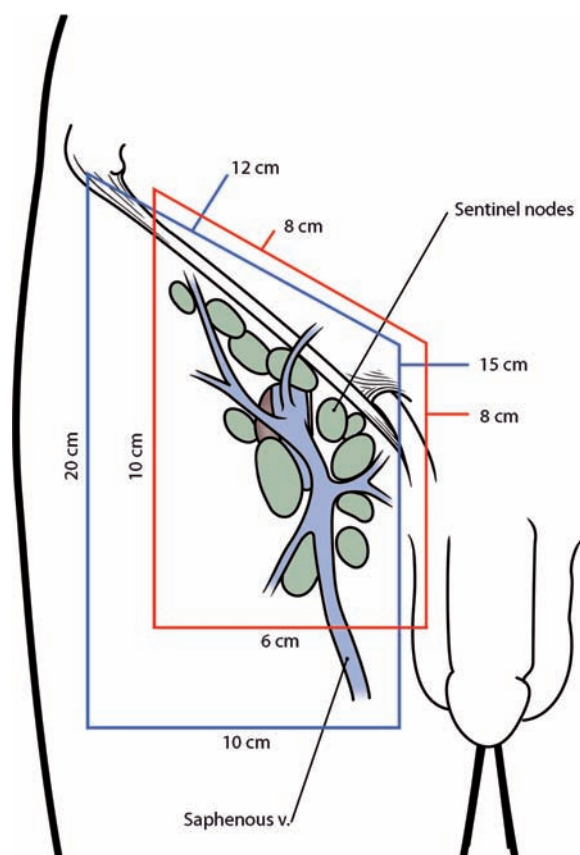


Figure 15.28

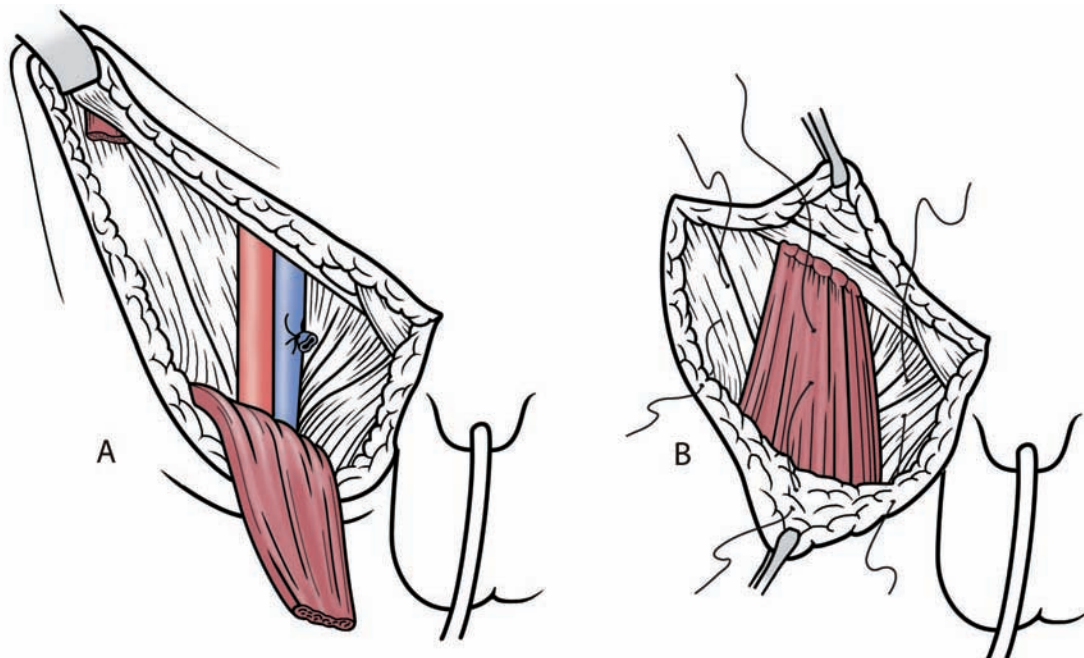
Inguinal Node Dissection

When there is a persistent inguinal adenopathy after antibiotic therapy, either palpable or noted on CT imaging, or when there is an increased risk of microscopic nodal metastases (with more aggressive, or locally invasive primary), then an inguinal node dissection is undertaken. For palpable node positive disease, the standard inguinal node dissection is performed. For suspected microscopic nodal disease, a modified approach is used, as it is associated with less lymphedema and less problems with superficial skin necrosis.

Standard Inguinal Node Dissection: A 15–20-cm sub-inguinal incision, is performed, 2 cm below the inguinal ligament, from just beneath the anterior superior iliac crest medially to just beneath the pubic tubercle. Skin flaps are created, preserving the subcutaneous tissue superficial to Scarpa's fascia. The superior limit is just above the external oblique aponeurosis and the spermatic cord to the inferior border of the inguinal ligament. The lateral limit is the sartorius muscle, and the medial limit is the adductor longus muscle. The inferior extent of the dissection is the apex of the femoral triangle, where the femoral artery and vein are encountered. The saphenous vein is excised with the nodes, being ligated and divided below, at the apex of the femoral triangle and above, at the saphenofemoral junction. The lymph node tissue is then dissected off the fascia lata from an inferolateral to a superomedial direction. The deep inguinal nodes are removed from beneath the fascia lata, medial and lateral to the femoral vein, and extend superiorly to and below the inguinal ligament. The sartorius muscle is divided at its origin to the anterior iliac spine and is rotated to cover the femoral vessels to protect the femoral vessels from erosion. PLND is usually performed if the superficial or deep inguinal lymph nodes are positive for tumor.

Modified Inguinal Node Dissection: A sub-inguinal incision, 2 cm below the inguinal ligament, approximately 8–10 cm long, is performed. Skin flaps are created 6 cm

Figure 15.29



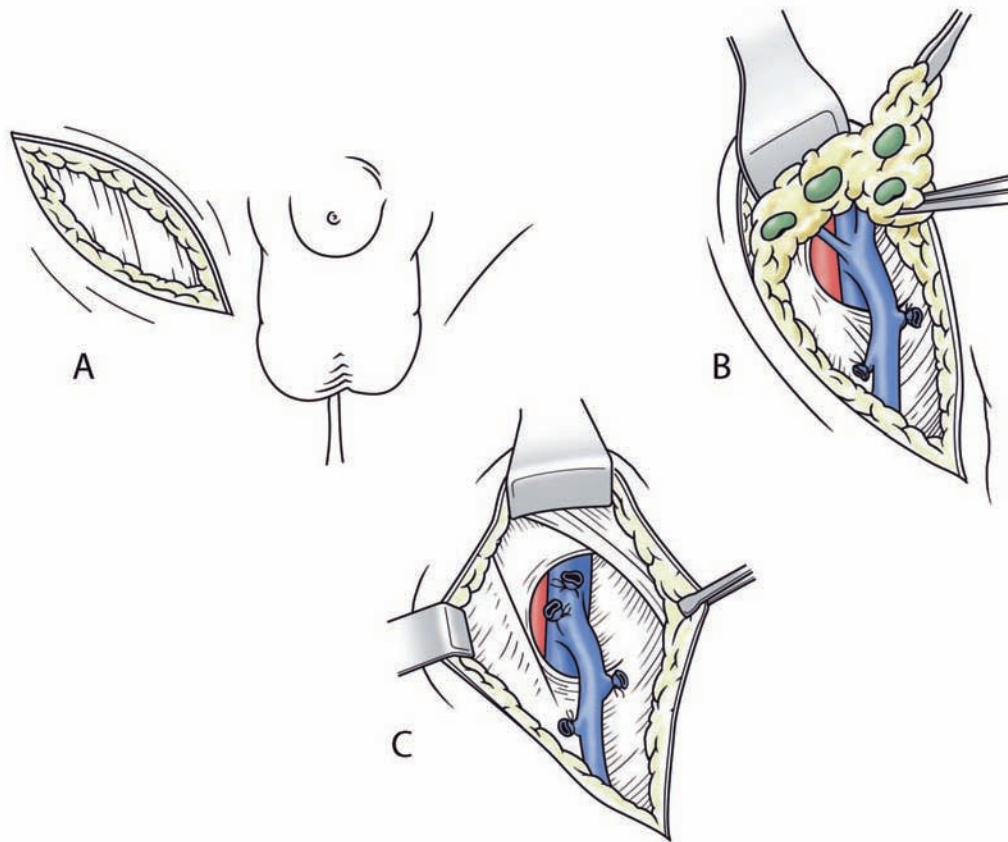


Figure 15.30

superiorly and inferiorly, preserving the subcutaneous tissue superficial to Scarpa's fascia. For the modified inguinal node dissection, the lateral limit is the lateral aspect of the femoral artery, the medial aspect is the adductor longus muscle, the superior limit is the inguinal ligament and spermatic cord, and the inferior limit is the apex of the femoral triangle. The superficial nodal tissue is teased off fascia lata and the fossa ovalis, in a lateral to medial fashion. The saphenous vein is identified in the fibrofatty node tissue, and dissected up to the saphenofemoral junction and preserved, while all the branches are ligated. The sartorius muscle is not mobilized. The deep inguinal nodes are teased off the femoral artery and vein. If the nodes that are removed with the modified dissection show metastatic disease, then a standard iliac node dissection, to include the nodal tissue lateral to the femoral artery and nerve, and pelvic lymphadenectomy is performed.

Anatomic Basis of Complications

- Injury to external iliac vein or bifurcation can result in significant blood loss.
- Injury to obturator nerve will cause loss of adduction of thigh.

Pelvic Lymph Node Dissection

- Lack of adequate control of the major pelvic lymphatic vessels will result in symptomatic lymphocele with possible deep venous thrombosis.
- Radical Retropubic Prostatectomy**
- Injury to neurovascular bundle of the prostate while dissecting the posterolateral capsule of the prostate may cause erectile dysfunction.
 - Failure to preserve the external sphincter during dissection of the prostatic apex will cause significant incontinence.
 - Incomplete or inadequate dissection of the dorsal venous complex may cause significant blood loss.
- Radical Perineal Prostatectomy**
- Injury to the anterior rectal wall during the division of the rectourethralis tissue may result in vesico-rectal fistula.
 - Excessive exposure of the urethral stump may damage the external sphincter, and result in urinary incontinence.
 - Injury to anal sphincter during perineal prostatectomy will occasionally cause temporary fecal incontinence.
 - Dissection of the cephalad tips of seminal vesicles may injure the neurovascular bundles and may cause erectile dysfunction.
- Inguinal Orchiectomy**
- Injury to ilioinguinal nerve will cause medial thigh numbness.
 - Injury to herniated bowel.
 - Failure to adequately ligate the cord or obtain hemostasis will result in scrotal hematoma.
- Retroperitoneal Lymph Node Dissection**
- Damage to lumbar sympathetic chain may result in retrograde ejaculation.
 - Major blood loss may result due to the dissection of the great vessels or their tributaries especially in postchemotherapy cases.

Key References

Donahue JP, Maynard B, Zachary JM. The distribution of nodal metastasis in the retroperitoneum from nonseminomatous testis cancer. *J Urol.* 1982;128:315

The authors map the differences and the percentage of nodal areas that more commonly receive metastatic lymphatic spread with regard to left and right testis involvement. They suggest templates of nodal dissection that can preserve the lumbar sympathetic chain in an effort to preserve seminal emission.

Donahue JP, Rowland RG. Complications of retroperitoneal lymph node dissection. *J Urol.* 1981;125:338

Due to the location of the lumbar sympathetic chain, the authors describe the common occurrence of failure of seminal emission after bilateral dissection of the retroperitoneal nodes. This work led to the development of the described nerve-sparing techniques, which can preserve potency in approximately 90% of the patients.

Martis G, Diana M, Ombres M, Cardi A, Mastrangeli R, Mastrangeli B. Retropubic versus perineal radical prostatectomy in early prostate cancer: eight-year experience. *J Surg Oncol.* 2007;95(6):513–8

Randomized study showing perineal prostatectomy was better with regard to hospital stay, duration of catheter drainage, intraoperative blood loss, and transfusion requirements. Surgical margin positivity and urinary continence were similar, and there was better erectile function in the retropubic prostatectomy group.

Menon M, Shrivastava A, Tewari A. Laparoscopic radical prostatectomy: conventional and robotic. *Urology* 2007;66(5 Suppl):101–4

By 2015, prostate cancer will become the most commonly diagnosed cancer in men. Radical prostatectomy reduces disease-specific mortality in patients with localized prostate cancer; however, the invasiveness of the surgery and its resultant side effects cause many men to seek other treatments. In 2000, laparoscopic radical prostatectomy emerged as a minimally invasive alternative to open surgery and has been refined recently by the addition of robotic technology. To examine the outcomes of robotic radical prostatectomy and to compare them with those from open and conventional laparoscopic radical prostatectomy, baseline demographic data on all the patients undergoing surgery for prostate cancer was prospectively collected over a 4-year period at our center. Urinary function and sexual function were evaluated using standardized criteria as well as a questionnaire preoperatively and at 1, 3, 6, 12, and 18 months after the procedure. Operative and postoperative outcomes were compared using values for open radical prostatectomy as the reference standard. A total of 100 men underwent open radical prostatectomy with conventional laparoscopic radical prostatectomy ($n = 50$) and robotic radical prostatectomy ($n = 50$). The odd ratios for operative times, blood loss, postoperative pain, complications, and median times to urinary continence and resumption of sexual activity were all lower for robotic than for open or laparoscopic radical prostatectomy. It appears safe to conclude that conventional laparoscopic radical prostatectomy is a reasonable alternative to open radical prostatectomy in the surgical treatment of patients with clinically localized prostate cancer. The incorporation of robotics may result in even better surgical outcomes than conventional laparoscopy. However, the surgical robot is expensive; few centers have access to the technology and even fewer have expertise in the technique. For robotic radical prostatectomy to become the standard of care for the treatment of localized prostate cancer, it will require economies of cost, dissemination of surgical expertise, and data from randomized trials.

Myers RP, Goellner JB, Cahill DR. Prostate shape, external striated urethral sphincter and radical prostatectomy. The apical dissection. *J Urol.* 1987;138:543

This reference delineates the anatomic relationship of the external striated urethral sphincter to the prostate apex and commissure. The authors noted that sphincteric tissue extended from the bladder base to the tunica albuginea of the corpus cavernosum. The proximal extent of the sphincter was found by the presence of an anterior apical notch. If present, the sphincter was shown to function due to the presence of sphincteric fibers. The authors recommend urethral transection as far proximal as possible without including the apex but preserving the verumontanum.

Skinner DG, Leadbetter WF, Kelley SB. The surgical management of squamous cell carcinoma of the penis. *J Urol.* 1972;107:2783

This remains as the classic description of the surgical and anatomic considerations in treatment and staging of the relatively uncommon squamous cell carcinoma of the penis.

Walsh PC, Lepor H, Eggleston JC. Radical prostatectomy with preservation of sexual function: anatomical and pathological considerations. *Prostate* 1983;4:473

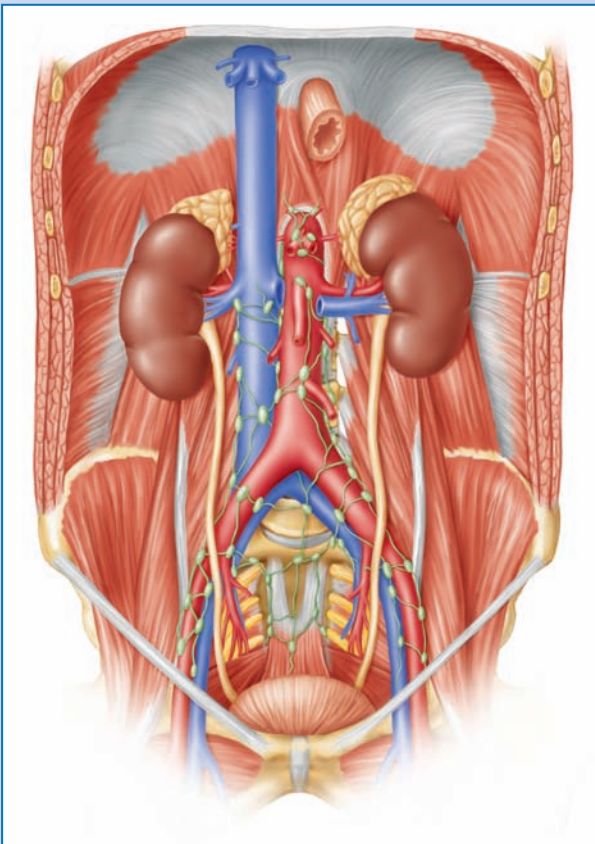
Having identified the location of the branches of the pelvic plexus that innervate the corpora cavernosa and their relationship with the prostate vascular supply and the lateral pelvic fascia, the authors describe a modified technique of radical retropubic prostatectomy used to preserve the critical branches of the pelvic plexus and preserve potency in more than 80% of their patients.

Suggested Readings

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Retroperitoneum

Keith A. Delman,
Roger S. Foster,
John E. Skandalakis



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Introduction

Soft tissue sarcomas are rare tumors, with less than 8,500 cases predicted in the United States in 2008. Tumors of the retroperitoneum are even more unusual because they comprise 10–20% of all sarcomas in adults. Of the malignancies that arise in the retroperitoneal space, and not in the retroperitoneal viscera, soft tissue sarcomas account for 40–70%. Lymphomas account for 15–30% of the total, and the less common tumors such as paragangliomas and malignant teratomas account for the remainder. The most frequent histologic types of retroperitoneal sarcoma are liposarcoma and leiomyosarcoma, followed by malignant fibrous histiocytoma and fibrosarcoma. Less common histologic types include malignant peripheral nerve tumors, lymphangiosarcoma, rhabdomyosarcoma, and hemangioendothelioma.

Soft tissue sarcomas arising in the retroperitoneal space present a challenge to surgeons because they tend to grow silently to a large size before detection, may invade adjacent organs, and as a result, may limit the surgeon's ability to resect them with adequate negative margins. Despite the difficulties of surgical resection, aggressive complete or near complete resection is the mainstay of treatment. Survival is related to the extent of resection. Unresected disease is uniformly fatal. Complete resection of retroperitoneal sarcomas leads to a 5-year survival rate of more than 50%, and for some low-grade tumors, even partial resection (defined as resection of more than 80–90% of the tumor) has led to a 5-year survival rate of more than 40%. Patients with recurrent local disease are candidates for aggressive repeat resection, as complete resection may lead to a median survival of 41 months. Unfortunately, repeated recurrences have decreasing benefit from surgical resection with patients successfully undergoing surgery for a second resection only 20% of the time and for a third recurrence less than 10% of the time. Patients with isolated lung metastases may also undergo metastasectomy with a measurable survival benefit.

It is important that the surgeon who performs the first definitive resection be prepared to carry out the widest possible resection, with the removal of adjacent organs if necessary, to obtain a clear margin. Breaking into and spilling the tumor leads to multifocal local recurrence, that is unlikely to be resectable. An en bloc resection of the sarcoma may require resection of any invaded adjacent organs such as the kidney and adrenal gland, colon, small intestine, pancreas, stomach, or pelvic organs. Complete resection of a retroperitoneal sarcoma requires removal of one or more involved organs in more than 70% of the procedures. In a few patients, resection of portions of the abdominal wall, diaphragm, or pelvic wall is necessary. Portions of the vena cava or iliac vessels may require resection. Involvement of the aorta or superior mesenteric vessels tends to limit the margin of resection. Reports from experienced surgeons indicate that complete excision (no clinical evidence of residual tumor, R1 resection) can be accomplished in over 65% of the patients with tumor deemed resectable on preoperative evaluation. If it appears that a generous margin of the resected tissue cannot be obtained, preoperative radiation therapy, especially for higher grade soft

tissue sarcomas, offers the best opportunity to sterilize the periphery of the tumor prior to resection.

The role of radiation therapy in soft-tissue tumors of the retroperitoneum has been a source of much discussion among surgical oncologists. Most of the knowledge about the management of retroperitoneal sarcomas is extrapolated from the studies of extremity lesions, which are more common (although still rare). The primary goal of radiation therapy is to optimize local tumor control. The evidence for adjunctive radiation therapy in patients with extremity sarcomas has evolved from two randomized trials and a number of large single-institution reports. Both the randomized trials showed benefit to local control in patients receiving radiation therapy with high grade tumors. There was no benefit in adding radiation for individuals with low grade lesions.

This has routinely led to the consideration for radiation as an adjunct in the treatment of all sarcomas where margins are at risk or tumors are high grade and large. In 2005, a multicenter trial sponsored by the American College of Surgeon's Oncology Group attempted to address the utility of preoperative radiation therapy in patients with retroperitoneal sarcoma but unfortunately the trial closed prematurely due to lack of accrual. At present, there is no randomized, prospective data available to determine the utility of preoperative radiation in resectable retroperitoneal sarcomas. Many surgeons advocate this approach only in selective application, in circumstances wherein preoperative imaging of the lesions implies difficulty in obtaining clear margins. Others advocate the routine use of radiation preoperatively, with the argument that the tumor serves as a tissue expander, displacing normal tissue from the effects of radiation. Many others advocate radiation to be used only in the setting of recurrence, unresectable disease, or when margins are inadequate, postoperatively. The result of this debate is that the only mainstay of treatment for this rare, but heterogeneous group of neoplasms, is complete surgical resection.

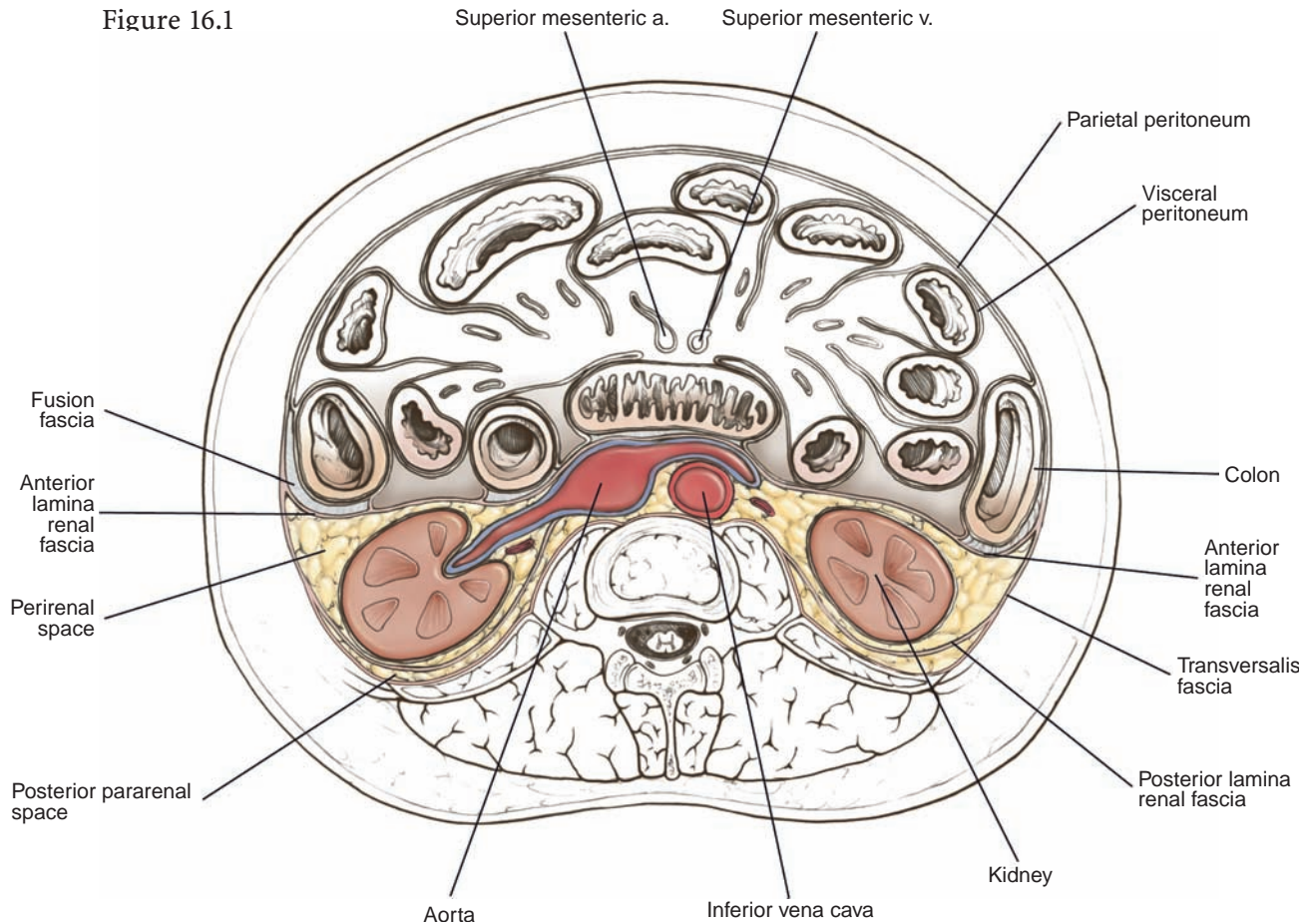
Surgical Anatomy

Anatomically, the retroperitoneal space is the area of the posterior abdomen located between the posterior parietal peritoneum and the posterior part of the transversalis fascia. Within this space, there are embryologically related organs such as the adrenal glands, kidneys, and ureters, which are referred to as the retroperitoneal viscera. Also within the retroperitoneal space is the neurovascular apparatus, formed by the aorta and its branches, the inferior vena cava and its tributaries, the lymphatic vessels and the lymph nodes, and the lumbar plexus with its branches and the sympathetic trunk.

The parietal peritoneum is in continuity with the visceral peritoneum and vice versa. Because the parietal peritoneum is not fixed or fused, it can be readily dissected. Only the transversalis fascia is fixed. It is fused with the subdiaphragmatic fascia above, the psoas fascia laterally, and the fascia of the quadratus lumborum to

General Considerations

Figure 16.1



form the anterior lamina of the lumbodorsal fascia. The transversalis fascia attaches medially to the vertebrae's spinous processes and later continues with the iliac and the fascia of the pelvic diaphragm.

The retroperitoneal space extends from the twelfth thoracic vertebra and the twelfth rib cephalad to the base of the sacrum, the iliac crest, and the pelvic diaphragm caudally. The lateral borders may be considered to be extended from an imaginary line from the tip of the twelfth rib down to the junction of the anterior half of the iliac crest with the posterior half of the iliac crest.

Within the upper retroperitoneal space there are three compartments created by the renal fascia of Gerota: anterior pararenal, posterior pararenal, and perirenal. The lower retroperitoneal space is contiguous with the two areas that must be considered from a surgical standpoint: the iliac fossa and the pelvic wall of the true pelvis.

The renal fascia has a peculiar pathway. It covers the fat of the anterior and the posterior surfaces of the kidney, having some fixation medially with the adventitial coverings of the renal vessels, with extension to the aorta on the left and the inferior vena cava on the right. Above and towards the adrenal glands and the diaphragm, the anterior and the posterior laminae unite, or perhaps fuse, and finally join the sub-diaphragmatic fascia. However, at the upper pole of the kidney, a fascia separates the adrenal gland from the kidney.

The iliac fossa is lined by the peritoneum, which covers the subperitoneal fat. It continues medially to the retroperitoneal space (lumbar area), downward to the pelvic wall and then to the anterior abdominal wall. Just behind the subperitoneal fat is the transversalis fascia. This narrow space is the home of the right and left iliac vessels, right and left ureters, right and left genitofemoral nerves, right and left gonadal vessels, and lymphatic vessels and lymph nodes.

The floor of the iliac fossa is the iliacus muscle, covered by the iliac fascia. On the way up, after covering the psoas major muscle, the fascia is attached to the brim of the pelvis or to the linea terminalis. On the way down, it is attached to the inguinal ligament together with the transversalis fascia.

The dominant soft-tissue structure in the retroperitoneum is the psoas muscle. For all practical purposes, the psoas muscle extends from the posterior mediastinum to the thigh. On its way downwards, it is closely associated with the perirenal space and the posterior pararenal space.

The retroperitoneal lymph nodes form a rich and an extensive chain from the inguinal ligament to the diaphragm and the posterior mediastinal nodes. The nodes are classified simply, logically, and anatomically as follows:

Lymphatics

Aortic group

Preaortic: celiac axis, superior mesenteric artery, inferior mesenteric artery

Para-aortic: right lateral, left lateral

Caval group

Precaval

Retrocaval

Paracaval: right lateral, left lateral

Pelvic group

Common iliac

External and internal iliac

Obturator

Sacral

As noted, the aortic group includes preaortic and para-aortic nodes. One to three celiac nodes are located around the base of the celiac artery. They are closely related to the celiac ganglion and the lymph nodes of the superior mesenteric artery. These nodes receive lymph from the stomach, liver, pancreas, and superior mesenteric nodes. Two or three superior mesenteric nodes receive lymph from the small bowel, right colon, part of the transverse colon, and pancreas. They communicate with the celiac and the inferior mesenteric nodes. The two nodes of the inferior mesenteric artery receive lymph from the left colon. The right lateral paraaortic nodes along with the left paracaval nodes form the right lumbar chain of nodes, which may be found around the inferior vena cava. The left para-aortic (left lumbar) lymph nodes are a group of 5–10 lymph nodes that communicate with the common iliac nodes and drain into the thoracic duct.

The caval group of nodes includes precaval, retrocaval and paracaval nodes. Precaval lymph nodes are located at the anterior wall of the inferior vena cava. Two of

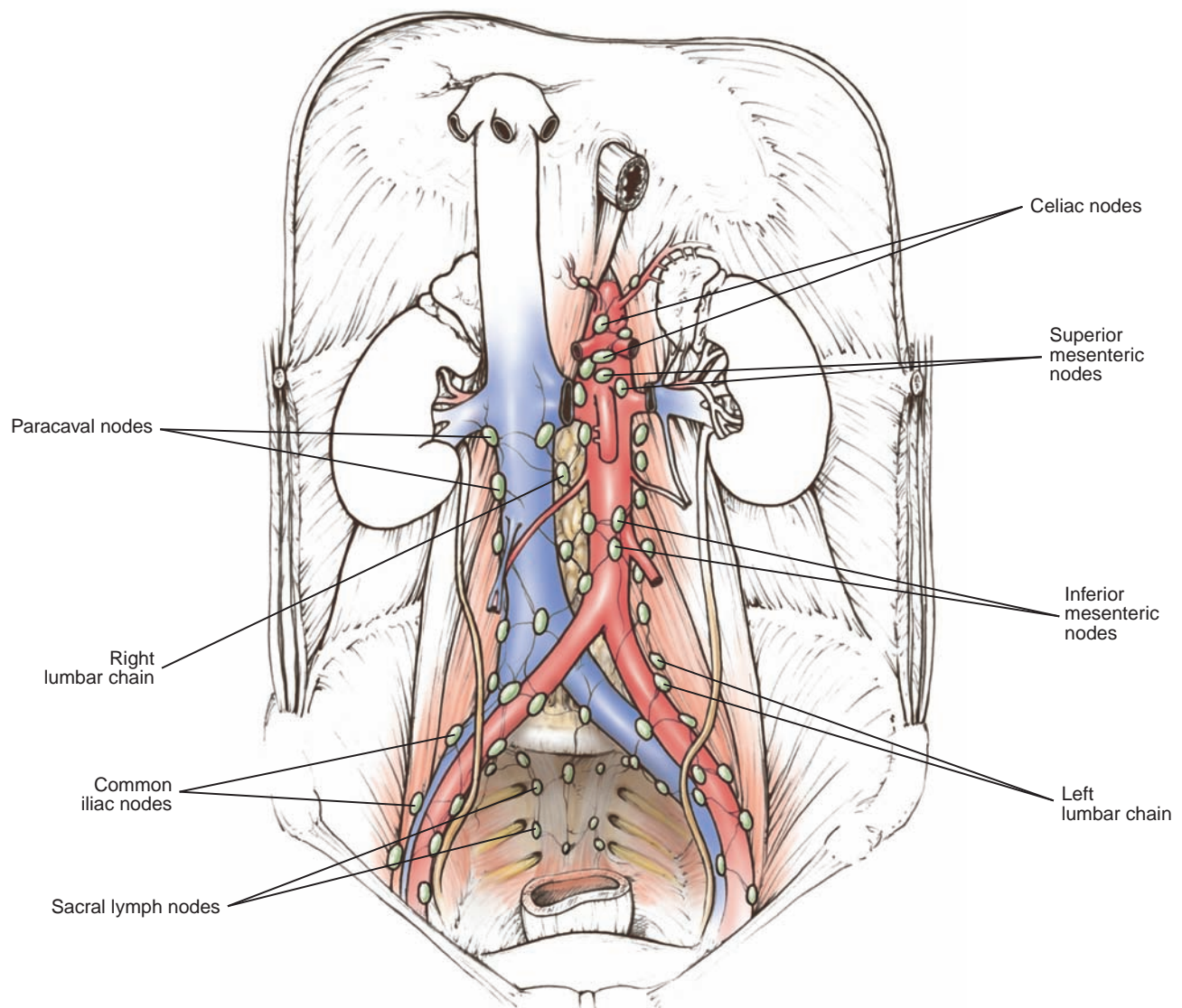


Figure 16.2

these nodes, one at the aortic bifurcation and the other at the termination of the left renal vein, are fairly constant. Retrocaval lymph nodes are located on the psoas muscle and the right crus of the diaphragm. The right paracaval nodes are found at the right lateral side of the inferior vena cava. The one at the entrance of the right renal vein to the inferior vena cava is the metastatic node for right testicular malignancy. The left paracaval nodes are in close association with the right aortic nodes.

The pelvic group of lymph nodes is frequently the site of metastases from tumors of gynecologic origin and of lower extremity melanomas. There are four to six common iliac lymph nodes, located around the iliac artery. There are 8–10 external iliac lymph nodes, located laterally and medially, and occasionally anteriorly. The internal iliac lymph nodes are located around the internal iliac vessels. There are fewer obturator lymph nodes (usually only 1 or 2), located at the obturator foramen close to the obturator neurovascular apparatus. The sacral lymph nodes are located close to the median and lateral sacral vessels.

The cisterna chyli is formed approximately at the L2 vertebra by the confluence of the right and the left lumbar lymphatic trunks with the intestinal trunk.

Six major nerves are present in the retroperitoneal space: iliohypogastric, ilioinguinal, genitofemoral, lateral femoral cutaneous, obturator, and femoral. All these are the branches of the lumbar plexus, which is formed by a branch of T12 and by the anterior primary divisions of L1–L4. Additionally, the sympathetic chain runs on either side of the vertebral column.

The iliohypogastric nerve, from T12 to L1, or L1 only, is the first nerve of the lumbar plexus. It emerges from the lateral border of the psoas muscle. After relating to the quadratus lumborum muscle, it travels downward between the internal oblique and the transversus abdominis muscles. The iliohypogastric nerve produces two branches. The lateral cutaneous nerve supplies the posterolateral skin of the gluteal area, and the anterior cutaneous nerve supplies the skin over the symphysis pubis.

The ilioinguinal nerve from L1 has the same general pathway as the iliohypogastric nerve, but on its way downward it transverses the inguinal canal together with the spermatic cord. In the thigh, it innervates the triangle of Scarpa, which is a part of the scrotal or labia majora skin.

The genitofemoral nerve from the L1 and L2 nerves pierces the psoas muscle anteriorly. It gives origin to two branches: the genital branch and the femoral branch. The genital branch, within the inguinal canal, is related to the iliopubic tract and supplies the cremaster muscle and part of the scrotal skin. The femoral branch passes below the inguinal ligament and participates in the innervation of the skin of the triangle of Scarpa.

The lateral femoral cutaneous nerve from L2 and L3 emerges from the lateral border of the psoas muscle approximately at the area of the fourth lumbar vertebra. After

Nerve Supply

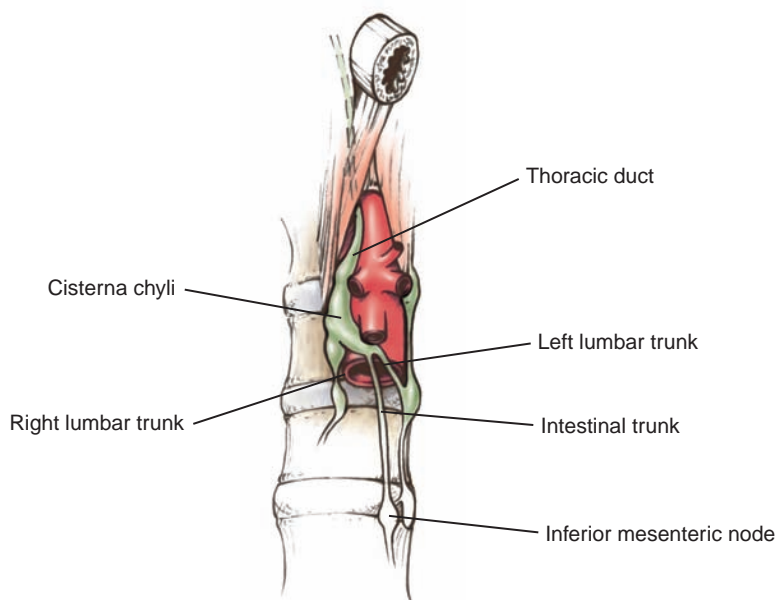


Figure 16.3

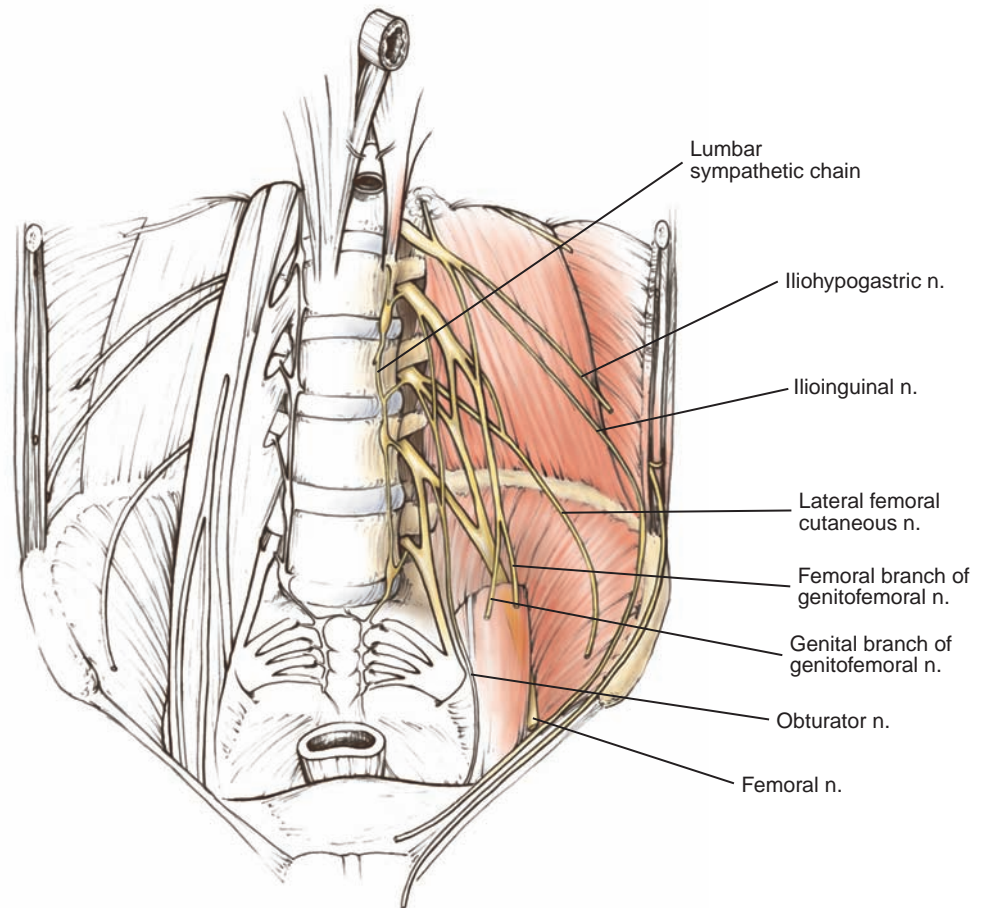


Figure 16.4

perforating the inguinal ligament close to the superoanterior iliac spine, it passes into the lateral aspect of the thigh.

The obturator nerve from L2 to L4 emerges from the medial border of the psoas muscle. It enters together with the obturator vessels into the obturator foramen, continuing downward to innervate the medial part of the thigh.

The femoral nerve from L2 to L4 emerges from the lateral border of the psoas muscle. It passes under the inguinal ligament and is closely associated with the iliopsoas muscle.

The lumbar sympathetic chain lies right and left, along the medial border of the psoas muscle. It is located anterior to the lumbar vertebrae and is covered by the inferior vena cava on the right and the right para-aortic nodes on the left. It is formed by four ganglia, which vary in size and position. They communicate with each other and with the thoracic trunk above and the pelvic trunk below.

Surgical Applications

Retroperitoneal sarcomas are generally best approached by the transperitoneal route. The surgical anatomy of these routes is described, with the presentation

of the surgical anatomy related to the excision of sarcomas in the right and left lumbar areas.

Biopsy is important to obtain an accurate histologic characterization of a retroperitoneal mass. This is critical as the management of the different types of tumors found in the retroperitoneum varies by diagnosis: (1) for soft tissue sarcomas, surgical resection is the primary therapy, (2) for lymphomas, surgical resection is inappropriate, and (3) for embryonal rhabdomyosarcoma or testicular carcinomas, preoperative chemotherapy is appropriate. Since many patients with retroperitoneal sarcomas may be the candidates for clinical trials, this is another reason why biopsy is often necessary. Attention to the technique of biopsy is critical to provide adequate material for pathologic diagnosis, and to minimize the chance of tumor seeding of uninvolved tissue or the peritoneum. A representative piece of tumor needs to be provided to the pathologist. Areas of necrosis or hemorrhage should be excluded. In spite of the significance of biopsy, certain tumors have distinct radiographic appearances, particularly with the broad use of magnetic resonance imaging (MRI) and high quality, thin slice, computed tomography (CT) scanning, which at times may alleviate the need for biopsy.

Biopsy

If needed, core needle biopsy is generally the best way to obtain a tissue sample, but at times the small size of the sample limits the ability of the pathologist to provide a diagnosis. Fine needle biopsy may be useful for the diagnosis of obviously unresectable tumors, for establishing the fact that a retroperitoneal tumor is something other than a soft tissue sarcoma, or for confirming the histologic features of a recurrent tumor.

In the past, there has been concern that needle biopsy could contaminate normal tissue planes or the peritoneal cavity. With the present day biopsy techniques this has not borne out to be true. Under optimal circumstances, planning the biopsy should include choosing the location for needle placement so as to allow the needle tract to be resected at the time of definitive surgery. Open biopsy of retroperitoneal sarcomas is discouraged as the utility of core biopsy eliminates the need for this approach in almost all instances and this procedure carries the same or a greater risk of peritoneal contamination. If the diagnosis can be established with percutaneous needle biopsy, the possibility of preliminary general anesthesia and laparotomy, simply to establish a tissue diagnosis is averted.

If it is not possible to obtain a definitive diagnosis of soft tissue sarcoma with percutaneous needle biopsy, incisional biopsy with frozen-section confirmation, of adequate tumor specimen should be performed. In general, a laparoscopic approach should be considered for this as this minimizes short term recover and may alleviate the need for a major surgical procedure, if the lesion does not require definitive surgical resection (i.e., a lymphoma or embryonal tumor). The pathologist may be unable to give a definitive reading from frozen-section analysis and therefore, the tissue should be sent for both immediate evaluation and permanent review. Sometimes, other malignancies such as lymphomas, malignant germ cell tumors, and anaplastic carcinomas may be distinguished only on permanent sections.

Resection of Left-Sided Retroperitoneal Sarcomas

CT scans or MRI studies are highly accurate in determining the extent of the involvement of the adjacent organs. The retroperitoneal sarcoma shown, involves the spleen, pancreas, and kidney. There is no obvious involvement of the colon or colonic mesentery; however, preoperative bowel preparation is carried out in case a colonic resection is necessary.

After making a long midline incision, general exploration of the abdomen is carried out. The greater omentum is dissected from the transverse colon, the short gastric vessels from the spleen to the stomach are divided, and the uninvolved stomach is retracted superiorly to expose the lesser sac. The retroperitoneal sarcoma has displaced the pancreas superiorly. The spleen and pancreas are adherent to the tumor. The tumor is lateral to the aorta, and the colon and colonic mesentery are free from tumor involvement.

The left colon is freed laterally by an incision along the peritoneal reflection. After the division of the splenicocolic ligament and the ligament of Treitz, the left colon and the duodenum are swept medially. Palpation of the retroperitoneum reconfirms that the aorta is free, but there is a firm adherence of the sarcoma to the kidney.

At the left lateral border of the aorta, the splenic artery and the vein are isolated and divided. The pancreas is transected, and if possible, the pancreatic duct is identified and individually ligated. The renal artery and the vein are ligated and divided, as are the ureter and the gonadal vein. The lateral peritoneal attachments of the spleen are divided, and the spleen and the tail of the pancreas are mobilized inferiorly.

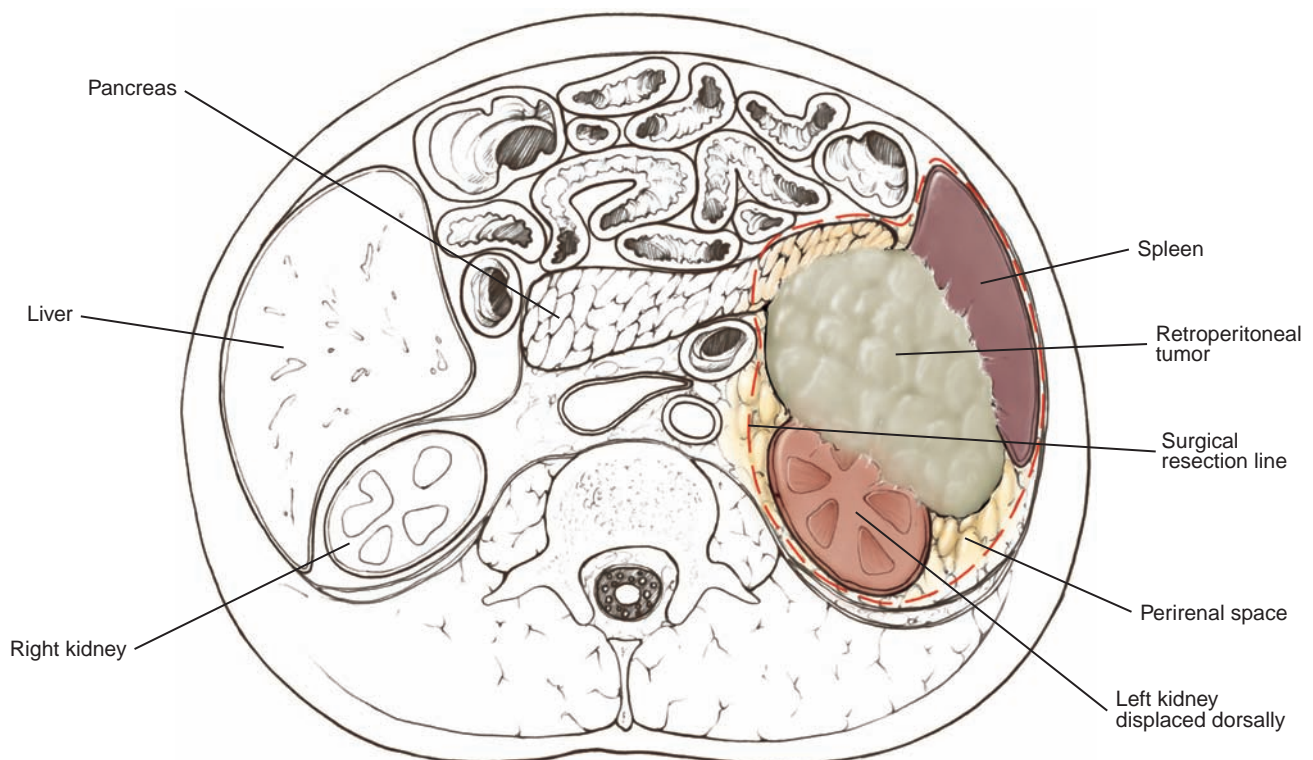


Figure 16.5a

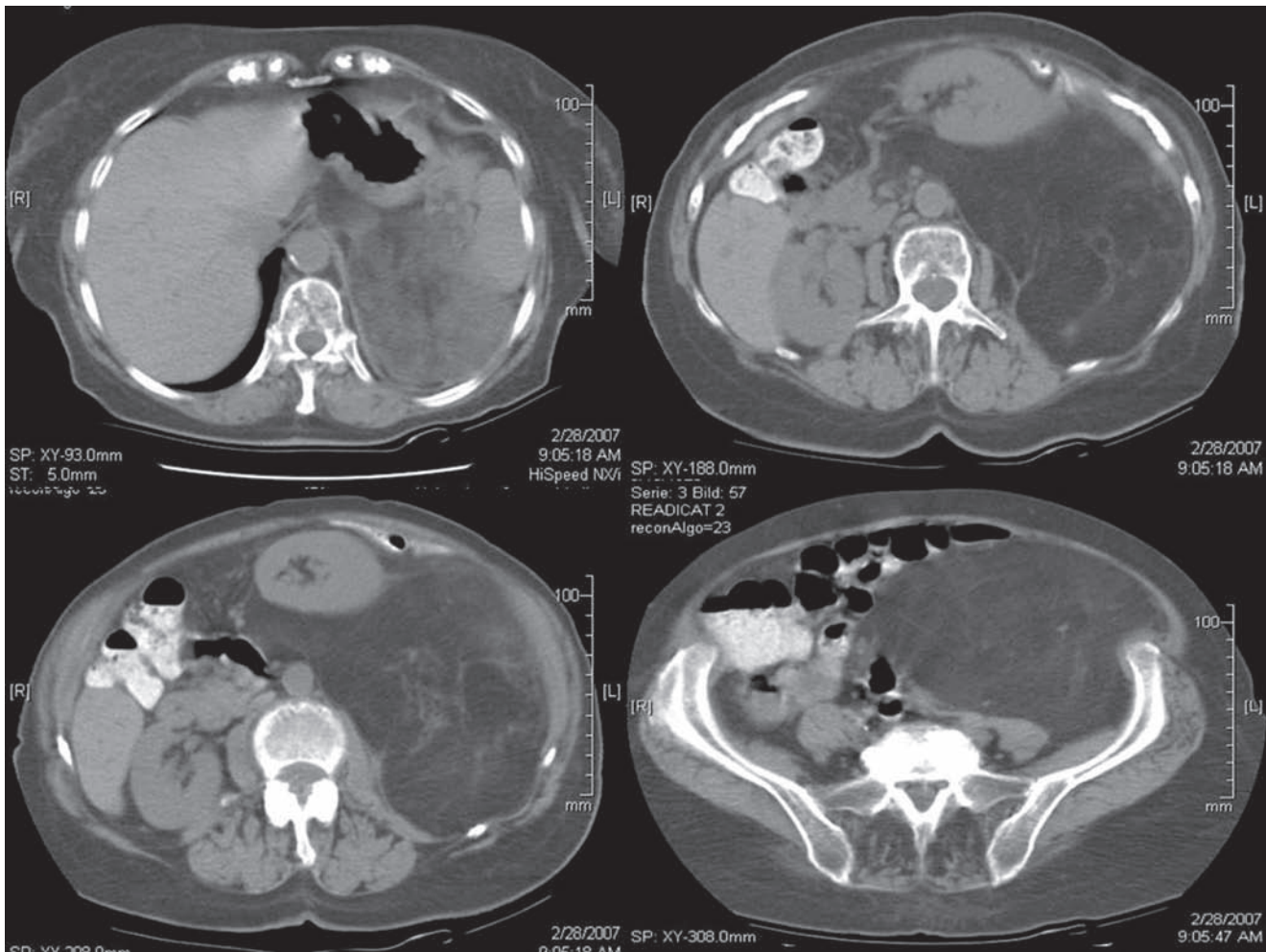


Figure 16.5b

With blunt dissection in the retroperitoneal plane behind the kidney and the sarcoma, the specimen containing the sarcoma, the kidney, adrenal gland, spleen, and the tail of the pancreas are mobilized from the diaphragm and the posterior abdominal wall, and delivered. Additional hemostasis is obtained as needed. If the mesocolon were involved, it would have been left attached to the tumor mass and the colon would have been mobilized with preservation of the marginal artery. Involvement of the marginal artery or of the colon itself would have led to en bloc resection of the colon with the sarcoma.

In the case shown, radiographic studies suggest that the retroperitoneal sarcoma involves the lower pole of the right kidney and the right colon. The duodenum and the vena cava appear not to be involved with the tumor. As with the left sided lesion, a long midline incision is made. A long incision is utilized for sarcoma surgery in that it allows access to the central vasculature as well as reasonable visualization of all the involved viscera. After general exploration of the abdomen confirms the location of the tumor and the absence of metastases, the relationship of the tumor to the superior mesenteric vessels and the vena cava is explored through an incision in the mesocolon.

Resection of Right-Sided Retroperitoneal Sarcoma

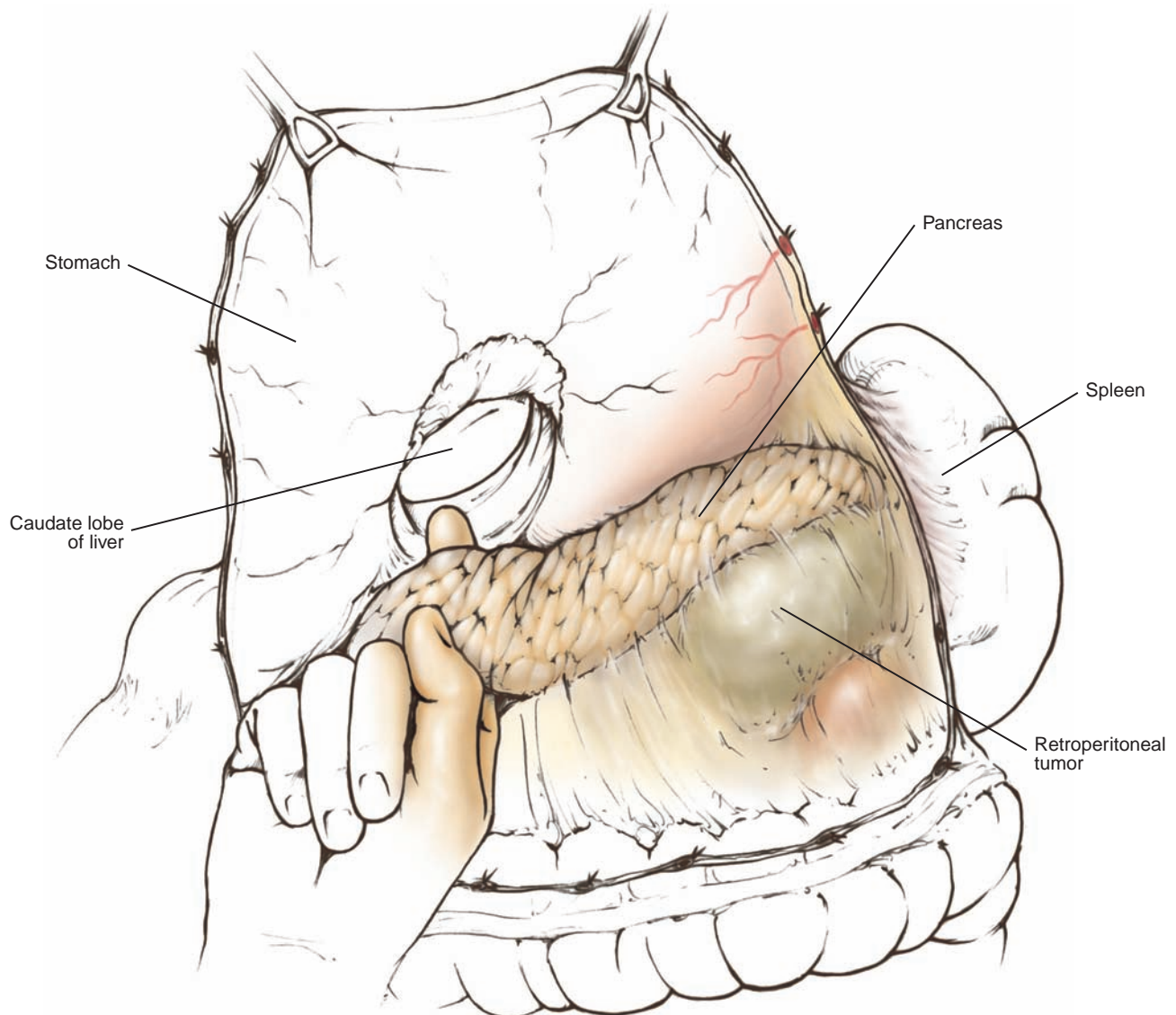


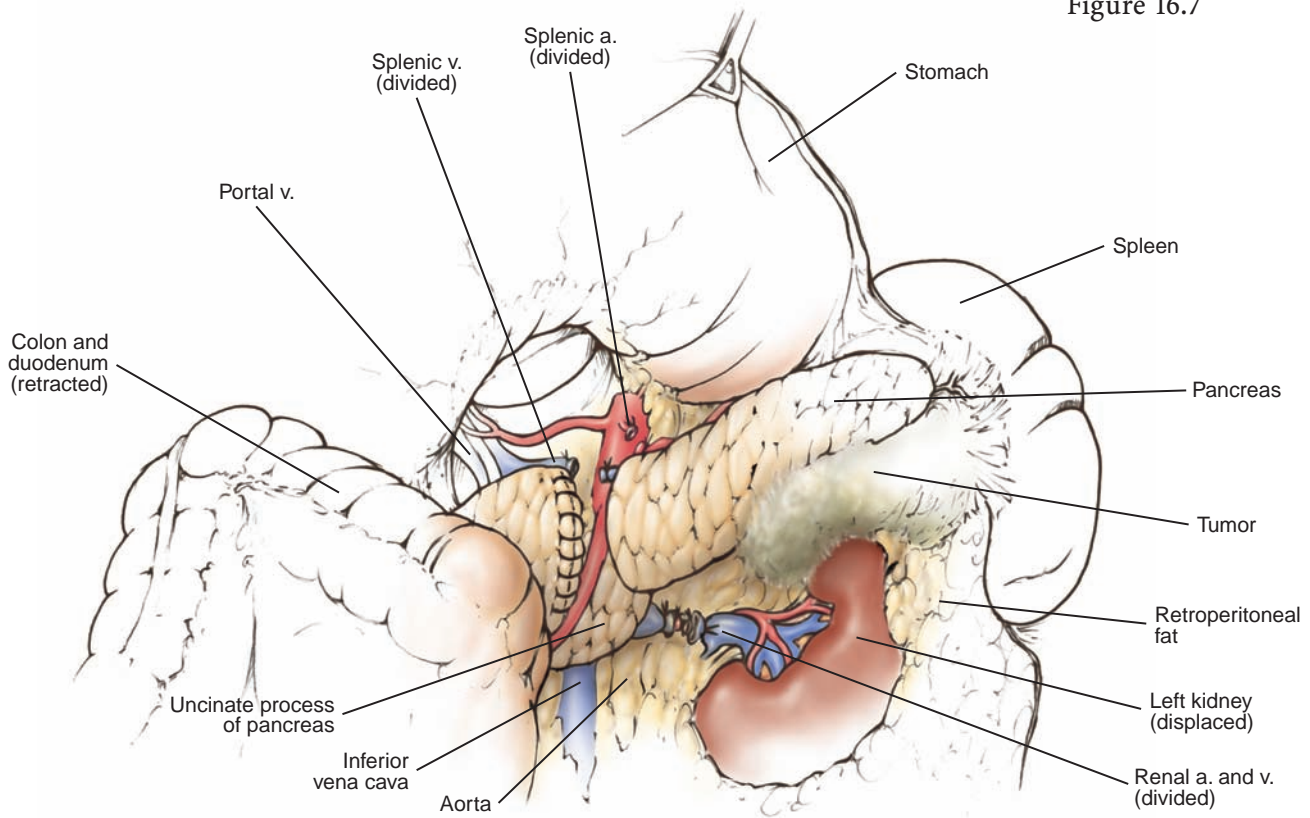
Figure 16.6

The transverse mesocolon is divided lateral to the right branch of the middle colic artery. The transverse colon and the distal ilium are clamped and divided. The medial border of the dissection is defined by exposing the third portion of the duodenum, the vena cava, and the iliac vessels.

The peritoneal reflection of the right colon is incised, and the hepatic flexure of the colon is mobilized caudad. With an extended Kocher maneuver, the duodenum and head of the pancreas are mobilized medially. Attachment of the tumor to the inferior pole of the kidney is confirmed, and the renal artery and the vein are exposed, isolated, and divided. The ureter and the gonadal vein are ligated and divided.

With blunt dissection in the retroperitoneal plane, the sarcoma, kidney, and colon are mobilized free from the posterior abdominal wall. If the tumor is adherent to an area of the posterior abdominal wall muscle, that portion of muscle is excised. The

Figure 16.7



procedure is completed with an ileocolostomy and a repair of the mesenteric window. After a secure hemostasis is confirmed, the abdomen is closed without drains.

The role of laparoscopic surgery in the management of retroperitoneal tumors is limited. As mentioned previously, many of these tumors grow asymptotically and commonly require multivisceral resections. Furthermore, the exposure needed

Minimally Invasive Surgical Techniques

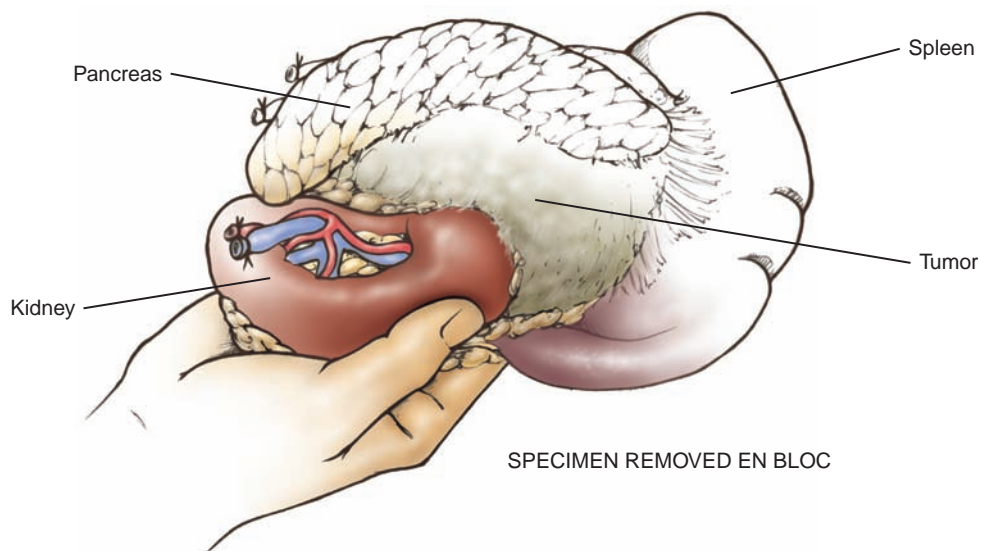
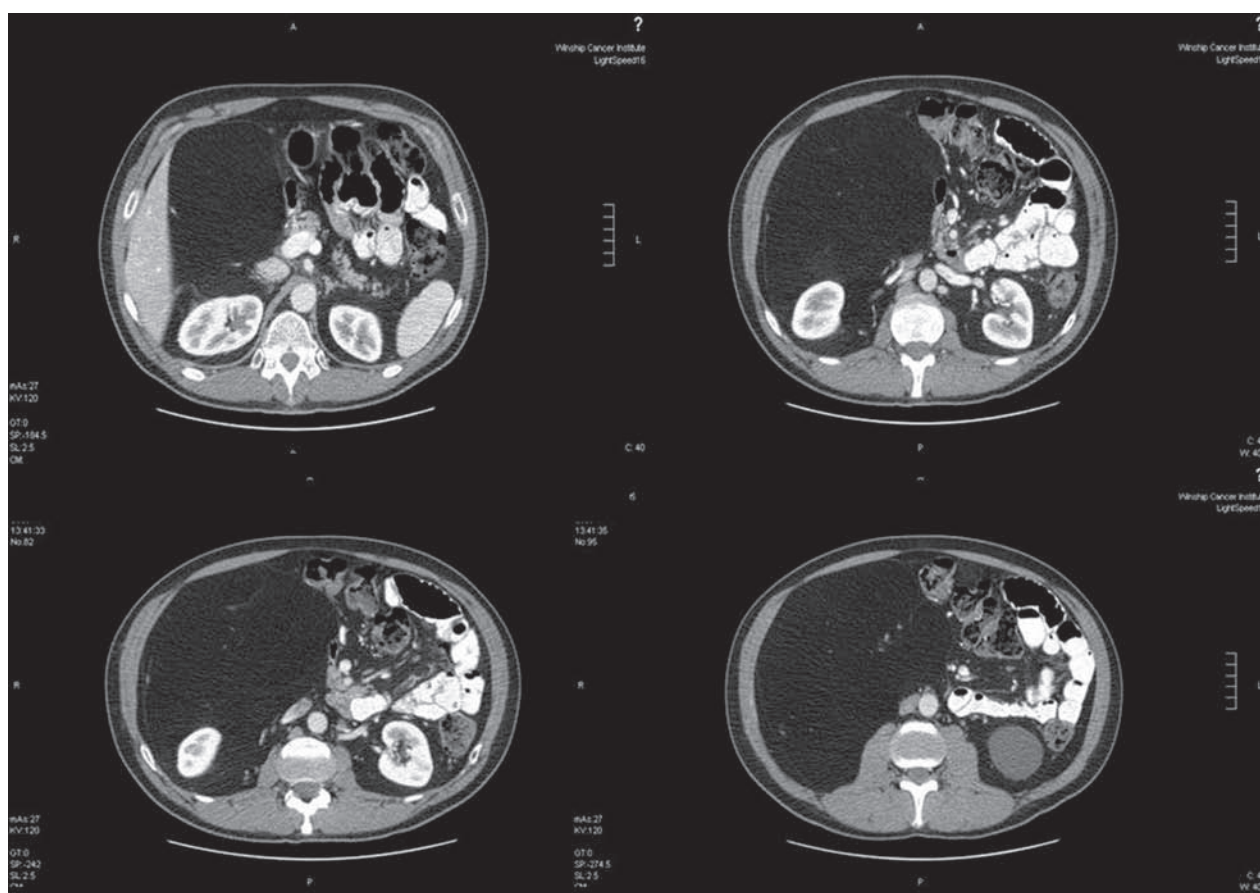
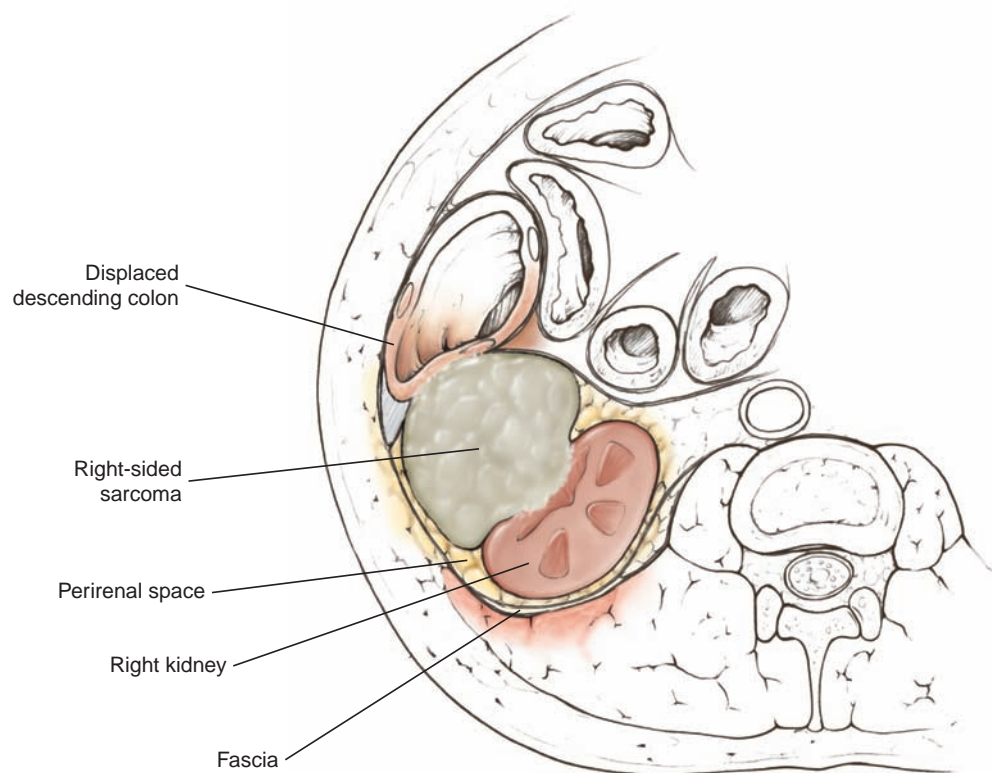


Figure 16.8

Figure 16.9



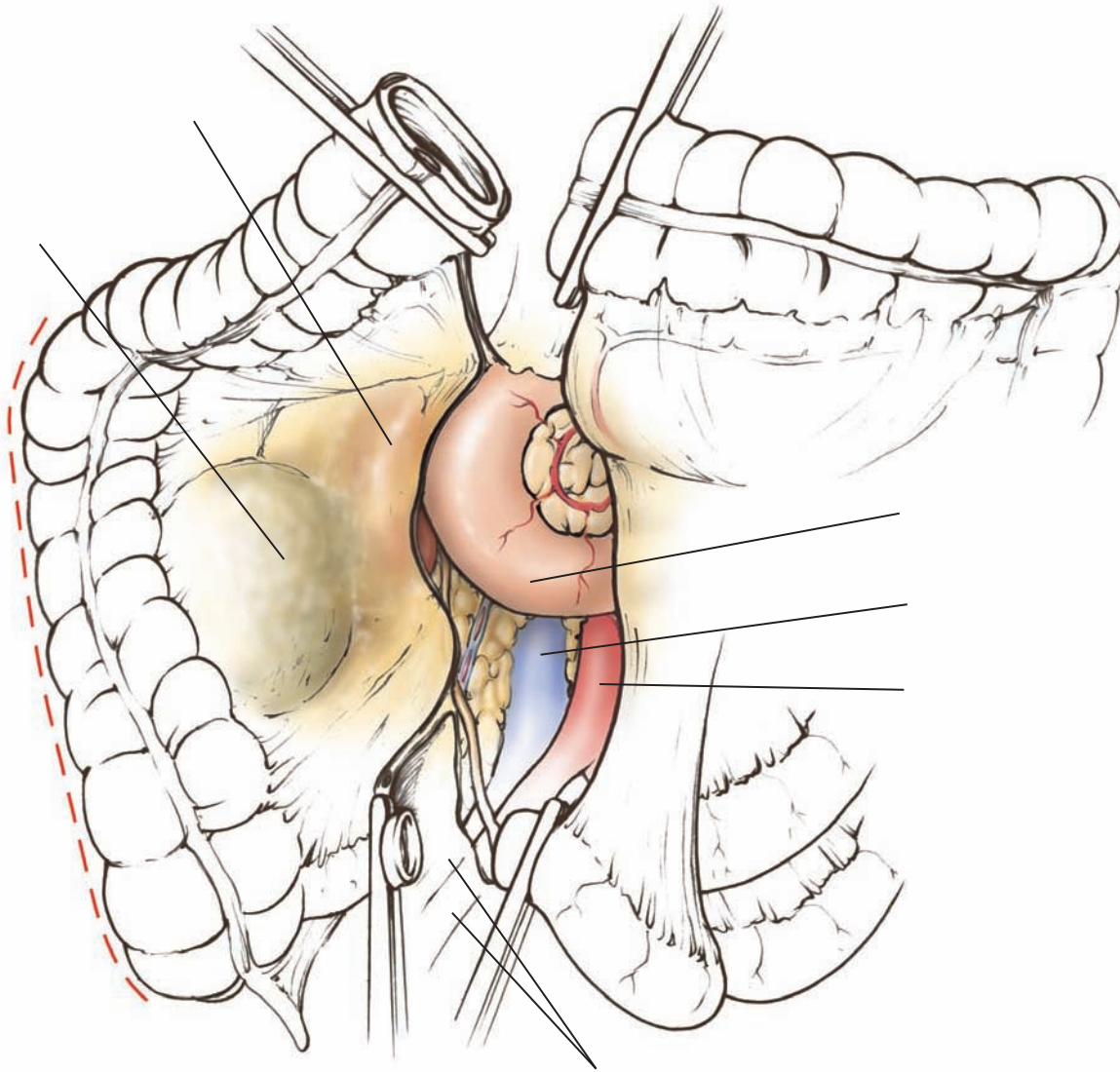


Figure 16.10

to gain access to midline vasculature and simultaneously to the organs supplied by these structures with a large tumor interceding makes laparoscopy fraught with pitfalls. As a result, the utility of minimally invasive approaches for definitive surgical intervention is limited to small, well-encapsulated, often benign (i.e., schwannomas) lesions.

Although laparoscopy is rarely used for definitive treatment of retroperitoneal sarcomas, it has all but eliminated the need for open surgical biopsy, as mentioned above. If core needle biopsy is not possible, or the results are indeterminate, then a minimally invasive approach is preferred over open surgical intervention for diagnosis. Additionally, regional lymphadenectomies, such as the one for genitourinary tumors can be performed via a laparoscopic approach, and this is covered elsewhere in this text.

Figure 16.11

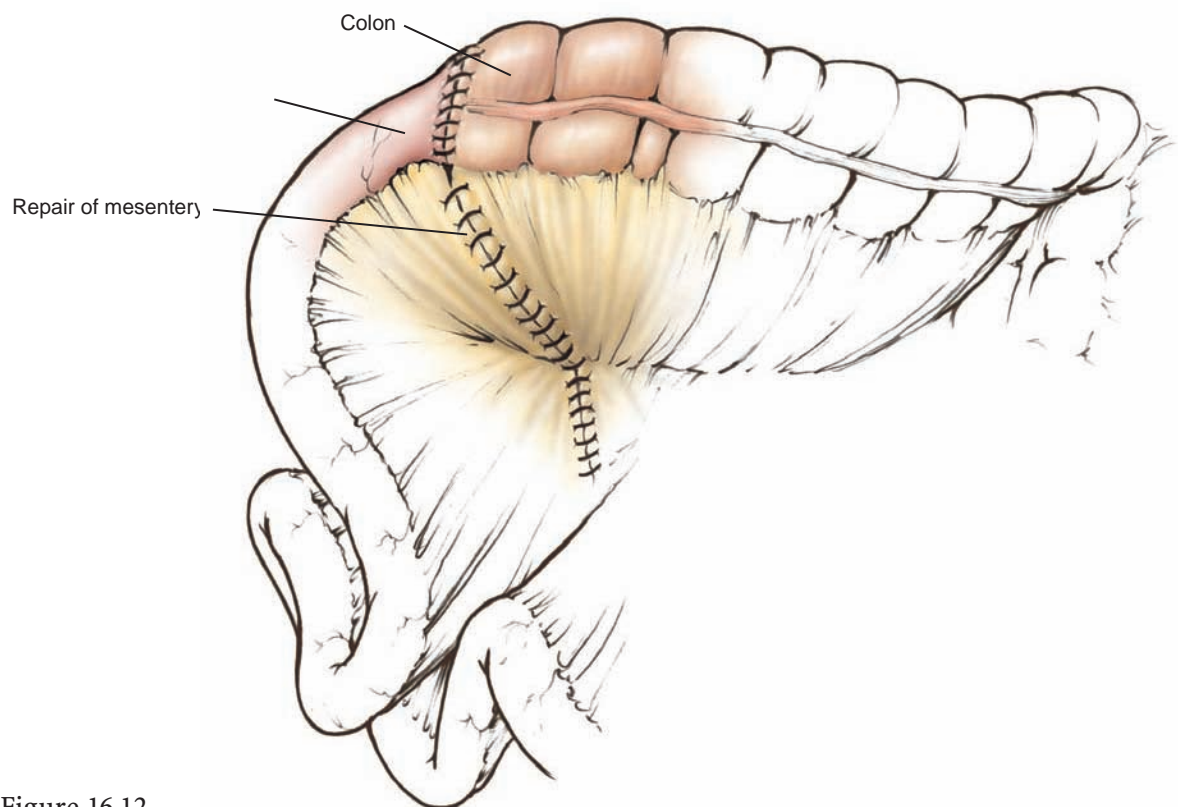
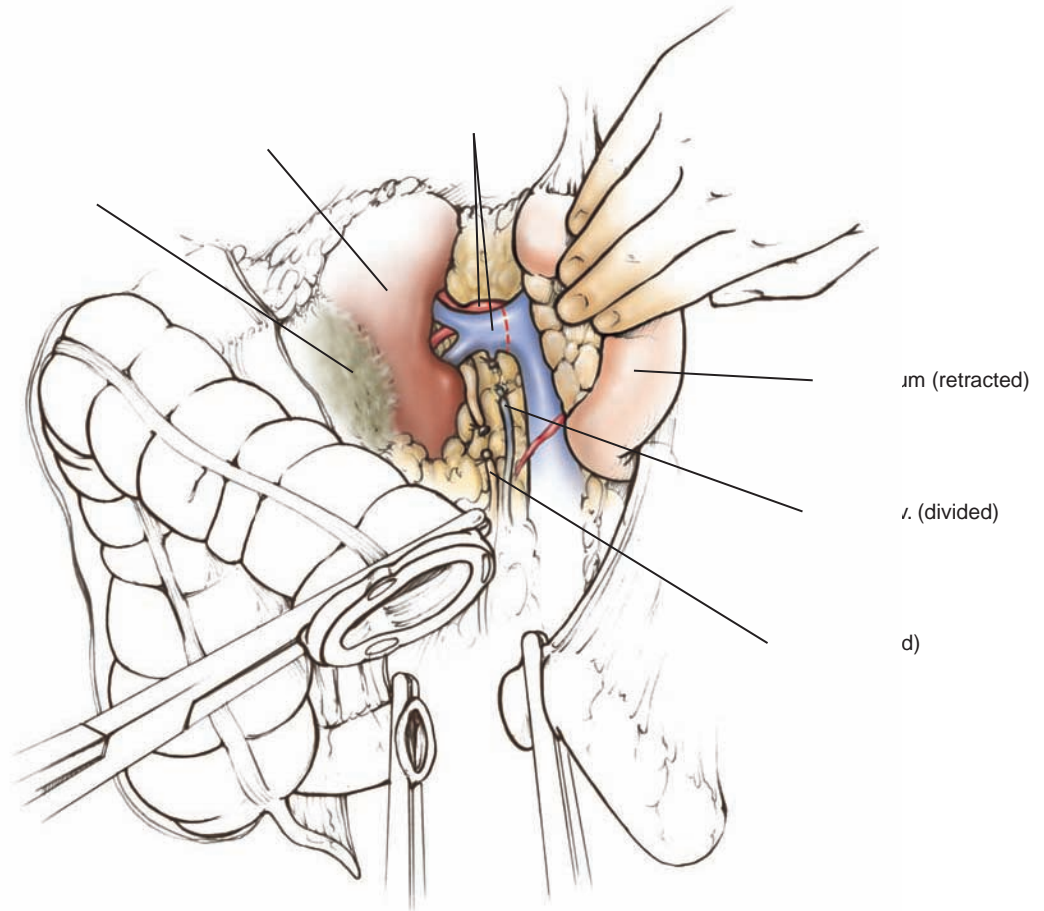


Figure 16.12

Anatomic Basis of Complications

- The most commonly reported major complications of the resection of retroperitoneal sarcomas are intra-abdominal abscess, enterocutaneous fistula, and intra-abdominal bleeding. Specific structures that can be injured include the pancreas, small and large bowels, ureter, retroperitoneal lymphatic vessels, including the cisterna chyli, and retroperitoneal nerves.
- Manipulation of the pancreas may induce pancreatitis. Injury to, or partial resection of, the pancreas that opens the ductal system may lead to a pancreatic leak and fistula.
- Entry into the intestine or compromise of the blood supply to the bowel that is not recognized and satisfactorily repaired can lead to abdominal sepsis or fistula. Sepsis in the area of a major vessel, particularly if the vessel has been injured, may be accompanied by bleeding.
- If an extensive pelvic dissection interrupts the iliac and the pelvic lymphatic vessels, permanent leg edema may develop. Dissection behind the aorta on, or cephalad to, L2 may injure the cisterna chyli or the lymphatic trunk and, if unrecognized, lead to a lymphatic fistula. If necessary, these structures may be ligated with impunity.
- Injury to the ureter may lead to hydronephrosis or urinary fistula.
- Injury to any of the six peripheral nerves coursing through the lumbar space (iliohypogastric, ilioinguinal, genitofemoral, lateral femoral cutaneous, obturator, femoral) can lead to dysesthesia or anesthesia over the cutaneous sensory distribution of the nerve. Injury to the femoral or obturator nerves may, in addition, result in motor loss in the anterior and medial thigh muscles, respectively.
- During extensive retroperitoneal dissection, it is important to maintain the patient's body temperature to prevent the coagulopathy that can occur with hypothermia.

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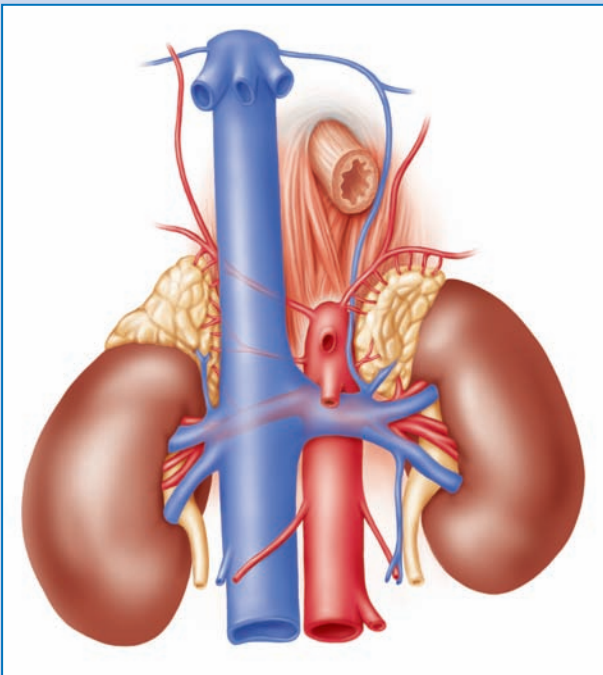
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Adrenal Glands

Roger S. Foster, Jr.,
John G. Hunter,
Hadar Spivak,
C. Daniel Smith,
S. Scott Davis Jr.



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Open Adrenalectomy

**Roger S. Foster Jr, John G. Hunter, Hadar Spivak,
C. Daniel Smith, and S. Scott Davis Jr**

The anterior transabdominal approach was once the standard operative procedure for almost all adrenal lesions. This chapter describes alternative approaches that may provide better exposure for specific types of tumors or permit excision of the adrenal tumor with decreased morbidity. In addition to the anterior abdominal approach, alternative surgical approaches that are discussed include, the posterior approach, posterolateral extraperitoneal approach, thoracoabdominal approach, thoracolumbar approach, and minimally invasive approaches. One of us (R.S.F.) has found each of the open procedures useful for specific adrenal tumors and four of us (J.G.H., H.S., C.D.S., S.S.D.) have performed endoscopic adrenalectomies

Surgical Embryology

Knowledge of adrenal development aids in the understanding of the potential locations of heterotopic adrenal glands and nodules of cortical tissue, as well as the locations of extra-adrenal chromaffin tissue.

The adrenal cortex begins to develop during the fourth or the fifth week of gestation, when coelomic mesothelial cells located at the root of the dorsal mesentery and the developing gonad begin to divide and proliferate. Concordant with the development of the adrenal cortex is the development of the autonomic nervous system and the adrenal medulla.

Ectodermal neural crest cells in the thoracic region migrate ventrally to reside on both sides of the spinal cord just behind the aorta. By caudal and rostral migration, these cells form primitive sympathetic ganglia from T1 to L2. During the migration of the sympathetic neuroblasts to form the sympathetic ganglia, small islands of cells become detached and form independent glandular elements along the vertebral column. Most of these islands of chromaffin cells spontaneously regress. However, a large group of chromaffin cells migrate along the adrenal vein and invade the adrenal cortex, and eventually are surrounded by the primitive adrenal cortex. Preganglionic sympathetic fibers synapse directly on these developing chromaffin cells, which form the adrenal medulla. A second group of neuroblasts form the aortic glands, or the glands of Zuckerkandl. The glands of Zuckerkandl, which have no known function, are located laterally to the aorta at the level of the inferior mesenteric artery. Occasionally, the glands of Zuckerkandl are the sites of development of an extra-adrenal pheochromocytoma or a neuroblastoma.

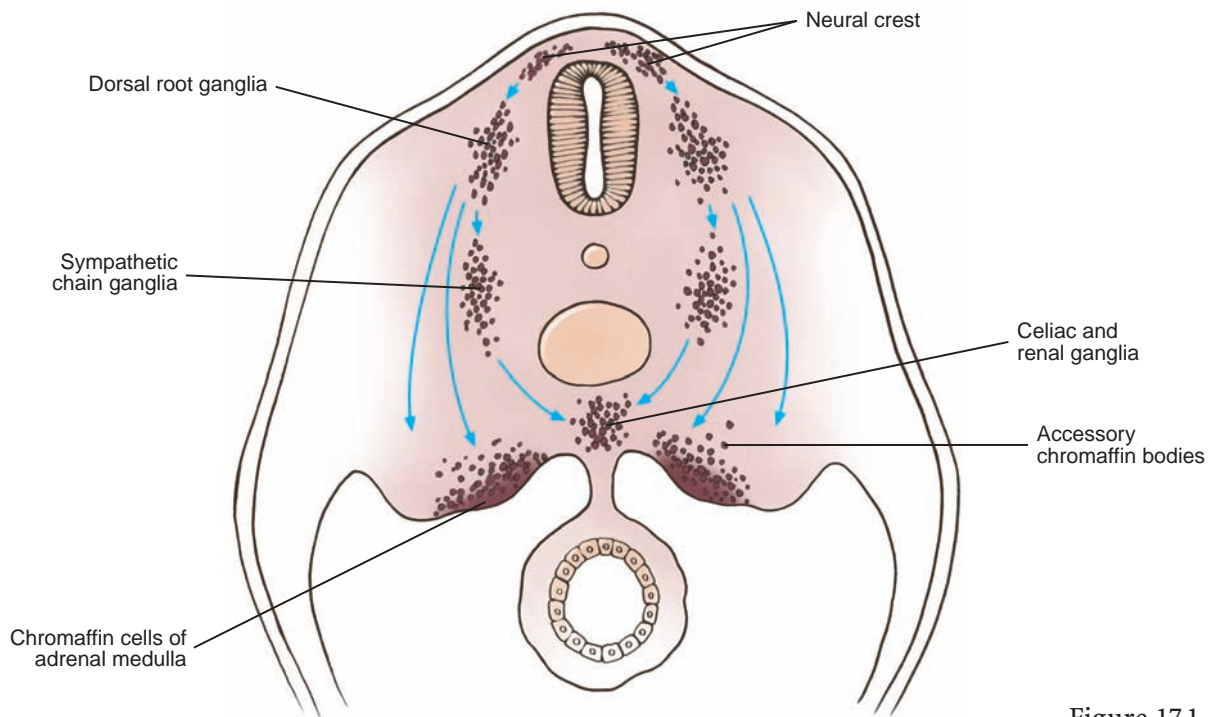


Figure 17.1

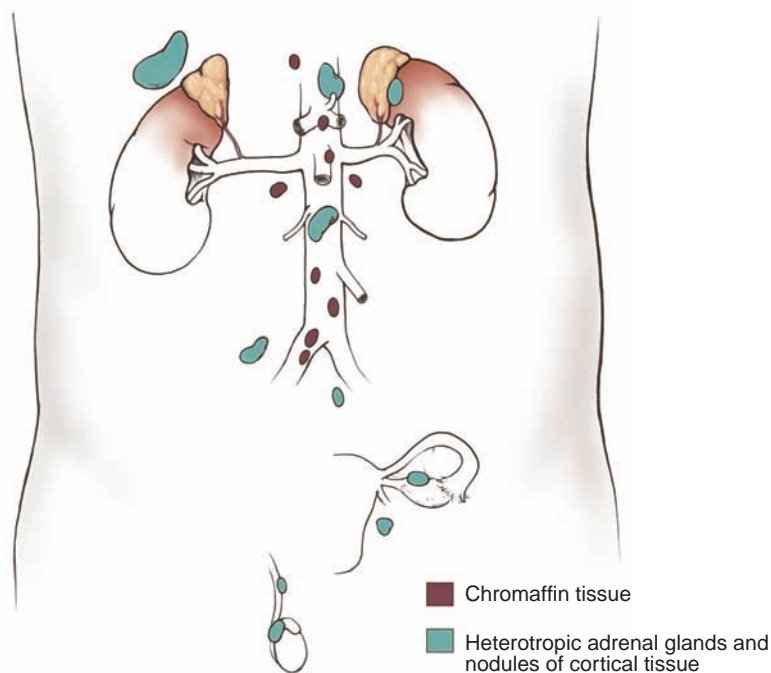


Figure 17.2

Heterotopic adrenal glands and nodules of the cortical tissue may be found at a variety of sites. Occasionally, an otherwise normal adrenal gland is totally separate from the kidney (suprarenal gland). Heterotopic cortical tissue may be found along the course of the aorta, iliac vessels, or gonadal vessels. This heterotopic tissue usually does not have a significant function.

Extra-adrenal chromaffin tissue at the sites of rest of the neuroblasts, along the vertebral column anterior to the aorta, may be the sites of pheochromocytomas, “nonfunctioning” paragangliomas without clinical evidence of hormonal activity, and neuroblastomas.

Surgical Anatomy

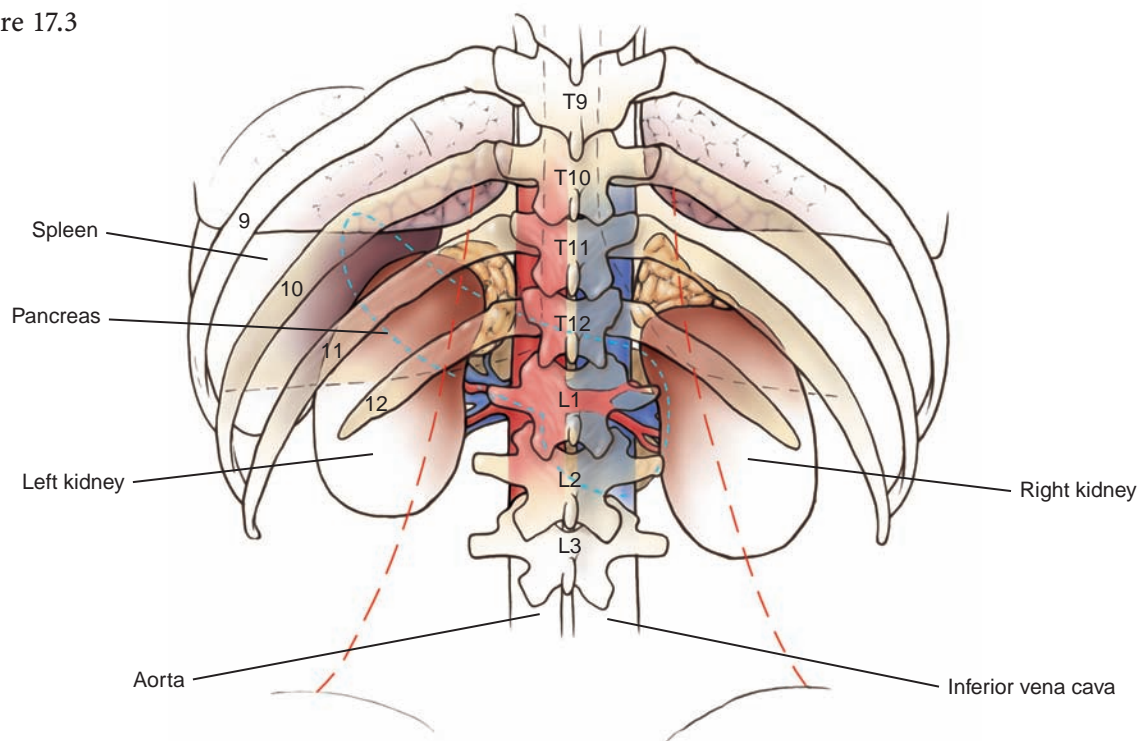
Topography

The adult adrenal glands weigh 4 to 8 g and measure about $4 \times 3 \times 1$ cm. On an average, the adrenal glands are larger in women than in men. They are composed of two distinct and highly specialized endocrine tissues, the cortex and the medulla, which are embryologically, anatomically, biochemically, and pathologically distinct. The cortex is the larger portion, eight to ten times the volume of the medulla.

The cortex is composed of the outer zona glomerulosa, the middle zona fasciculata, and the inner zona reticularis layers. The approximate proportion of the cortex occupied by each zone is 15, 78, and 7%, respectively.

Although a wide variety of steroid molecules are made in the adrenal cortex, only a few hormones are secreted and are biologically active. Aldosterone, the major mineralocorticoid, is made in the zona glomerulosa. The zona fasciculata produces the major glucocorticoid, cortisol, and also smaller amounts of corticosterone and the weak androgen dehydroepiandrosterone (DHEA). The major hormone produced by

Figure 17.3



the zona reticularis is DHEA, but small amounts of glucocorticoids and estrogens are also made here.

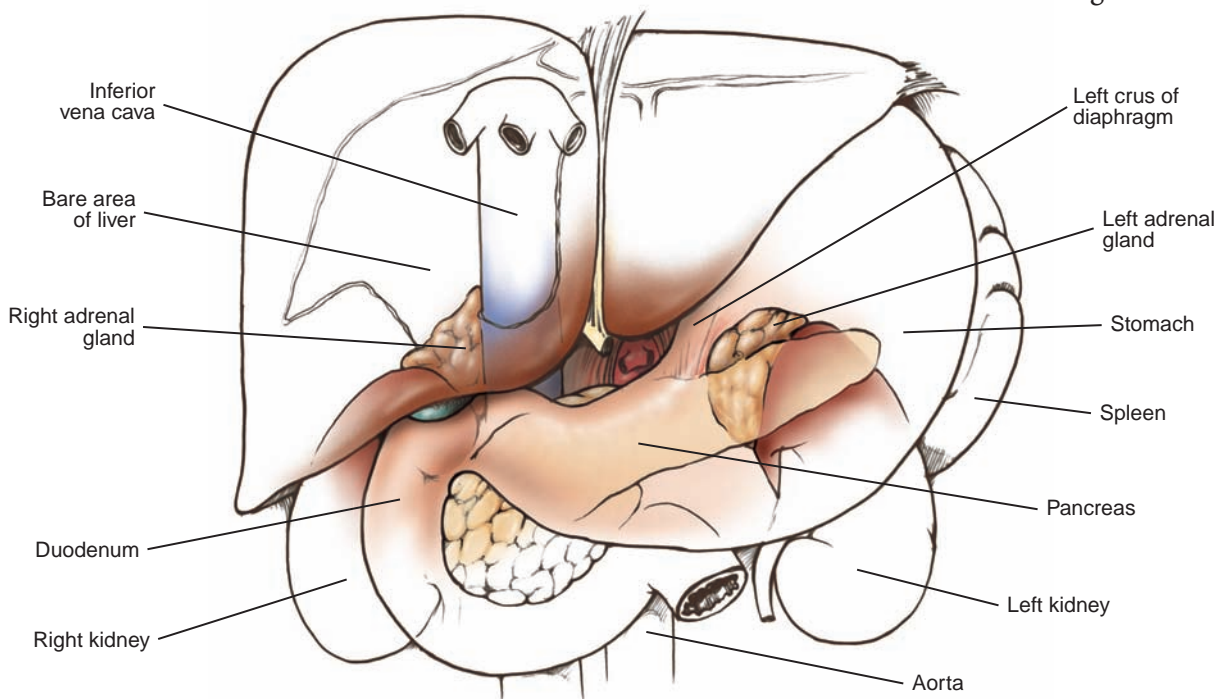
The adrenal medulla, which is surrounded by the adrenal cortex, is composed of chromaffin cells, which synthesize dopamine, epinephrine, and nor-epinephrine.

The adrenal glands lie on the anteromedial surfaces of the kidneys near the superior poles. Both, the adrenal glands and the kidneys are retroperitoneal. The adrenal glands differ in shape. The left adrenal gland is more flattened and is in more extensive contact with the kidney. It may extend onto the medial surface of the kidney, almost to the hilum. The right adrenal gland is more pyramidal and lies higher on the kidney. Because of its shape and location, the right adrenal gland is higher than the left adrenal gland, the reverse of the relative position of the kidneys. Each adrenal gland is covered by a thin capsule-like connective tissue called the stroma.

The adrenal gland, together with the associated kidney, is enclosed in the renal fascia (of Gerota) and is surrounded by fat. This perirenal fat is more yellow and firmer than fat found elsewhere in abdomen.

The adrenal glands are firmly attached to the renal fascia, which in turn is firmly attached to the abdominal wall and to the diaphragm. Several violin string-like cords, as well as arteries and veins are also responsible for holding the adrenal glands in situ. A layer of loose connective tissue separates the capsule of the adrenal gland from that of the kidney. Because of this separation of the kidney and adrenal gland, the kidney may be ectopic or ptotic without corresponding displacement of the gland. However, fusion of the kidneys (horseshoe kidney) is often accompanied by fusion of the adrenal glands. Occasionally, the adrenal gland is fused with the kidney such that

Figure 17.4



separation is almost impossible. Adrenalectomy in such cases requires at least partial nephrectomy.

For all practical purposes, each adrenal gland has only an anterior and a posterior surface. Their relationships to other structures are as follows. For the right adrenal gland, the anterior surface is superiorly in contact with the “bare area” of the liver, medially with the inferior vena cava, laterally with the bare area of right lobe of the liver, and inferiorly there is an occasional contact with the first part of the duodenum and rarely the peritoneum. The posterior surface of the right adrenal gland is superiorly in contact with the diaphragm, and inferiorly with the antero-medial aspect of the right kidney. For the left adrenal gland, the anterior surface is superiorly in contact with the peritoneum (posterior wall of the omental bursa) and the stomach, and inferiorly with the body of the pancreas. The posterior surface is in contact medially with the left crus of the diaphragm and laterally with the medial aspect of the left kidney.

The medial borders of the right and left adrenal glands are about 4.5 cm apart. In this space, from right to left, are the inferior vena cava, the right crus of the diaphragm, part of the celiac ganglion, the celiac trunk, the superior mesenteric artery, part of the celiac ganglion, and the left crus of the diaphragm.

Important aspects of adrenal anatomy include the following:

1. For all practical purposes, the right adrenal gland is located posterior to the duodenum and the right lobe of the liver.
2. The medial part of the right adrenal gland is often related to the inferior vena cava.
3. The right adrenal vein is short and enters the posterolateral surface of the vena cava, and thus may be difficult to ligate.
4. The right adrenal gland is anterior to the diaphragmatic and pleural reflections.
5. The left adrenal gland is located posterior to the stomach and the pancreas and medial to the splenic portas.
6. The left adrenal gland is located inferior to the reflections of the diaphragm and pleura.
7. The left adrenal gland is related to the medial aspect of the upper pole of the left kidney, occasionally extending to the left renal vascular pedicle.

Blood Supply

The adrenal glands vie with the thyroid gland for having the greatest blood supply per gram of tissue. The arterial supply to the adrenal glands is from three general sources:

1. A group of six to eight arteries arises separately from the inferior phrenic arteries. One artery may be larger than the others or all may be of similar size.
2. A middle adrenal artery arises from the aorta at or near the level of the origin of the superior mesenteric artery. It may be single, multiple, or absent and may supply only the perirenal fat.
3. One or more inferior adrenal arteries arise from the renal artery, an accessory renal artery, or a superior polar renal artery. Small twigs may arise from the upper ureteric artery.

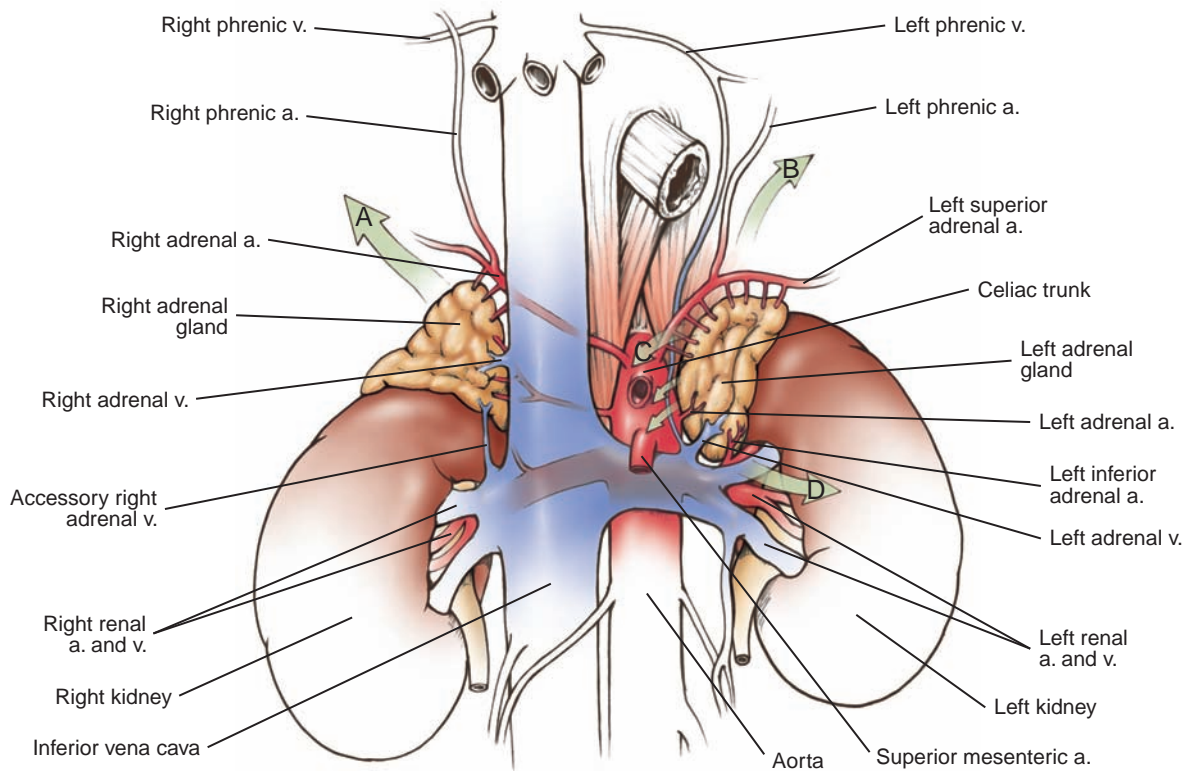


Figure 17.5

All of these arteries branch freely before entering the adrenal gland; thus 50–60 small arteries penetrate the capsule over the entire surface.

The adrenal venous drainage does not accompany the arterial supply and is much simpler. Usually a single vein drains the adrenal gland, emerging at the hilum. The left adrenal vein passes downward over the anterior surface of the gland and is joined by the left inferior phrenic vein before entering the left renal vein. The short right adrenal vein passes obliquely to open into the inferior vena cava posteriorly. It does not have any tributaries. Occasionally there are two veins, one having a normal course and the accessory vein entering the inferior phrenic vein. Accessory veins have been encountered several times in our 40 years in the dissecting room.

When using the posterior approach to the adrenal gland, the left adrenal vein is found on the anterior surface of the gland. The right adrenal vein is found between the inferior vena cava and the gland. Careful mobilization of the gland is necessary for good ligation of the vein.

The lymphatic vessels of the adrenal gland consist of a subcapsular plexus that drains with the arteries and a medullary plexus that drains with the veins. Lymphatic drainage from both adrenal glands is to renal hilar nodes, periaortic nodes, and by way of the diaphragmatic orifices for the splanchnic nerves to nodes of the posterior mediastinum, above the diaphragm. Rouviere stated that lymphatic vessels from the upper pole of the right adrenal gland may enter the liver.

Lymphatic Drainage

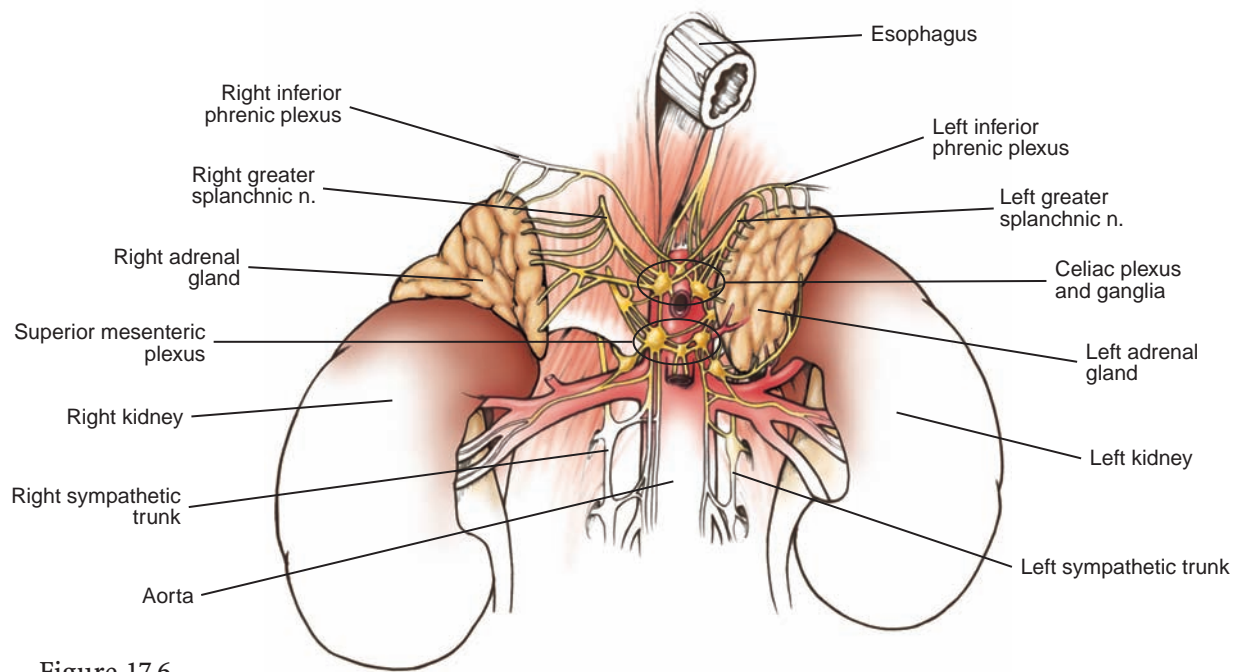


Figure 17.6

Nerve Supply

The adrenal cortex appears to have only vasomotor innervation. Most of the fibers, which reach the gland from the splanchnic nerves, lumbar sympathetic chain, celiac ganglion, and celiac plexus go to the medulla. These nerve fibers are preganglionic and end on the medullary chromaffin cells. This arrangement is not as anomalous as it might appear; chromaffin cells arise from the same embryonic source as do the postganglionic neurons elsewhere. Most of these preganglionic fibers in humans are nonmyelinated.

Surgical Applications

The anterior approach for adrenalectomy may be preferred when the adrenal disease is bilateral (10% of patients), the tumor is larger than 10 cm, or the adrenal tumor has invaded the surrounding structures. Both the glands can be inspected, palpated, or biopsied with the anterior approach. In spite of these advantages, improvements in preoperative diagnosis, such as computed tomography (CT), adrenal scintigraphy, and selective adrenal venous sampling, have increased the use of other approaches. The evolving procedure of minimal access endoscopic adrenalectomy may prove to have the lowest morbidity. Of the open adrenalectomy approaches, the posterior approach has the least postoperative morbidity. The posterolateral extraperitoneal approach also has a relatively lower morbidity than transabdominal or thoracoabdominal approaches. The thoracolumbar approach through the chest and then through the diaphragm is relatively well tolerated for large high-lying tumors.

Under rare circumstances, thoracoabdominal and abdominosternal approaches may be necessary for large tumors, tumors with nodal metastases, or tumors that have invaded adjacent organs or the vena cava. A few surgeons have developed the skills to remove benign adrenal tumors endoscopically.

The incision chosen for the anterior approach may be midline, transverse, chevron, or extended Kocher. The use of a table-attached retractor, such as the upper hand retractor, greatly improves exposure and decreases the necessity of using a thoracoabdominal incision.

Anterior Approach

Exposure of the left adrenal gland usually begins with an incision of the posterior parietal peritoneum lateral to the left colon. The incision is carried upward, dividing the splenorenal ligament. Care must be taken to prevent injury to the spleen or the splenic capsule, or to the splenic vessels and the tail of the pancreas. The latter are enveloped by the splenorenal ligament.

Exposure and Mobilization of the Left Adrenal Gland

Another approach to the left adrenal gland is by opening the lesser sac through the gastrocolic omentum, which may be incised longitudinally outside the gastroepiploic arcade. Care must be taken to prevent traction on the spleen or on the splenocolic ligament. The ligament may contain tortuous or aberrant inferior polar renal vessels or a right gastroepiploic artery.

A third approach to the left adrenal gland, which may occasionally be useful when an adrenal lesion is anterior, is to gain exposure by an oblique incision of the

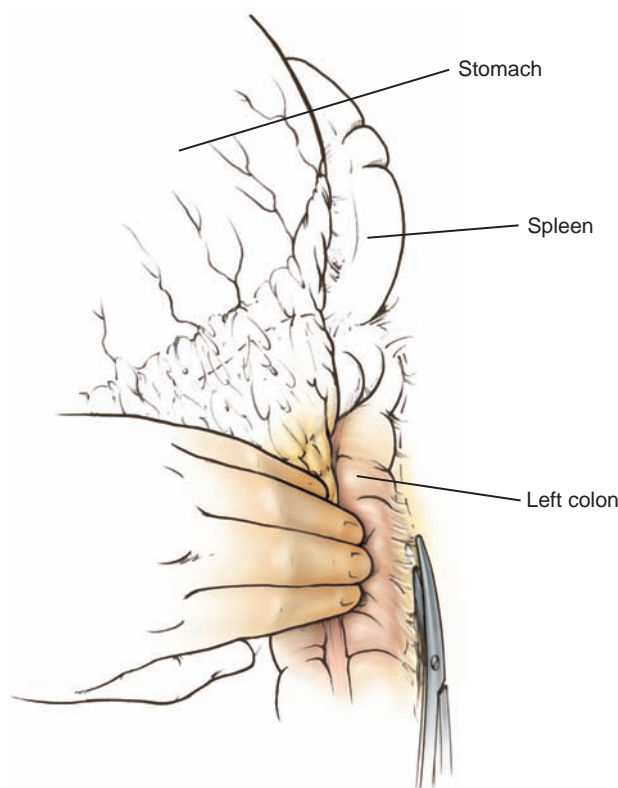


Figure 17.7

Figure 17.8

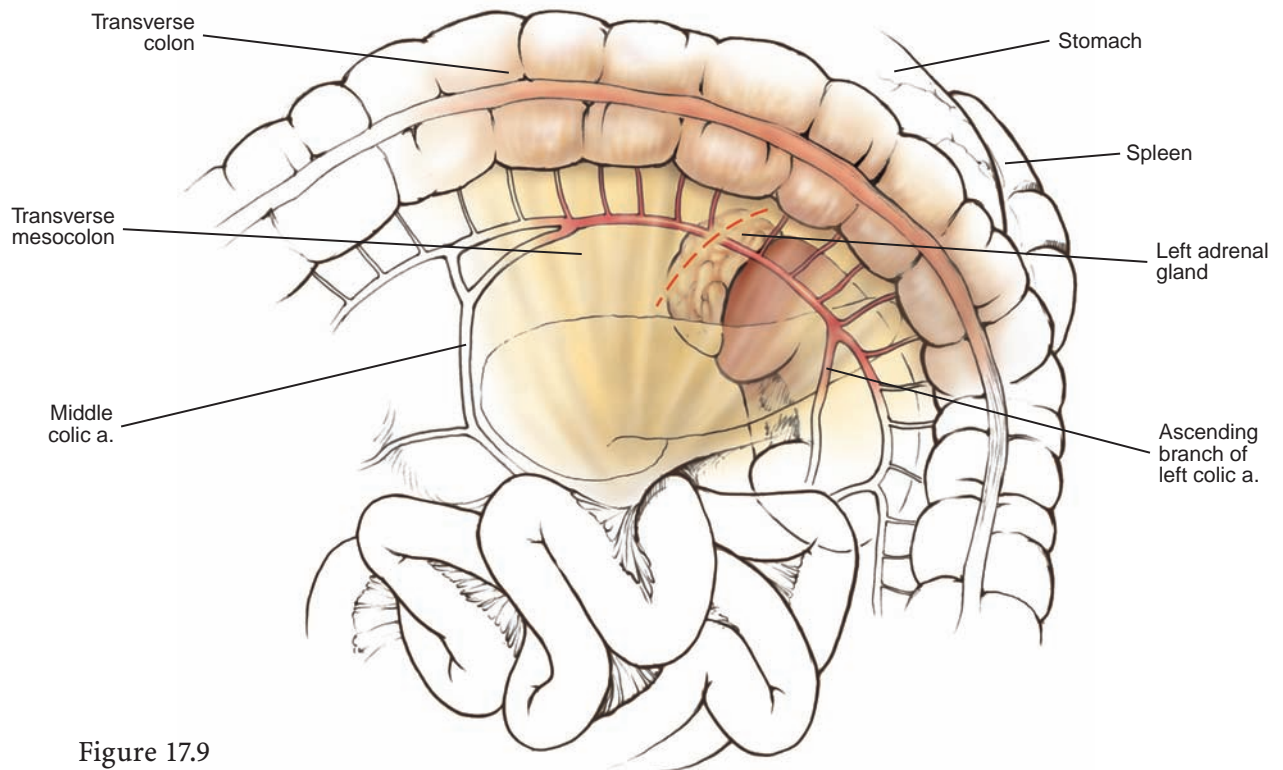
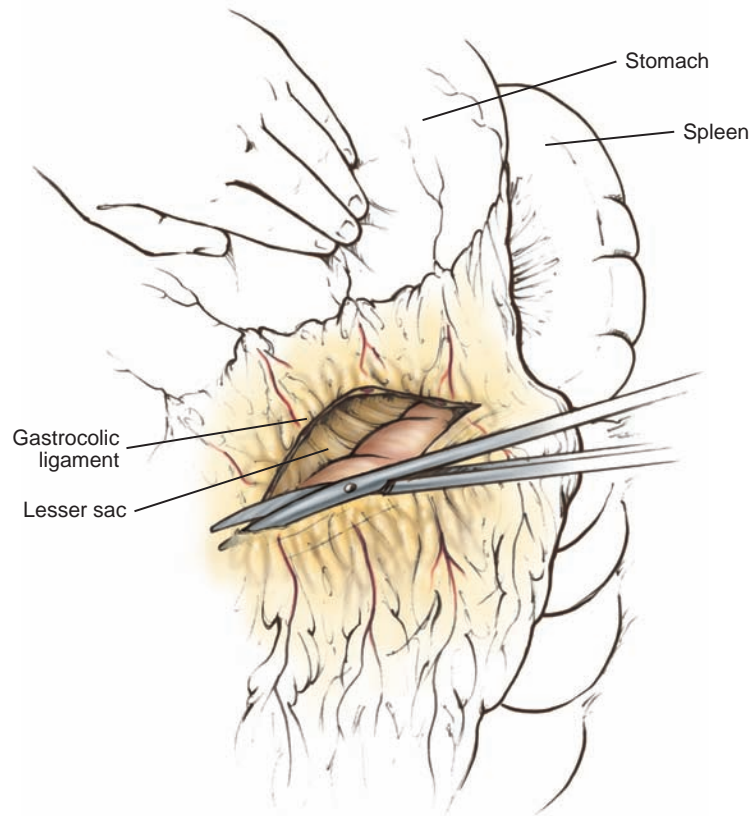


Figure 17.9

left mesocolon. The arcuate vessels may be divided, but the major branches of the middle and the left colic arteries must be preserved. Taking care to avert excessive retraction will prevent injury to the wall of the left colon.

Following any of the approaches to get an exposure posterior to the colon, the peritoneum under the lower border of the tail of the pancreas is incised medially about 10 cm. The pancreas can then be gently retracted upwards, preventing injury. This maneuver will expose the left adrenal gland on the superior pole of the left kidney, both of which are covered with the renal fascia (of Gerota). The gland will be lateral to the aorta, about 2 cm cranial to the left renal vein. Incision of the renal fascia completely exposes the adrenal gland and permits access to the adrenal vein. If the operation is to remove a pheochromocytoma, the adrenal vein should be ligated first to decrease the release of catecholamines into the circulation, during subsequent manipulation of the gland. Retraction on the mesocolon must be gentle to prevent tearing the inferior mesenteric vein from the splenic vein. Although the inferior mesenteric vein may be ligated without sequelae, it is prudent to avoid this complication if possible.

In some lesions with high metabolic rates, such as primary aldosteronism, the adrenal gland is hypervascular and friable and so, meticulous attention to hemostasis is essential. The adenoma may be disguised or mimicked by hematomas caused by “operative trauma.” The surgeon may use part of the adjacent periadrenal fascia to manipulate the gland. Manipulation should be done with fine forceps only. Hemostasis from the numerous arteries can be maintained by clips, ligatures, or electrocoagulation.

Dissection should start at the inferolateral aspect of the left adrenal gland and proceed superiorly. The surgeon should keep in mind the possible presence of a superior renal polar artery. The adrenal gland may be retracted superiorly. Remember that the left adrenal gland extends downward, close to the left renal artery and the vein.

After the removal of the adrenal gland, its bed should be inspected for bleeding points. Surrounding organs, especially the spleen, should be inspected for injury. Splenic injury may be repaired with sutures over a piece of retroperitoneal fat, gelatin sponge (Gelfoam), or Avitene. More severe injury may require partial or even total splenectomy.

Anatomic Basis of Complications

- The inferior mesenteric vein may be avulsed by excessive traction at its junction with the splenic vein. Bleeding is difficult to control, and the vessel may have to be ligated.
- The middle and left colic arteries, or their larger branches, may be severed by sharp dissection through the left mesocolon. A segmental colectomy may be necessary if the blood supply is compromised.

Vascular Injury

- Superior renal polar arteries are present in about 15% of patients. Their position, superior to the renal arteries, renders them vulnerable. They may be ligated if necessary.
- The left adrenal gland extends down the medial surface almost to the hilum and so injury to the renal vessels while mobilizing the gland is possible. Careful repair is required. If repair is not possible, nephrectomy may be necessary. Remember, however, that the left kidney may be saved if the left renal vein is ligated proximal to its junction with the adrenal and the gonadal veins. If ligation is distal to these tributaries, venous infarction will occur, and repair of the vein or nephrectomy is mandatory. If nephrectomy is performed, the renal and gonadal veins should be ligated separately. Extensive experience has demonstrated that major divisions of the renal vein at the hilum may be ligated with impunity. The intrarenal collateral circulation will compensate for segmental venous ligation.

Organ Injury

- Excessive traction on the spleen with the tearing of the capsule is the greatest single operative risk in anterior left adrenalectomy. Splenic injury requiring splenectomy has been reported in up to 20% of adrenalectomies. It is believed that the splenic injury rate should be much lower. When there is injury to the spleen, repair or partial splenectomy should be performed whenever possible.
- The pancreatic parenchyma may be injured during upward reflection of the organ. This may lead to postoperative pancreatic pseudocysts or clinical pancreatitis. Injury to the tail of the pancreas requires ligation and drainage or ligation, resection, and drainage. If injury to the inferior border is minor, drainage is required, if major, repair and drainage or resection of the entire distal pancreas and drainage is required.
- Sharp dissection of the inferior medial margin of the left adrenal gland can injure the capsule of the left kidney. Capsular tears need not be repaired, but parenchymal injuries should be repaired.
- Incision of the left mesocolon or excessive retraction of the colon could injure the colon wall or even perforate it.

Exposure and Mobilization of the Right Adrenal Gland

On the right, the anterior approach to the adrenal gland begins with the mobilization of the hepatic flexure of the colon. Sharp dissection is necessary to divide the posterior adhesions of the liver to the peritoneum. Remember that medial attachments may contain hepatic veins.

Mobilization of the colon will expose the duodenum. The second portion of the duodenum is freed by incision of its lateral, avascular peritoneal reflection. It may now be separated from retroperitoneal structures and reflected forward and to the left (Kocher maneuver).

Mobilization of the hepatic flexure of the colon and the Kocher maneuver on the duodenum will expose the vena cava, the right adrenal gland, and the upper pole of the right kidney. The surgeon must remember that the common bile duct and the gastroduodenal artery are also in this area.

Unlike the left adrenal gland, the right gland rarely extends downward to the renal pedicle. The right adrenal vein usually leaves the gland on its anterior surface

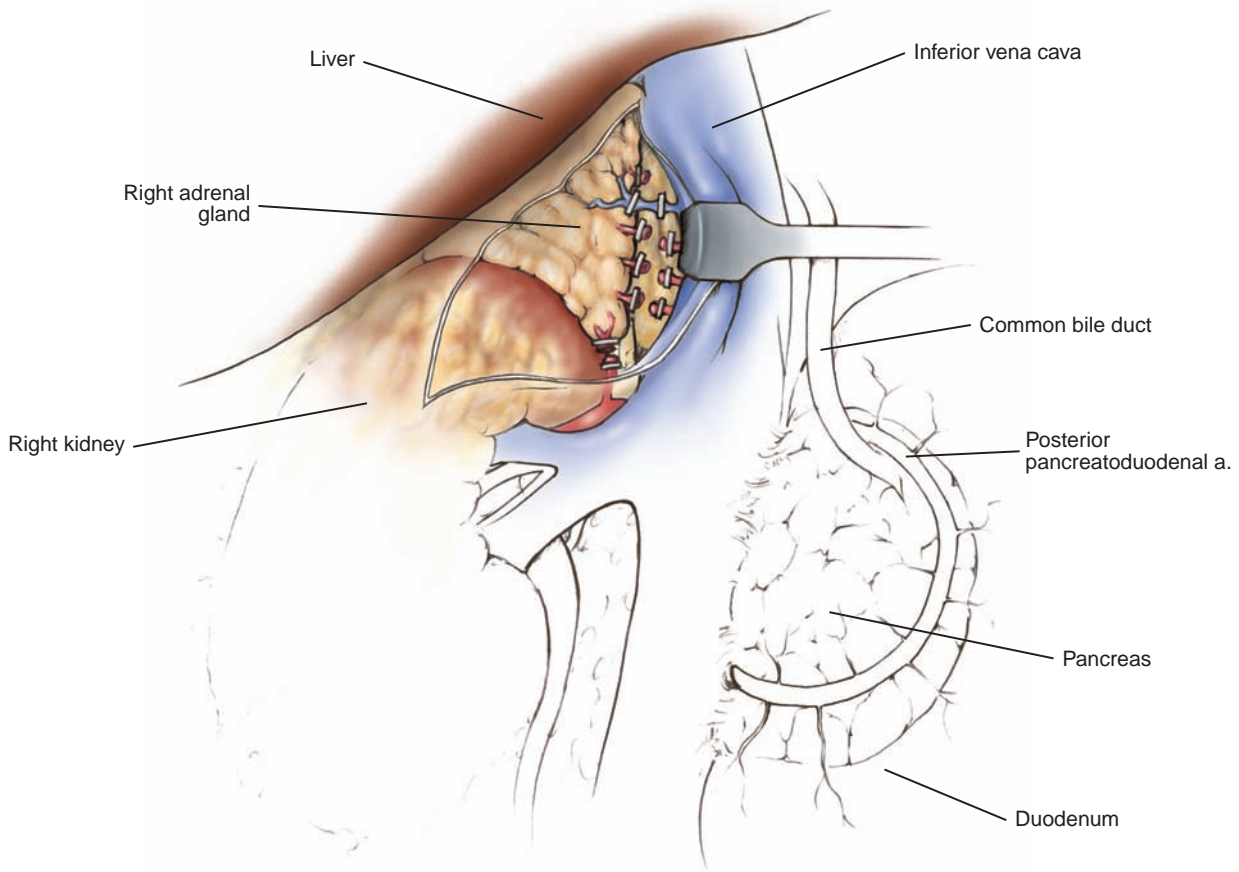


Figure 17.10

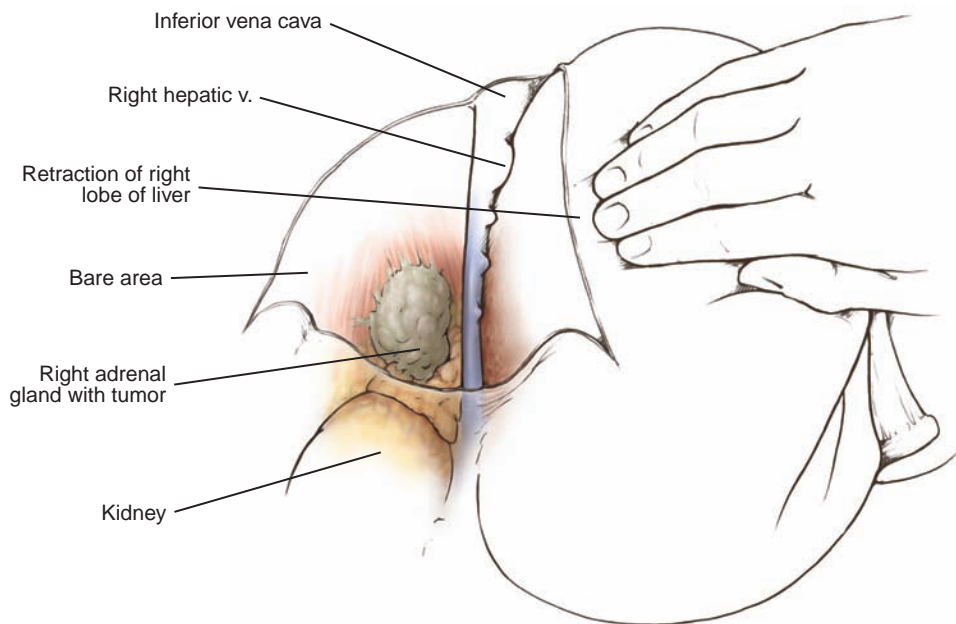


Figure 17.11

close to the cranial margin and enters the vena cava on its posterior surface. Rather than attempting to expose the right adrenal vein by retracting the adrenal gland laterally and inferiorly, the vena cava should be dissected away from the gland. To prevent the release of catecholamines, when operating on a pheochromocytoma, hemostatic clips should be placed as soon as both the borders of the vein are visible. Excessive stretching of the vein invites hemorrhage from the vena cava.

If the adrenal tumor is large or is obscured by the right lobe of the liver, additional exposure can be gained by reflecting the right lobe of the liver medially. The falciform and the triangular ligaments are incised anteriorly, laterally, and superiorly. Dissection of the bare area of the right lobe of the liver permits reflection of the right lobe medially. Care must be taken not to injure the right hepatic vein.

Anatomic Basis of Complications

Vascular Injury

- Remember that the medial posterior attachments of the liver contain the hepatic veins and so it should be retracted with care. The right hepatic vein may be ligated. Hepatic resection after major hepatic vein ligations is necessary in some animals but not in humans.
- Aggressive lateral retraction of the adrenal gland should be avoided. Traction on the right adrenal vein may rupture the vena cava; hemorrhage here is difficult to control and so immediate repair is necessary.
- As on the left, the occasional superior renal polar artery lies close to the operative field and may be injured. If injured, it may be ligated.
- The gastroduodenal artery should be identified and avoided during the Kocher maneuver. If injured, ligation is necessary.

Organ Injury

- Injury to the liver may result from excessive retraction. Pressure, cautery, Gel-foam, or Avitene may be used for repair.
- Mobilization and reflection may injure the duodenum and result in catastrophic postoperative duodenal fistula. Avoid harp dissection and be prepared to repair any defect.

Posterior Approach

Exposure and Mobilization of the Adrenal Gland

The posterior approach may be used for any adrenalectomy unless a large or ectopic tumor is a strong possibility.

With the patient in the prone position, a curvilinear incision is made through the latissimus dorsi muscle to the posterior lamella of the lumbodorsal fascia. This exposes the sacrospinalis muscle. Lumbar cutaneous vessels must be ligated or cauterized. The usual posterior approach is through the bed of the twelfth rib. Some surgeons have advocated removing the eleventh rib in approaching the right adrenal

gland. However, dissecting the pleural fold and preventing the pneumothorax is more difficult through the eleventh rib bed.

The sacrospinalis muscle attachments to the dorsal aspect of the twelfth rib should be detached, exposing the rib. The rib must be removed subperiosteally to avoid damaging the underlying pleura. The periosteum should be stripped on the superior surface from medial to lateral and on the inferior surface from lateral to medial. Injury to the twelfth intercostal nerve bundle at the inferior angle of the rib should be avoided. The nerve is separate from but parallel to the blood vessels. The vessels may be ligated if necessary.

The pleura must be separated from the upper surface of the diaphragm, and the diaphragm should be incised from lateral to medial. Gerota's fascia may be opened, and the upper pole of the kidney identified. Inferior retraction of the kidney will usually bring the adrenal gland into the field. Care must be taken to avoid tearing the renal capsule or stretching a possible superior polar artery.

Dissection of the left adrenal gland should begin on the medial aspect, with clips applied to the arteries as they are encountered. Remember that the pancreas lies just beneath the gland and is easily injured. The last step in the posterior approach is to identify the left adrenal vein, which usually emerges from the medial aspect of the gland and courses obliquely downward to enter the left renal vein. Undue traction on the gland can tear the renal vein.

The right adrenal gland is approached by retracting the superior pole of the right kidney inferiorly. The posterior surface of the adrenal gland can then be dissected free from fatty tissue. The liver must be retracted upward as the apex of the gland is reached. The lateral borders are freed, leaving only the medial margins to remain attached.

The right adrenal gland should be retracted laterally, and the arterial branches from the aorta and the right renal artery to the gland, should be ligated. The right adrenal vein should also be ligated. We recommend freeing up the vena cava far enough to ensure room for an angle clamp, should hemorrhage from the vena cava or adrenal vein require it. After removal of the gland, careful inspection for air leaks and bleeding should be made before closing the incision.

Anatomic Basis of Complications

- Vascular injury with bleeding can be difficult to manage through the limited exposure of the posterior approach. If necessary, extra exposure can be obtained by extending the incision cephalad, at the lateral edge of the sacrospinalis muscle, and transecting the eleventh rib, the pleura, and the diaphragm. Transection of the tenth rib should give additional exposure if necessary.
- As in other approaches, the superior renal polar arteries, which are inconstant, are vulnerable to inadvertent injury. They may be ligated if necessary.

Vascular Injury

- A hepatic vein lies just cephalad to the right adrenal vein. It may be torn by excessive traction, and may be ligated if necessary.
- In a right adrenalectomy, the vena cava may be injured by retraction or sharp dissection. Such injury must be repaired.

Organ Injury

- The pleura at the twelfth rib must be identified and pushed out of the way. If perforation occurs, evacuation of air from the pleural cavity by a catheter with pulmonary inflation will be necessary. If possible, the pleural defect should be repaired.
- The twelfth intercostal nerve should be protected. Its injury will result in annoying postoperative hypesthesia.
- Excessive retraction may tear the renal capsule and should be repaired if necessary.
- Remember that in the posterior approach the pancreas lies just beneath the adrenal gland.

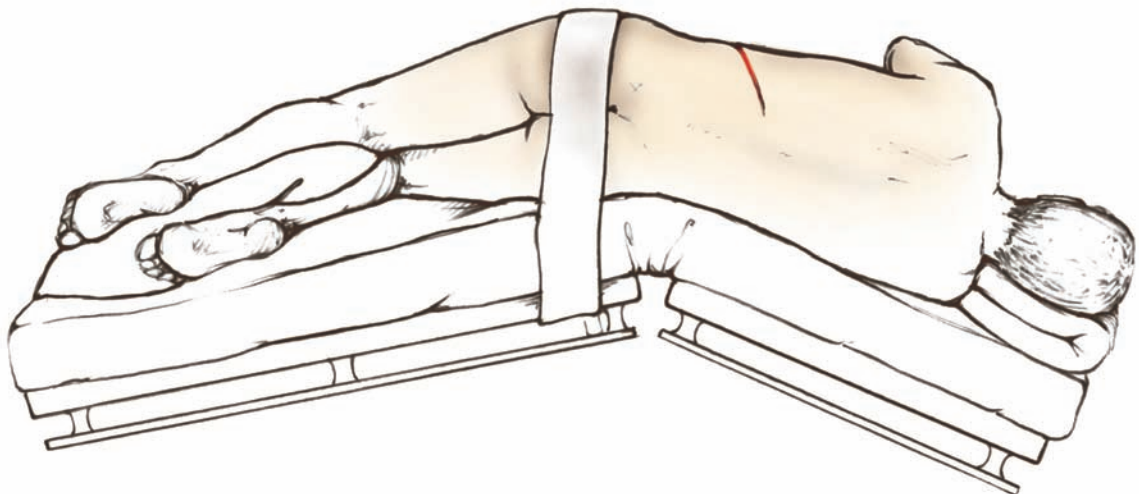
Posterolateral Extraperitoneal Approach

The extrapleural, extraperitoneal, eleventh rib resection approach is an excellent approach for either left or right adrenal tumors, when the tumors are judged to be too large (>4 cm) to resect through the posterior approach.

The patient is positioned in the lateral decubitus position with the flank area over the break in the table, with appropriate support in the axilla and a pillow between the knees.

The incision is made over the eleventh rib through the latissimus dorsi muscle and external oblique muscle, and the rib is excised after the periosteum has been stripped. The incision is then carried through the periosteal bed and the internal oblique muscle with care to push the peritoneum and the structures within it, medially. With dissection from lateral to medial along the posterior abdominal and diaphragmatic musculature, Gerota's fascia containing the kidney and the adrenal gland is swept medially and traction is maintained on the kidney in an inferomedial

Figure 17.12



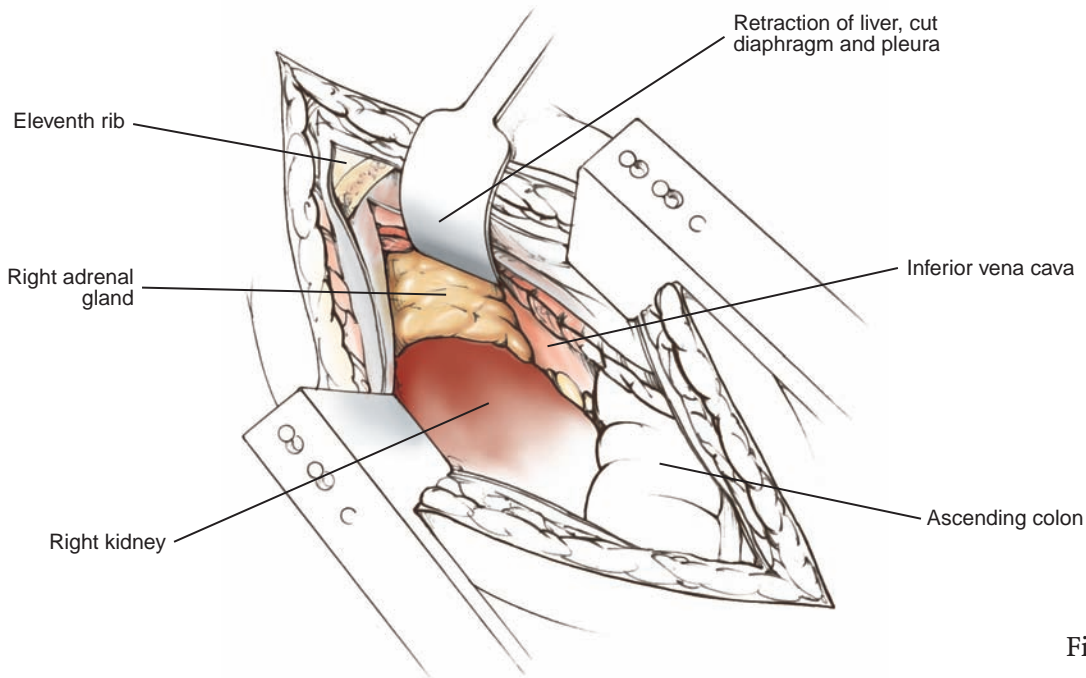


Figure 17.13

direction. To maintain the usefulness of traction on the kidney for exposure, dissection of the inferior surface of the adrenal gland, off the kidney is the last part of the adrenalectomy.

For the resection of the right adrenal gland, the liver within the peritoneum is retracted anteriorly and superiorly off the anterior surface of the gland. The dissection is carried from lateral to medial behind the superior portion of the gland, along the posterior abdominal and diaphragmatic musculature. The multiple adrenal arteries are clipped superiorly as traction on the kidney is maintained inferiorly. Release of the superior vasculature and attachments improves exposure of the adrenal gland, making it possible to clip the medial arteries and expose and mobilize the vena cava. The adrenal vein, which is relatively high and posterior, is doubly clipped or ligated. At this point, the dissection of the adrenal gland from the superior pole of the kidney is usually quite simple, unless a malignancy has directly invaded the kidney, in which case en bloc nephrectomy may be necessary.

For the left adrenal gland, sweeping Gerota's fascia medially exposes the spleno-renal ligament, which is divided so that the spleen and pancreas within the peritoneum can be lifted cephalad to expose the anterior surface of the gland.

With inferior traction on the kidney, the superior arteries are clipped first. Superiorly and medially the adrenal-phrenic vein should be divided. With further dissection along the aorta and the crus of the diaphragm and clipping of the small arteries entering the gland medially, the renal vein is encountered, and the adrenal vein emptying into the renal vein is doubly ligated. Then the adrenal is removed from the kidney. The incision is closed without drainage.

Anatomic complications of the posterolateral extraperitoneal extrapleural approach to adrenalectomy include bleeding and organ injury, as with the anterior

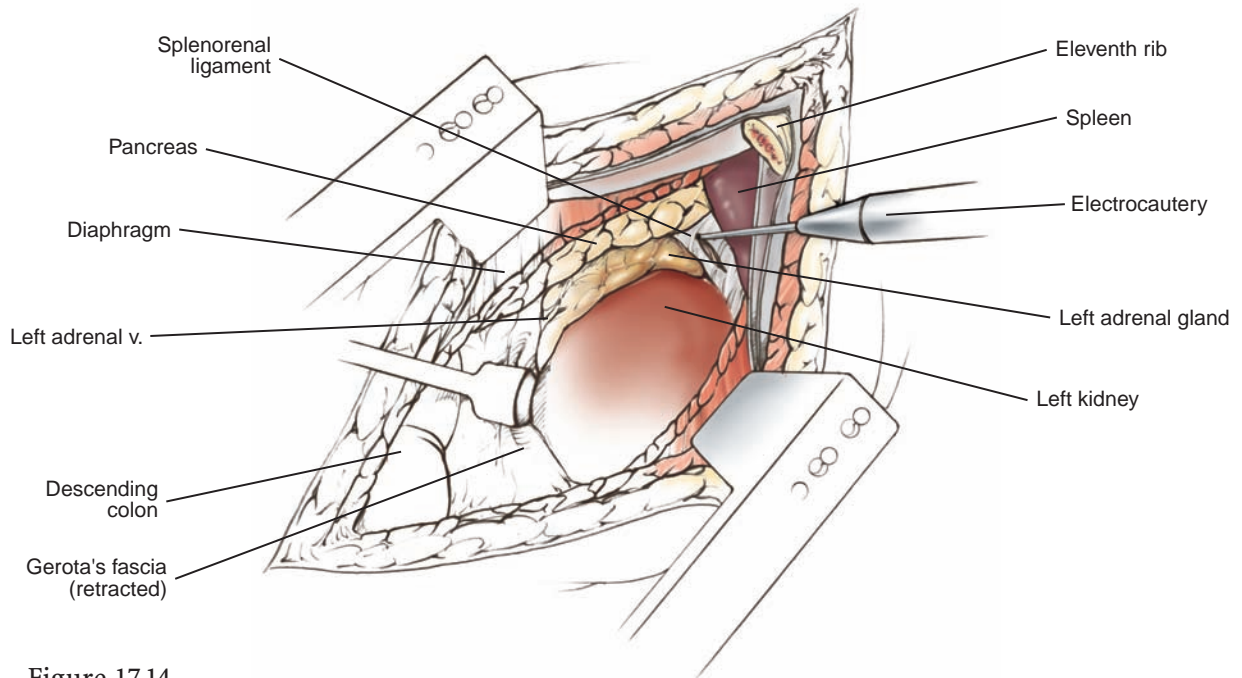


Figure 17.14

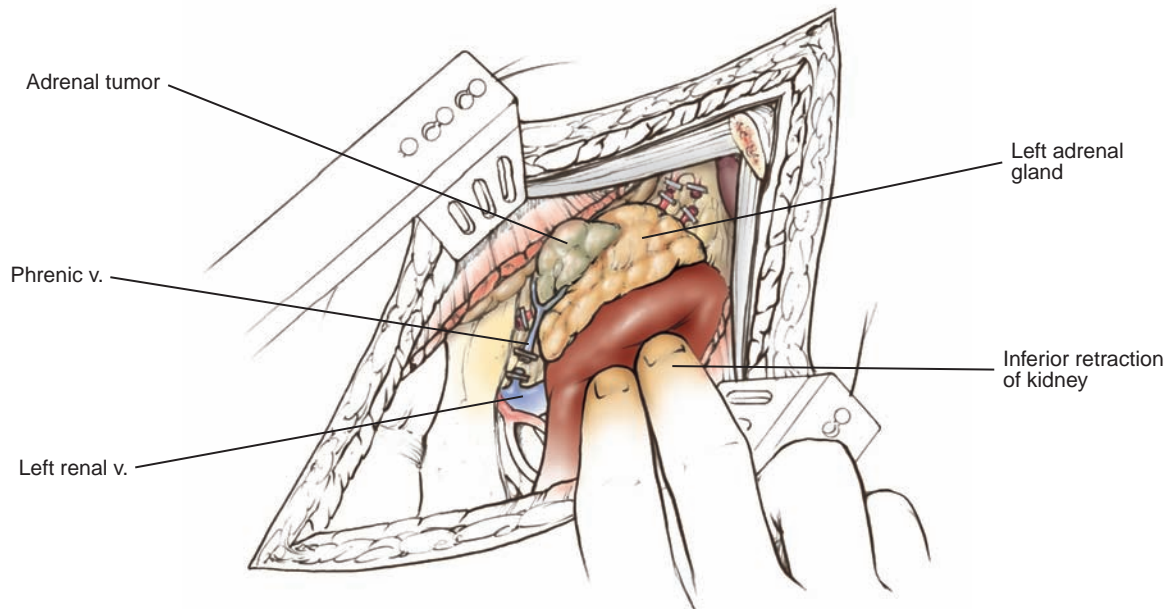


Figure 17.15

and posterior approaches. The area of the diaphragm should be inspected for any pleural tears.

Thoracoabdominal Approach

The thoracoabdominal approach may occasionally provide better exposure for a very large tumor of a single adrenal gland. It enables the removal of the spleen, distal pancreas, or a portion of the liver, if they are involved with the adrenal tumor.

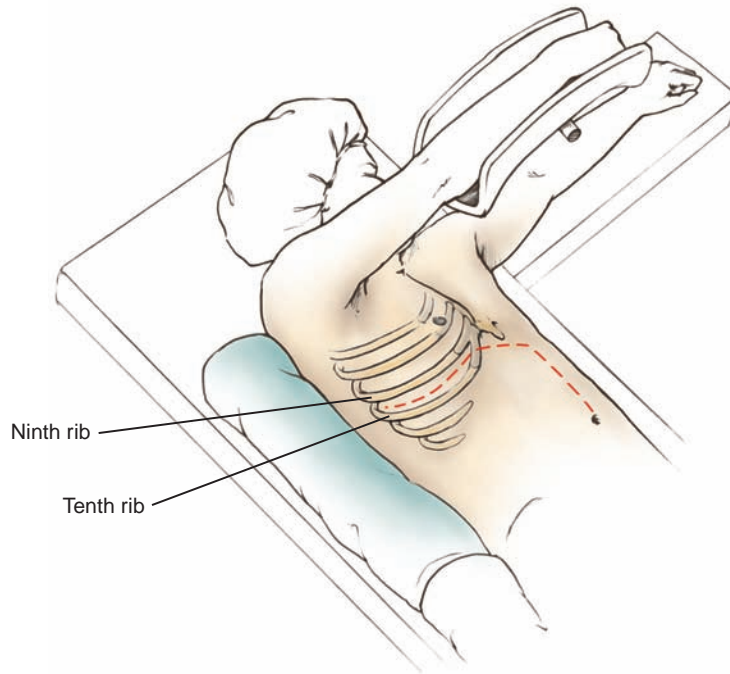


Figure 17.16

The incision extends from the angle of the ninth or tenth rib, across the midline to the midpoint of the contralateral rectus muscle, just above the umbilicus. The underlying rib is removed. The pleura may be opened or be carefully dissected off the chest wall and diaphragm. The diaphragm is incised radially. The remainder of the procedure is similar to the anterior approach.

Most potential vascular and organ injuries are similar to those described for the anterior approach to adrenalectomy. In addition, the lung and the phrenic nerve are at risk for injury in the thoracolumbar approach. An injury to the lung should be repaired to provide an airtight closure. Incision of the diaphragm must be planned to prevent section of the major branches of the phrenic nerve.

Large adrenal carcinomas, particularly on the right side, may grow into the adrenal vein with extension into the vena cava and occasionally, as far as the right atrium. The tumor is usually not adherent to the vascular endothelium and, with the proper operative approach, can be removed in continuity with the primary tumor in the adrenal gland. The abdominosternal approach can be ideal when there is a need to gain control of the vena cava or the right heart atrium and ventricle, or when the tumor is extremely large and is extending medially.

The midline abdominal incision is extended into a standard median sternotomy. Excellent exposure to both the subdiaphragmatic and supradiaphragmatic vena cava is provided. If necessary, the right side of the heart can be cannulated and hypothermic circulatory arrest can be induced.

The transthoracic transdiaphragmatic approach provides excellent exposure to the left adrenal gland and occasionally, very good exposure to the right adrenal gland, when a high-lying tumor has pushed the liver medially.

Thoracolumbar Approach

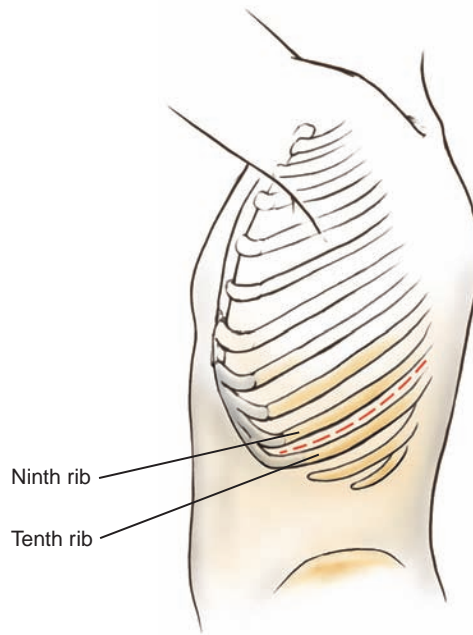


Figure 17.17

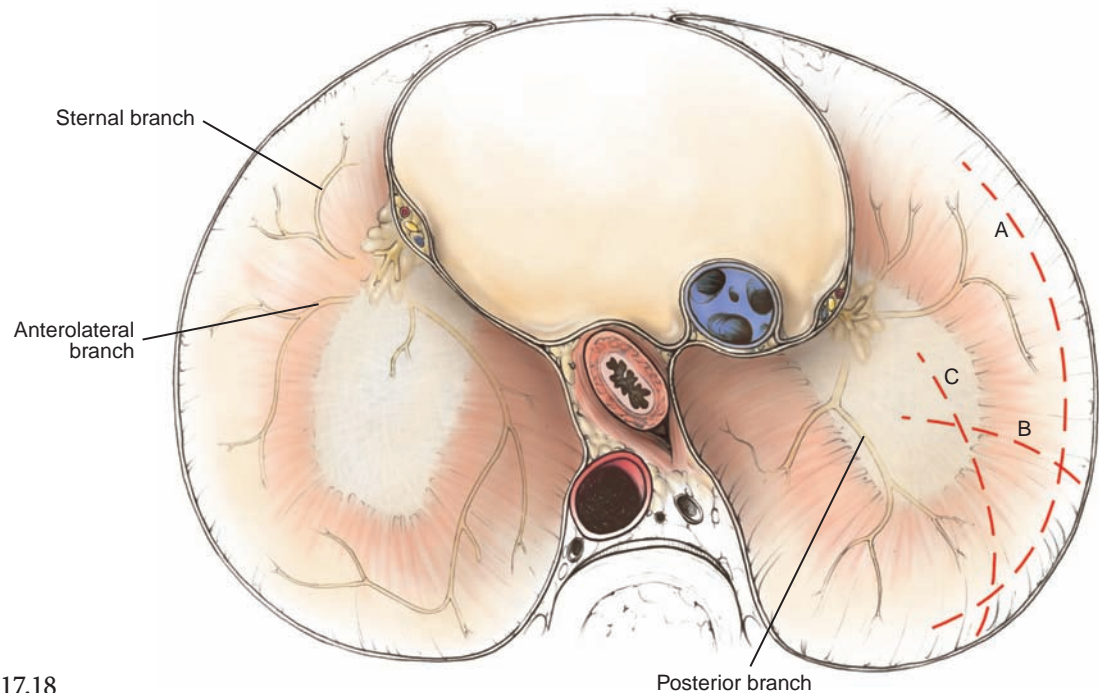


Figure 17.18

Either an intercostal incision is made or, after the excision of the rib, the incision is made through the bed of the ninth or the tenth rib.

The main branches of the phrenic nerves on the cranial surface of the diaphragm are illustrated. The dashed lines indicate the possible incisions that can be used to avoid the phrenic nerves. For the thoracolumbar approach to the adrenal gland, incision B provides excellent exposure. The incision is made approximately 2–3 cm from

the chest wall to minimize transection of the phrenic nerve fibers. Adrenalectomy is carried out much as described for the posterolateral eleventh rib approach.

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Laparoscopic Adrenalectomy

S. Scott Davis Jr, C. Daniel Smith, Hadar Spivak, and John G. Hunter

The technique of laparoscopic adrenalectomy was first introduced in 1992 and has rapidly gained popularity, largely because of the many advantages of minimally invasive surgery. Diminished pain, rapid rehabilitation and short hospitalization are all realized with laparoscopic adrenalectomy, making this the gold standard, of the present day, for removing most adrenal lesions.

There are three vital considerations in selecting patients for laparoscopic adrenalectomy. First, malignant tumors or large pheochromocytomas are best treated by transabdominal or thoracoabdominal exposure. The potential reduction in operative trauma is insufficient justification for minimal access when radical resection is necessary. Second, the indications for surgery, perioperative biochemical testing, and pharmacologic coverage should be the same regardless of the method chosen for adrenal access. Third, only surgeons who have adequate experience in open adrenalectomy and have mastered the techniques of advanced laparoscopic surgery should perform the procedure.

Although there are few absolute contraindications to laparoscopic adrenalectomy, tumors larger than 10 cm should not be approached laparoscopically, primarily because of the difficulty created by the tumors of this size in exposure and mobilization, rather than cancer risk. Tumors with evidence of invasion should also not be resected laparoscopically. Careful analysis of preoperative imaging for the evaluation of size, or evidence of invasion (obscured fat planes), is mandatory to assess resectability by minimally invasive means. Other contraindications are those of any laparoscopic operation: uncorrectable coagulopathy, prior abdominal surgery preventing safe laparoscopic access or exposure, and cardiopulmonary disease preventing general anesthesia or pneumoperitoneum.

Two minimal access approaches to the adrenal gland are described: the lateral transperitoneal approach and the posterior retroperitoneoscopic approach. Multiple series have shown very similar results with both of these techniques with regard to operative time and patient recovery. This discussion will describe both the techniques.

Table 17.1 Selected large series comparing open to minimally invasive approaches to adrenalectomy

Author	No. of patients		Tumor size (cm)		Operating time (min)		Complications (%)		Hospital stay (days)	
	LA	OA	LA	OA	LA	OA	LA	OA	LA	OA
Ichikawa	38	36	2.3	2.6	225	122	11	8	8.5	12.9
Gill	110	100	2.9	2.8	189	219	15	32	1.9	7.6
Thompson	50	50	2.9	2.9	167	127	6	72	3.1	5.7
Imai	40	40	2.8	2.7	147	79	25	8	2.9	7.2
Mean	59.5	56.5	2.7	2.8	182	136.7	14.3	30	4.1	8.4

The transabdominal lateral laparoscopic adrenalectomy, as described by Gagner, provides the best overall access to the adrenal gland and the areas of adrenal exposure and dissection. This approach enables gravity retraction of the surrounding organs and simplifies exposure of the adrenal gland, and enables the surgeon to inspect the entire abdomen and use familiar anatomic landmarks. This approach has been traditionally favored by general surgeons whose familiarity is transabdominal surgery.

Although less popular, retroperitoneoscopic adrenalectomy may be ideal for non-obese patients who have had previous abdominal surgery and for patients undergoing bilateral adrenalectomy. The potential advantage of this approach is the avoidance of the peritoneal cavity, theoretically benefitting the incidence of postoperative ileus and intraabdominal adhesion formation. This technique is less useful for lesions larger than 7–8 cm in size due to limited working space. This approach has been traditionally favored by urologists whose familiarity is retroperitoneal access surgery.

Endoscopic surgery is an access method; therefore anatomic considerations and recognition of tissue planes, as well as the principles of careful dissection, are similar to those of open adrenalectomy.

Surgical Applications

In the transabdominal lateral approach to adrenalectomy, the patient is placed in the lateral decubitus position (right or left, depending on the side to be operated on) with knees bent to enable gravity-facilitated exposure of the adrenal glands. In this position, tissue and organs overlying the adrenal glands need not be manipulated with laparoscopic instruments, but fall away from the retroperitoneum with the help of gravity. With this gravity-facilitated exposure, the complications and bleeding associated with such manipulation are avoided.

The operating room and patient preparation are similar for right and left procedures. An operating table which flexes at the kidney rest should be used in conjunction with a bean bag to stabilize the patient. An arm board or sling should be available to position the ipsilateral arm without pressure. After the induction of general

Lateral Transabdominal Adrenalectomy

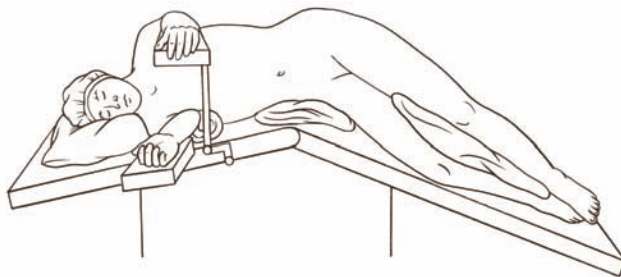


Figure 17.19



Figure 17.20

anesthesia, a Foley catheter and an orogastric tube are placed to decompress these structures. The patient is positioned in lateral decubitus position over the kidney rest which is then elevated, and the table is flexed fully. This maximizes the distance between the iliac crest and the costal margin for better access. The bean bag is then stabilized to hold the patient securely in position, but making sure that the abdominal wall is free for insertion of ports. The ipsilateral arm is then positioned on a board or in a sling and all pressure points are examined before prepping.

Left Adrenalectomy

Cannula sites and uses are illustrated. Preincisional local anesthesia is used. Moderate reverse Trendelenburg positioning is used. Carbon dioxide pneumoperitoneum to 15 mm Hg is initiated with a Veress needle which is inserted at the midclavicular line 2 cm below the left costal margin (cannula site for the camera). This primary trocar may be placed with the Hasson technique or optically viewing trocar if desired. A 30° angle scope is introduced, and the abdomen is completely inspected. Under direct vision, two additional 10-mm trocars are positioned about 2 cm below the costal margin, near the epigastrium and at the anterior axillary line. Placement of

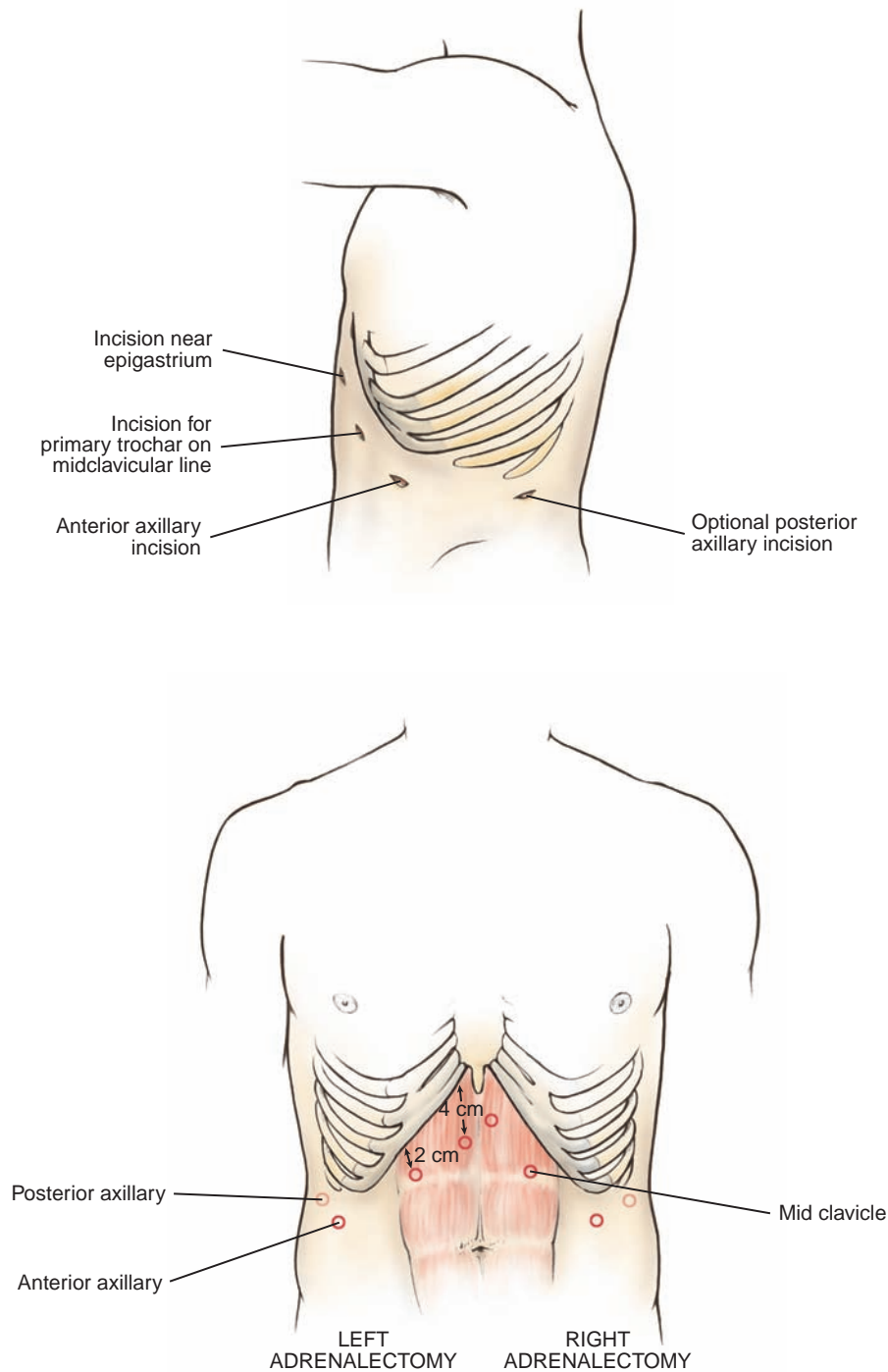


Figure 17.21

the most lateral trocar may require mobilization of the splenic flexure of the colon. A fourth trocar is placed in 50% of left-sided adrenalectomies and should be located in the posterior axillary line.

The first step of the operation is to establish the plane along the anterior surface of the left kidney just lateral and dorsal to the spleen and the tail of the pancreas. This

Figure 17.22

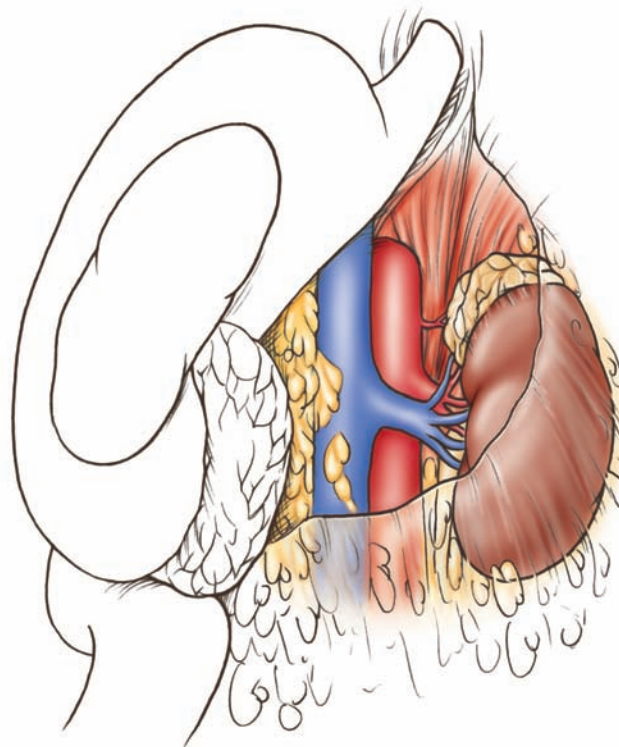
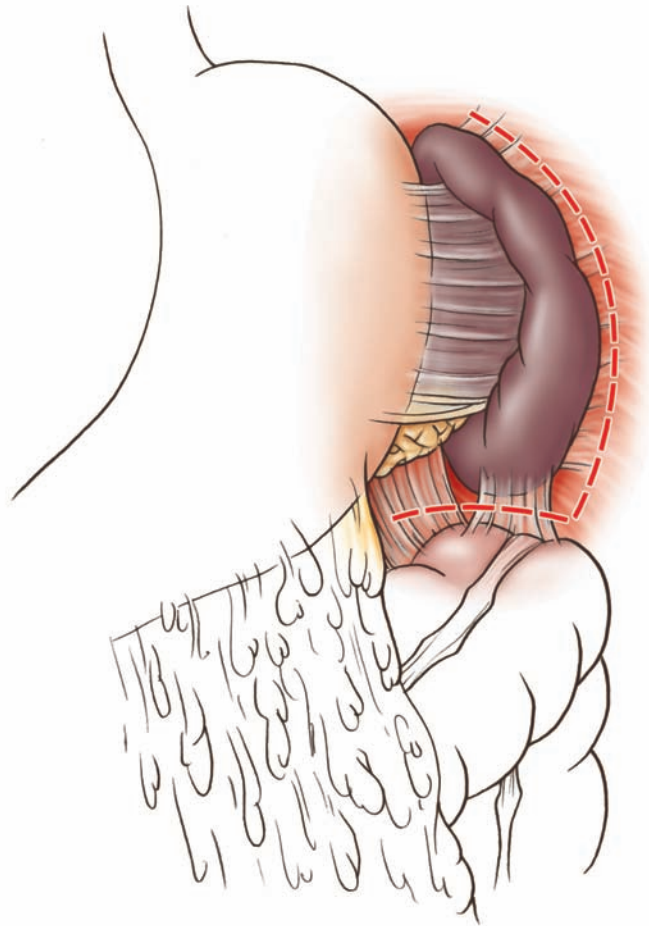


Figure 17.23

is accomplished by incising the splenorenal ligament and mobilizing the spleen laterally. Decubitus positioning facilitates this dissection and mobilization.

With gravity pulling the spleen, medially and away from the anterior surface of the kidney, the spleen and the tail of the pancreas are dissected away from the retroperitoneum, and the superior pole of the kidney is exposed. This dissection plane is relatively avascular. If excessive bleeding is encountered, the wrong plane of dissection is being developed. It is important to continue the mobilization up to the diaphragm and close to the greater curve of the stomach and short gastric vessels. The left adrenal gland, an orange-yellow gland nested in the perinephric fat, is often visible at this point.

The exposure is analogous to opening a book, with the pages of the book being the spleen–pancreatic tail and the anterior surface of the kidney–adrenal gland, and the spine of the book being a line just beyond the medial edge of the adrenal gland. Depending on the adrenal pathology and the amount of retroperitoneal body fat, the lateral and the anterior surfaces of the adrenal gland will become visible during this dissection. It is important not to mobilize the adrenal gland along its lateral edge too early in the exposure. If this mistake is made, gravity will allow the mobilized adrenal gland to fall medially, preventing visualization and access to the medial and inferior edges of the gland, where the left adrenal vein is most likely encountered.

When the retroperitoneal fat prevents clear visualization of the gland, its medial and inferior edges can be localized by ballottement of the retroperitoneal tissue along the anterior surface of the kidney. Even in the most obese patients or those with Cushing's syndrome, where localization can be difficult, this technique has enabled identification of the dissection plane between the anterior surface of the kidney and the inferior border of the adrenal gland. Once this cleavage plane is estimated, careful dissection with a hook cautery eventually exposes the inferior and the medial edge of

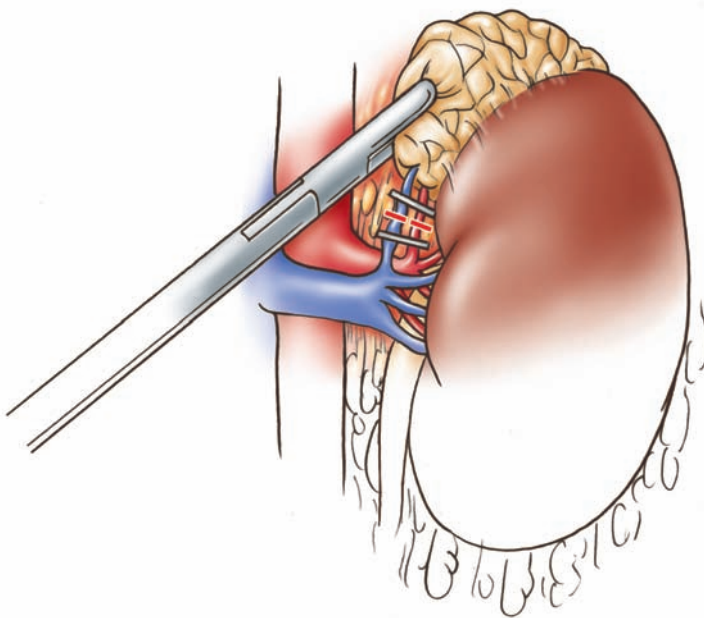


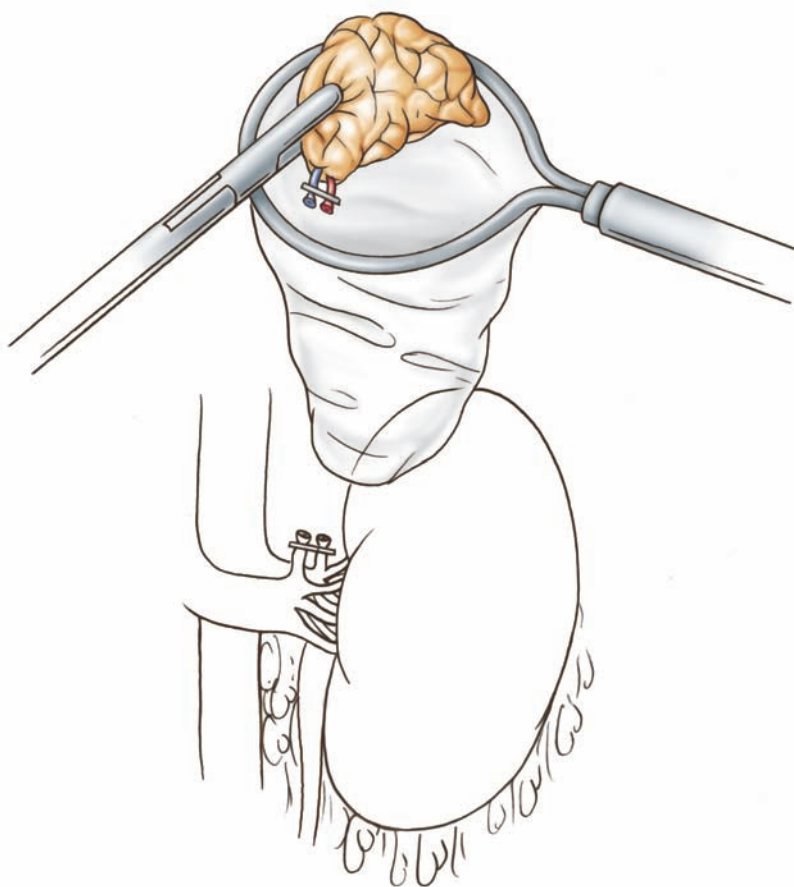
Figure 17.24

the gland. In these difficult situations, some have advocated the routine use of intraoperative laparoscopic ultrasonography to localize the gland. Although the authors have been prepared to apply this, with the techniques described above, there was never the need to rely on ultrasound for gland localization.

The next step is isolation of the left adrenal vein, which is typically located at the inferior pole of the adrenal gland and draining into the left renal vein. With small tumors (<5 cm), this is most easily accomplished by first dissecting the inferior and medial aspects of the adrenal gland, while staying close to the gland until the vein is isolated and clipped. A right-angle dissector greatly facilitates this exposure and isolation. By staying close to the gland, risk to the left renal vein is minimized. The vein is then clipped with a medium to large ligature clip. A 5-mm clip applicator has been found to be adequate for this ligation. Once the vein is transected, dissection is continued from inferior and medial to superior and lateral following the anterior surface of the kidney. For large tumors, early identification of the adrenal vein may be difficult. In these cases, the gland is mobilized laterally and inferiorly to find the inferior border of the gland and the adrenal vein.

Final dissection and gland excision is progressed from medial to lateral and inferior to superior. While some have advocated the use of an ultrasonic dissector to dissect the soft tissues surrounding the adrenal gland, monopolar electrocautery with a hook dissector was found to be the most effective method in the confined space and relatively avascular planes of dissection. The inferior phrenic artery is frequently encountered along the superior edge of the adrenal gland and should be sought and ligated with clips. Alternatively, the numerous left adrenal arteries can be individually

Figure 17.25



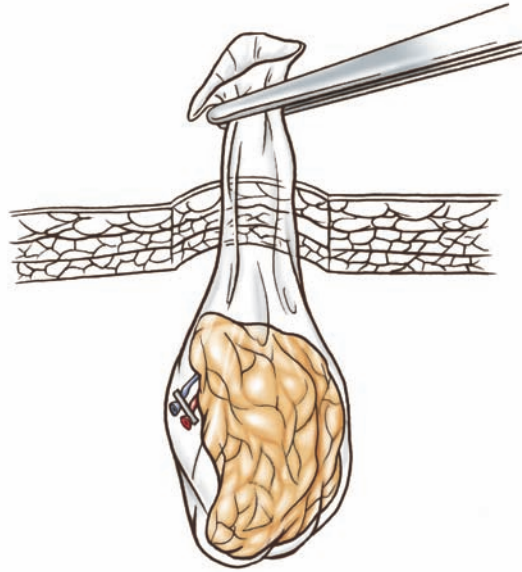


Figure 17.26

secured with bipolar electrosurgery, an ultrasonic dissector, or vascular clips. Dissection is continued until the adrenal gland is completely free. The gland should not be handled directly but rather by manipulating the attached tissues after they have been dissected free from the retroperitoneum.

Before specimen extraction, the operative field is carefully inspected for hemostasis. The area is irrigated and suctioned dry. Points of bleeding from retroperitoneal fat are coagulated with electrocautery. Areas of bleeding from visible vessels are clipped.

When hemostasis is ensured, the adrenal gland is placed in a specimen retrieval sac, which is inserted through the medial 10-mm cannula. Sac size will depend on the specimen to be removed. The sac must be stout enough so as not to rupture during extraction.

The sac is removed through one of the 10-mm cannula sites. The fascia of the cannula site of extraction may need to be stretched with a Kelly clamp to facilitate removal. For large tumors, the entire incision may need to be extended. The adrenal gland should not be morcellated, because histologic architecture must be preserved for pathologic analysis.

The operation is completed by closing the fascia of the 10-mm incisions with absorbable suture. If a significant amount of irrigation was used during the procedure, it will tend to disperse to the lower and right abdomen, out of the reach of suction. It may be difficult to aspirate all of this irrigant and, when the patient is again supine, it will tend to drain from the lateral cannula site.

The patient is placed in the lateral decubitus position, with the right side up. Pneumoperitoneum to 15 mm Hg is initiated with a Veress needle, which is inserted at the midclavicular line below the right costal margin (cannula site for the camera). After establishing pneumoperitoneum, the remaining cannula sites are marked. A fourth

Right Adrenalectomy

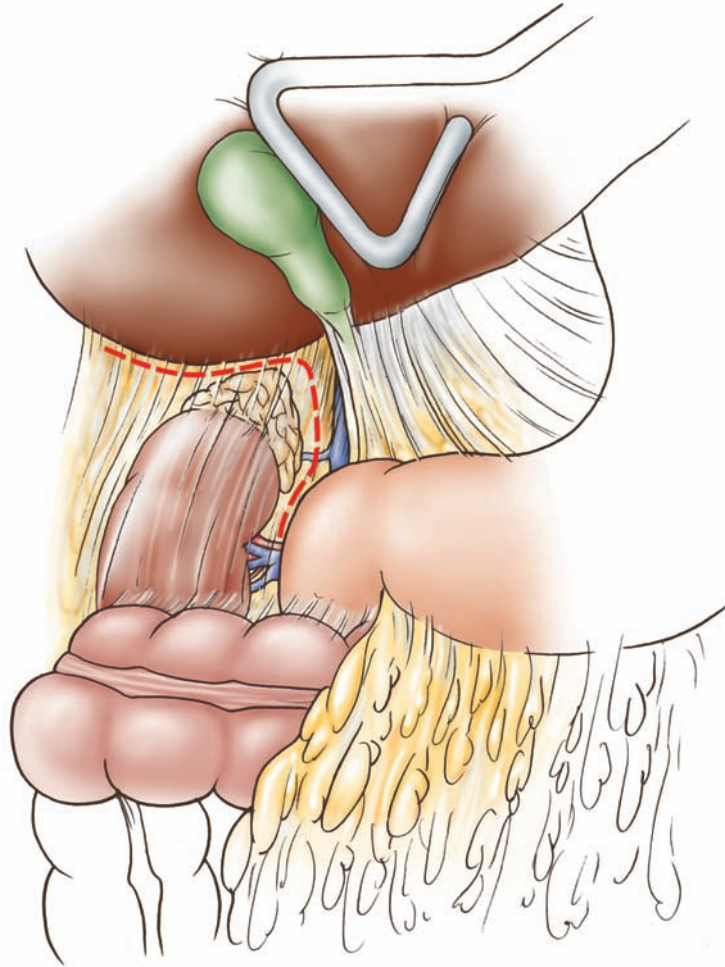


Figure 17.27

cannula in the epigastrium is necessary for a retractor to elevate the right lobe of the liver. This cannula site needs to be several centimeters below the costal margin, allowing the angle of retractor insertion to be parallel to the underside of the right lobe of the liver. Insertion too far cephalad will create an acute angle to the undersurface of the liver, making positioning of the liver retractor difficult. A 5-mm triangle liver retractor is used allowing trocar sites to remain as small as possible. The liver retractor can be held by the first assistant or the camera operator. A table-mounted liver retractor is used allowing the first assistant to stand at the surgeon's left side.

With the liver retractor positioned, the anterior surface of the right kidney and the lateral edge of the inferior vena cava can be clearly seen. The duodenum falls medially with gravity. The dissection commences by creating a hockey stick-shaped incision along the retroperitoneal attachment of the right lobe of the liver and the medial border of the inferior vena cava. This mobilizes the right lobe of the liver posteriorly and allows exposure of the anterior surface of the adrenal gland, as the liver is pushed cephalad. If necessary, the hepatic flexure of the colon is mobilized and reflected inferomedially, and the duodenum is mobilized medially, exposing Gerota's fascia and the perinephric fat surrounding the upper pole of the right kidney and the adrenal gland.

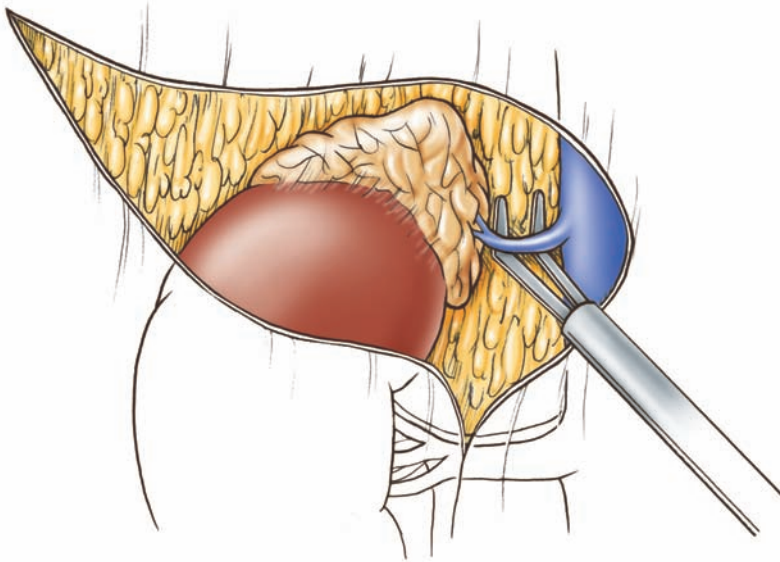


Figure 17.28

The medial border of the inferior vena cava is carefully exposed while looking for the right adrenal vein. This vein is typically broad, short, and enters the vena cava at a right angle and slightly posteriorly. A blunt-tipped right-angle dissector was found to be most useful for this dissection. Once the adrenal vein has been isolated, it is ligated with three medium to large ligature clips proximally and two distally. Because of the short length of this vein, the most proximal clip should be immediately at the edge of the vena cava.

After controlling and dividing the right adrenal vein, the dissection is continued laterally, dividing small vessels and attachments until the gland is completely mobilized. As with the left adrenalectomy, the lateral edge of the gland should not be dissected too early, because gravity will cause the laterally mobilized gland to hang over the medial edge, making visualization difficult.

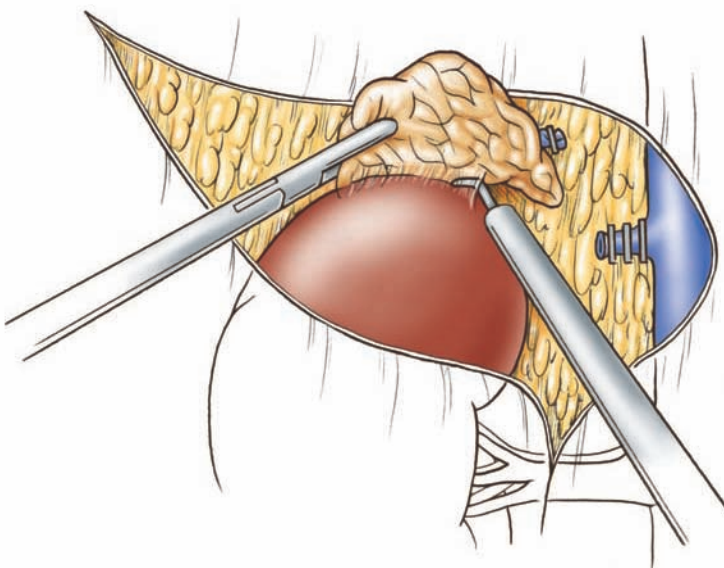


Figure 17.29

By dissecting from medial to lateral and inferior to superior, the superior pole of the kidney can be used as a dissection plane, and the dissection is progressed away from any anatomic concerns (inferior vena cava and renal vein). As with left adrenalectomy, monopolar electrocautery is adequate for the majority of the dissection. Visible vessels are clipped, and the inferior phrenic vessels are commonly encountered at the superior and lateral borders of the gland.

After completion of the dissection, the adrenal bed is inspected for hemostasis. The incision is dilated or extended as necessary to remove the specimen. Trocars should be removed under visual inspection, and the fascia is approximated with absorbable sutures.

Retroperitoneoscopic Adrenalectomy

For the retroperitoneoscopic approach, most surgeons also prefer the lateral decubitus or flank position. The operating room set up and patient positioning are similar to that described above. Some authors prefer prone positioning citing easier access to the vascular structures and lack of need to rotate the patient for bilateral procedures. Access is gained by sharp and blunt dissection off of the tip of the twelfth rib. A space in the retroperitoneum is developed using either finger dissection or a space dissecting balloon. A blunt trocar with an inflatable balloon tip is useful in this position. Pneumoretroperitoneum is created by CO₂ at a pressure of 12–25 mm Hg. Two additional 5-mm trocars are then inserted lateral and medial to this port along the costal margin. A 30° viewing scope is helpful for improved visualization angles.

The dissection is typically started lateral to the adrenal and kidney in the avascular plane. This is carried cranially to the angle of the diaphragm and the diaphragmatic branch vessels. The Gerota's fascia can be incised longitudinally from the lateral border of the kidney to the angle of the diaphragm cranially to gain access to the kidney and adrenal gland. Dissection at the angle of the diaphragm includes division of the short adrenal arteries arising posterior to the vena cava (for right sided lesions) and these can be divided using clips or ultrasonic dissection.

For right sided lesions, the medial border of the adrenal gland is mobilized, and the short suprarenal vein and the central adrenal vein must be identified and clipped for division. For left sided lesions, this vein will be seen on the inferior aspect of the adrenal arising from the left renal vein.

Once the medial and the inferior borders of the adrenal gland are mobilized, and the vein is ligated and divided, the remaining attachments of the gland posteriorly and inferiorly, along the superior pole of the kidney, can be divided using monopolar cautery or ultrasonic dissection.

Postoperative Care

The orogastric tube and Foley catheter are removed before the patient awakens. Postoperatively the patient is given clear liquids, and ambulates on the night of surgery. Pain is controlled with intermittent parenteral narcotics until the patient is able to take oral pain medication. Diet is advanced on postoperative day 1, and the patient is discharged when oral intake is tolerated and pain is controlled with oral analgesics.

Special Considerations

Bilateral adrenalectomy is performed as described for each individual side. Since right adrenalectomy is at a higher risk for conversion to an open procedure because of the immediate consequences of adrenal vein or caval injury, left adrenalectomy is performed first. Thus, the patient has the greatest likelihood of benefiting from a laparoscopic approach. Before repositioning for right adrenalectomy, the entire left adrenalectomy is completed, including wound closure and abdominal desufflation (minimizing duration of carbon dioxide pneumoperitoneum). Average operative time for bilateral adrenalectomy is about 4 h, including turnover time between sides.

Some authors have described using a supine transabdominal approach with a rotating bed, and others a prone approach using the retroperitoneoscopic technique. Either approach might avoid the need for patient repositioning.

Bilateral Adrenalectomy

Debate continues regarding the management of adrenal incidentalomas (nonfunctioning tumors). Current imaging identifies these tumors in 1–4% of patients having studies for other reasons. Once discovered, masses should be worked up for hormonal function. Traditionally, nonfunctioning adrenal tumors discovered during abdominal CT or ultrasound for other indications, have been managed based on tumor size: tumors >5 cm are removed; tumors <3 cm are considered inconsequential and require no further management beyond surveillance; incidentalomas in the 3–5-cm range are typically observed with serial CT or MRI and removed if they increase in size, or have an atypical appearance on imaging studies. With the success of laparoscopic adrenalectomy and the dramatically improved patient recovery, more referring physicians are requesting adrenalectomy for 3–5 cm nonfunctioning tumors. It has been suggested that this may be a more cost-effective management strategy, avoiding multiple CT/MRI evaluations or the potential for patients being lost to follow-up and returning with advanced lesions later in their course. While this may be appropriate in selected patients, more data are necessary before recommending adrenalectomy for all nonfunctioning tumors, which are 3–5 cm in size.

Incidentaloma

Complications and Outcomes

Bleeding from small vessels that have not been properly ligated or cauterized is the most frequent complication of laparoscopic adrenalectomy. Injury to the pancreas, spleen, or colon is also possible. The most devastating injuries are avulsions or tears of the renal vein, inferior mesenteric vein, or even the vena cava. These major venous injuries are extremely rare. When encountering such an injury, the surgeon must quickly convert to an open procedure if the repair is not straightforward and easy. Grasping of the friable adrenal gland should be avoided as much as possible.

Table 17.2 Selected published series (>100 cases) of laparoscopic adrenalectomy

Author	Year	No. of procedures	Operating time (min)	Conversion (%)	Complication (%)	Hospital stay (days)
Transperitoneal						
Gagner	1997	100	123	3	12	2.4
Terachi	1997	100	240	3	12	n.a.
Mancini	1999	172	132	7	8.7	5.8
Guazzoni	2001	160	160	2.5	5.1	2.8
Henry	2000	169	129	5	7.5	5.4
Lezoche	2000	108	99	1	2.9	2.5
Miccoli	2002	137	111	4.3	3.9	3.8
Propiglia	2001	125	139	3.2	11.2	4
Retroperitoneoscopic						
Bonjer	2000	111	114	4.5	11	2
Solomon	2001	115	118	0.8	15.5	4
Walz	2001	142	101	5	13	3
Mean		130.8	133.3	3.6	9.3	3.6

Several authors have similarly detailed their experience with laparoscopic adrenalectomy. Those series with 100 or more laparoscopic adrenalectomies are summarized. These large series clearly demonstrate the safety and feasibility of these approaches as well as the improved outcomes with regard to patient recovery that were outlined previously.

However, gentle grasping with an oval ring grasper may occasionally be required. Alternatively, placement of EndoLoops around the gland and pulling on the loops may prevent avulsion of the gland.

Endoscopic clips are sufficient for ligating the adrenal vessels. However, laparoscopic suturing should be one of the surgeon's skills. The right adrenal vein usually enters the vena cava on the posterolateral aspect and may be difficult to ligate. Mobilization of the lateral and superior margins of the gland, followed by dissection along the renal vein and vena cava, provides good exposure of the right adrenal vein. It should also be kept in mind that the vein may have anomalous drainage to the right hepatic or renal vein.

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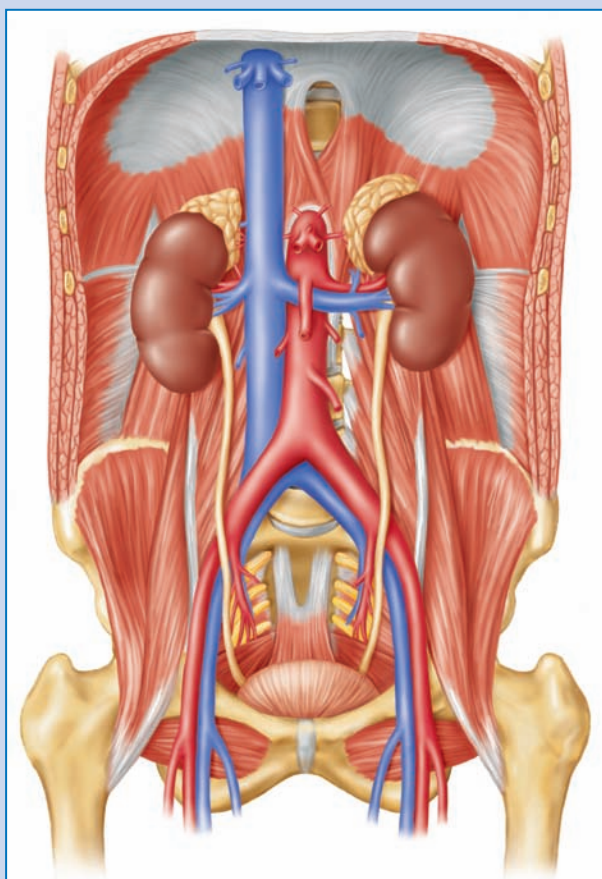
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Kidneys, Ureters, and Bladder

Daniel T. Saint-Elie,
Kenneth Ogan,
Rizk E.S. El-Galley,
Thomas E. Keane



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Upper Urinary Tract

Surgical Anatomy

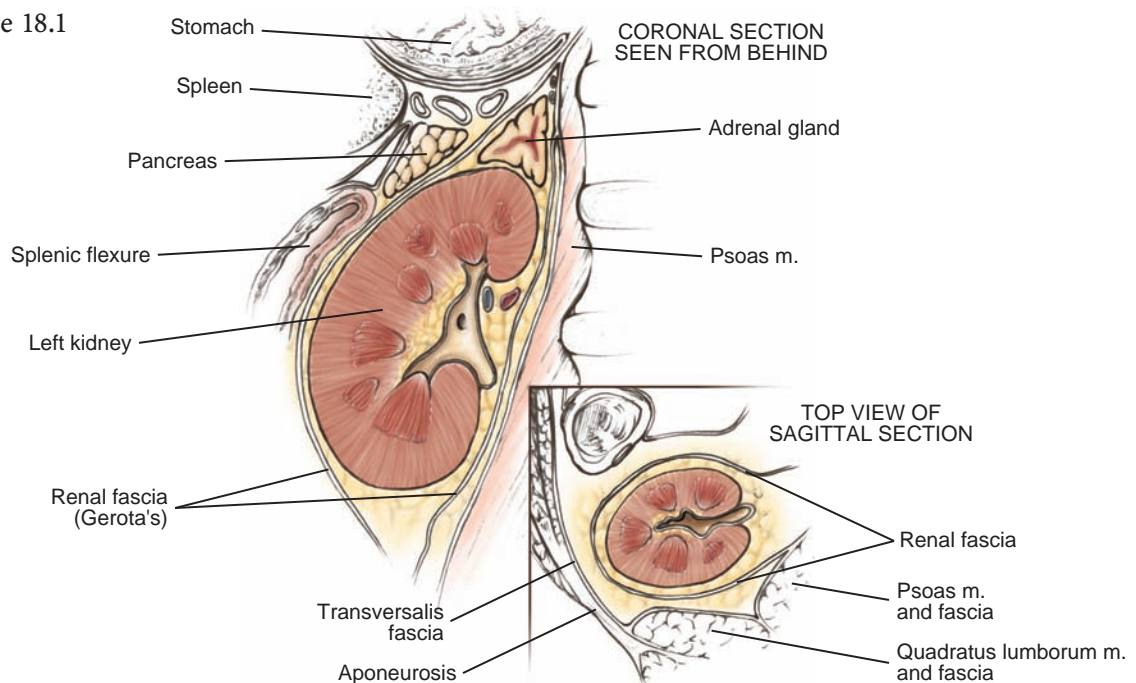
Kidneys

Topography The kidneys are paired, reddish brown, solid organs situated on each side of the mid-line in the retroperitoneal space. Their weight depends on body size, averaging 150 and 135 g each in the adult male and female, respectively. Kidneys in mature adults vary, in length from 11 to 14 cm, in width from 5 to 7 cm, and in thickness from 2.5 to 3.0 cm. Due to the effect of the liver, the right kidney is shorter and broader and lies 1–2 cm lower than the left kidney.

Gerota's Fascia

Each kidney is surrounded by a layer of perinephric fat covered by the Gerota's fascia. Gerota's fascia is completely fused above and lateral to the kidney; medially and inferiorly fusion is incomplete. This incomplete fusion is of clinical importance in determining the possible routes of spread of malignancy, bleeding or infection around the kidneys. Both the layers of Gerota's fascia probably stretch across the midline, with the posterior layer crossing behind the great vessels and the anterior

Figure 18.1

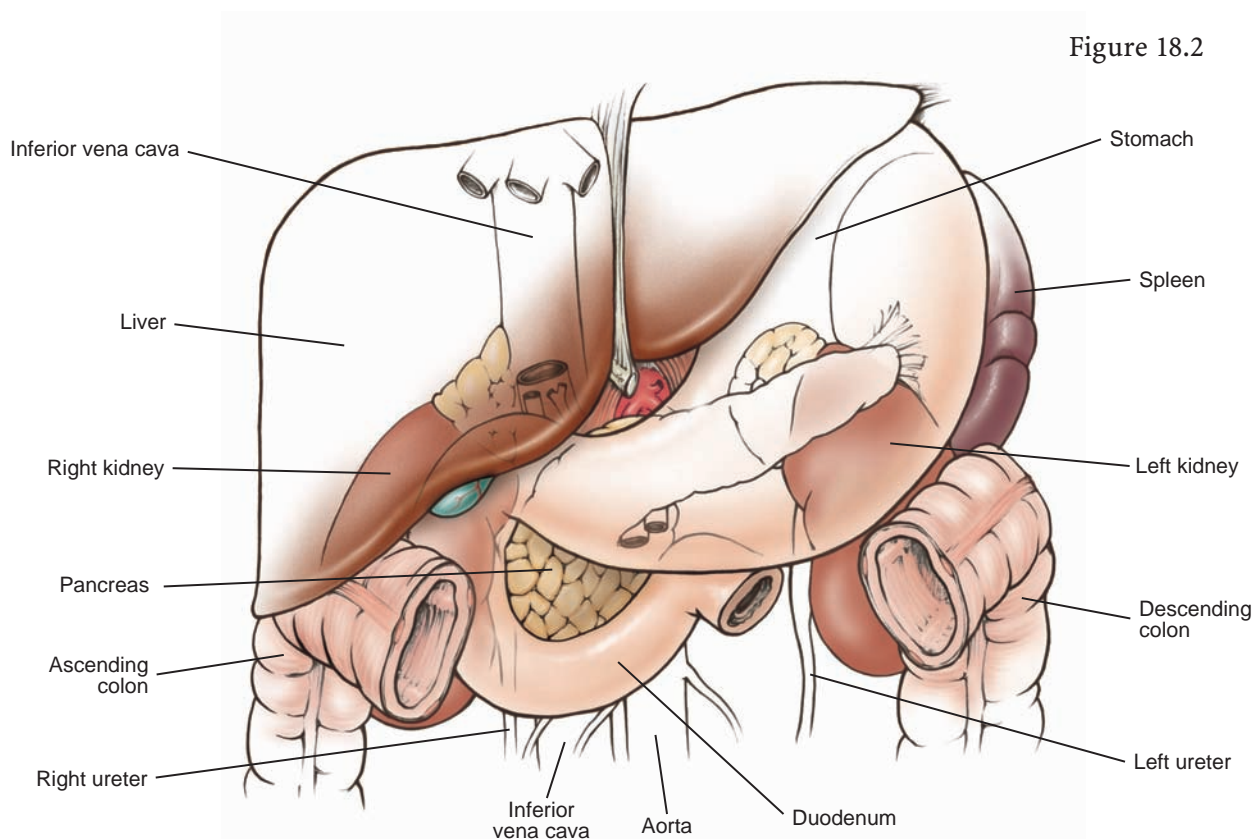


layer extending in front of the great vessels. The parietal peritoneum fuses with the anterior layer of Gerota's fascia to form the white line of Toldt laterally. During surgical approaches to the kidneys, incision along this line enables the surgeon to reflect the peritoneum with the mesocolon through a relatively avascular plane and gives access to the retroperitoneum.

Anatomic Relationships

The upper pole of the left kidney lies at the level of the twelfth thoracic vertebral body and the lower pole lies at the level of the third lumbar vertebra. The right kidney usually extends from the top of the first lumbar vertebra to the bottom of the third lumbar vertebra. Due to the free mobility of the kidneys, these relationships change with both body position and respiration.

The right adrenal gland covers the uppermost part of the anteromedial surface of the right kidney. The anterior relationships of the right kidney include the liver and the hepatic flexure of the colon, which overlies the upper and lower pole, respectively. The right renal hilum is overlaid by the second part of the duodenum. Mobilizing the duodenum (Kocher maneuver) is an important step for right renal hilar exposure. The anterior surface of the kidney, beneath the liver is the only area covered by peritoneum. The hepatorenal ligament, an extension of the parietal peritoneum, attaches the right renal upper pole to the posterior liver. The anteromedial surface of the left kidney upper pole is also covered by the left adrenal gland. The spleen, tail of the pancreas, stomach,



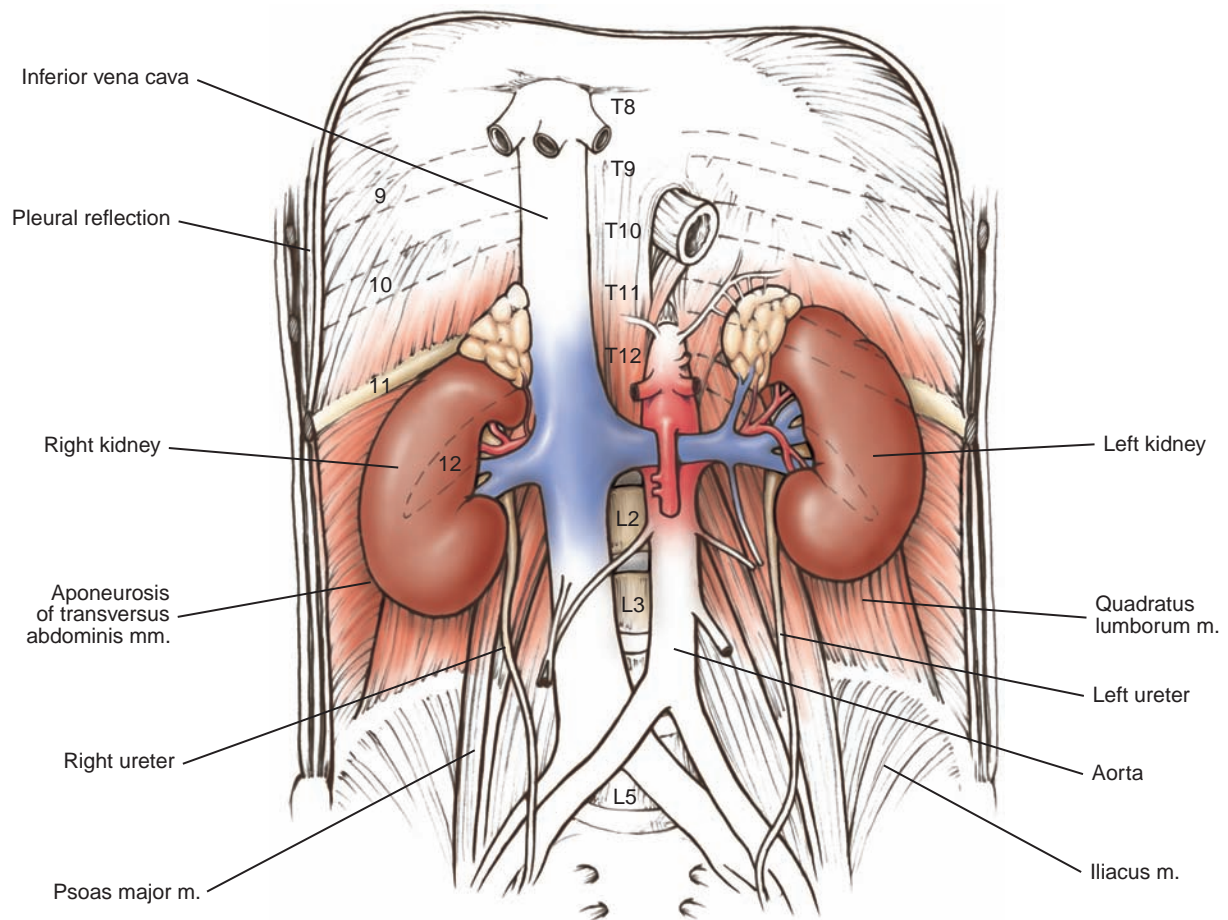


Figure 18.3

and splenic flexure of the colon are all anterior to the left kidney. The splenorenal ligament attaches the spleen to the left kidney. Excessive downward traction or tension to the kidney can lead to capsular tears of the spleen. The area of the kidney beneath the small intestine, the spleen, and the stomach is covered by the peritoneum.

Both the kidneys share relatively symmetric relations to the posterior abdominal wall. The upper pole of each kidney lies on the diaphragm, behind which is the pleural reflection. An operative approach to this area with a high incision above the eleventh rib risks entering the pleural space. The superior border of the left kidney typically corresponds to the eleventh rib while the superior aspect of the right kidney, which is lower, is usually at the level of the eleventh intercostal space. The lower two thirds of the posterior surface of both the kidneys lie on three muscles, which from medial to lateral, are the psoas major, quadratus lumborum, and the aponeurosis of the transversus abdominis muscles. The renal vessels and the pelvis lie against the contour of the psoas muscle, which tilts the lower pole of each kidney laterally away from the midline. Alterations in this alignment may be seen with space-occupying lesions and should prompt careful assessment. In addition, the renal medial aspect is more anterior than the lateral aspect because of the rotational axis of the kidneys. Also, the upper pole is positioned more posterior than the lower pole, which may be important when attaining percutaneous access to the collecting system.

Renal Parenchyma

The renal parenchyma is divided into an internal darker medulla and an external lighter-hued cortex. The medulla is composed of 8–18 conical structures called the renal pyramids, which are made of ascending and descending loops of Henle and collecting ducts. The round tip of each pyramid is known as the renal papilla. These papillae cannot be seen during surgical dissections because each papillary projection is encompassed by a smooth muscular sleeve called a minor calyx. However, with the development of small caliber flexible endoscopes, all of the minor calyces may be accessed for diagnostic and therapeutic procedures. There is a great variation in the number and size of the calyces. These minor calyces coalesce to form two or three major calyces, which in turn join to form the renal pelvis.

The renal pelvis extends through the renal hilum behind the renal vessels and continues as the ureter. Anatomic variations in the renal pelvis are not uncommon. The renal pelvis, which is usually partially extrarenal, may lie completely outside or within the kidney. Occasionally, the renal pelvis may be duplicated, with duplication of the renal units. Anatomic variations of the renal pelvis tend to occur bilaterally, which should be considered when evaluating urographic studies to differentiate pathologic conditions from normal variations.

The renal cortex lies between the bases of the pyramids and the renal capsule. The tongues of cortical tissue that extend between the renal pyramids are called the columns of Bertin, and when enlarged, can closely resemble a renal mass (hypertrophic column of Bertin). These columns are traversed by renal vessels from the renal sinus to the cortex. The outer border of the renal cortex is covered with a capsule, which should be smooth. Indentations on the cortical surface might represent

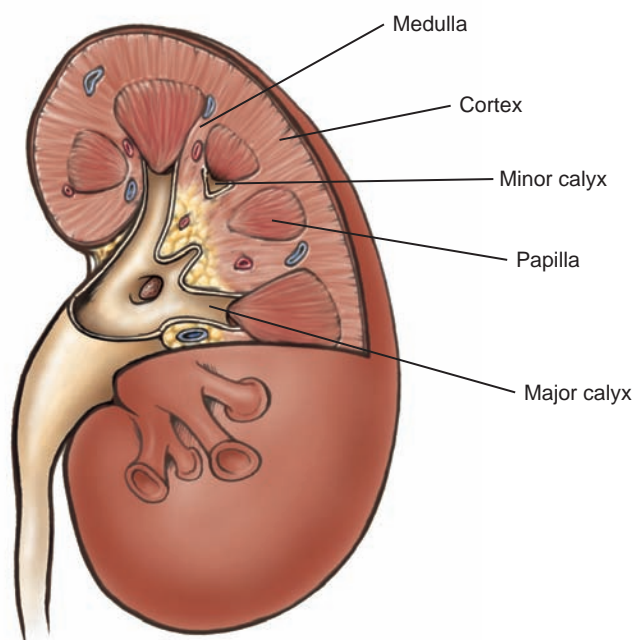


Figure 18.4

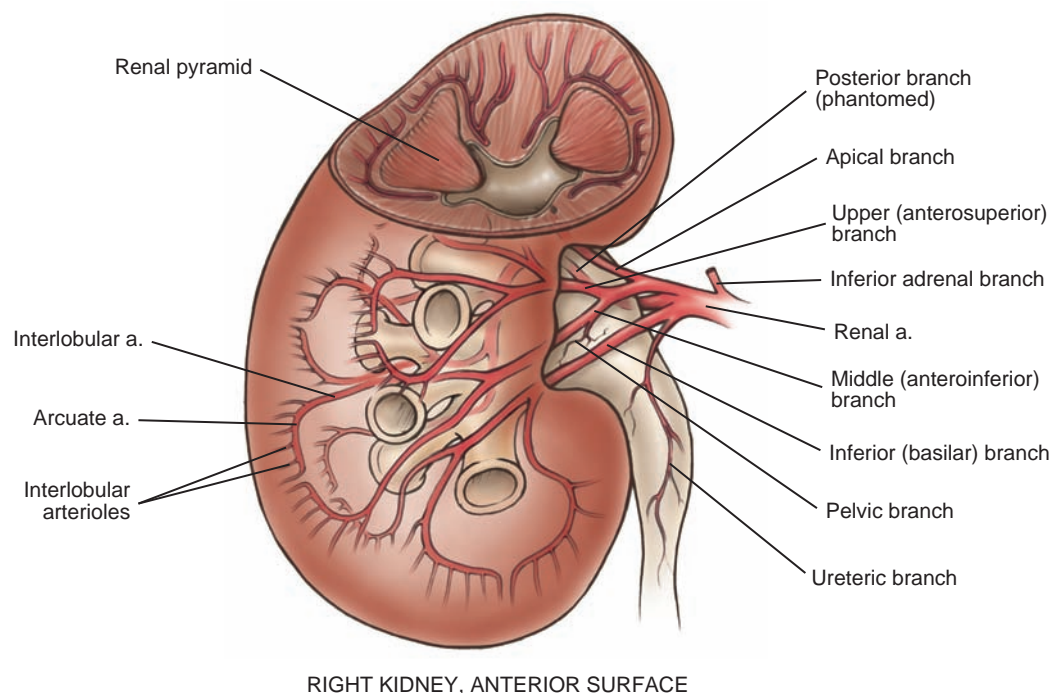
persistent fetal lobulations (dromedary hump), previous scarring, and infection or space-occupying lesion.

Blood Supply

Each kidney is classically supplied by a renal artery and a larger renal vein, arising from the aorta and the inferior vena cava, respectively, at the level of the second lumbar vertebra below the takeoff of the superior mesenteric artery. These vessels enter the renal hilum medially, with the vein anterior to the artery and both lie anterior to the renal pelvis. Although the right kidney is lower than the left kidney, the right renal artery arises from the aorta at a higher level and takes a longer course than the left renal artery. It travels downward behind the inferior vena cava to reach the right kidney, whereas the left renal artery passes slightly upward to reach the left kidney. Due to the posterior position from rotational axis of the kidneys, both the renal arteries course slightly posterior. Multiple renal arteries occur unilaterally and bilaterally in 23% and 10% of the population, respectively. Lower pole renal arteries that pass anterior to the ureteropelvic junction are thought to be the cause of ureteropelvic junction obstruction. During pyeloplasty to correct this condition, the newly formed anastomosis is formed anterior to the lower pole crossing vessel to prevent recurrent obstruction. Variations of the renal venous anatomy include left circumaortic (5.5%), left retroaortic (4.6%), double and triple renal veins. Multiple renal veins are found in 9–30% of individuals.

Two small but important branches arise from the main renal artery before its termination in the hilum: the inferior adrenal artery and the artery that supplies the renal pelvis and upper ureter. Ligation of this branch may result in ischemia to the proximal ureter with stricture formation. The main renal artery divides into five segmental arteries at the renal hilum. Each segmental artery is an end artery; therefore

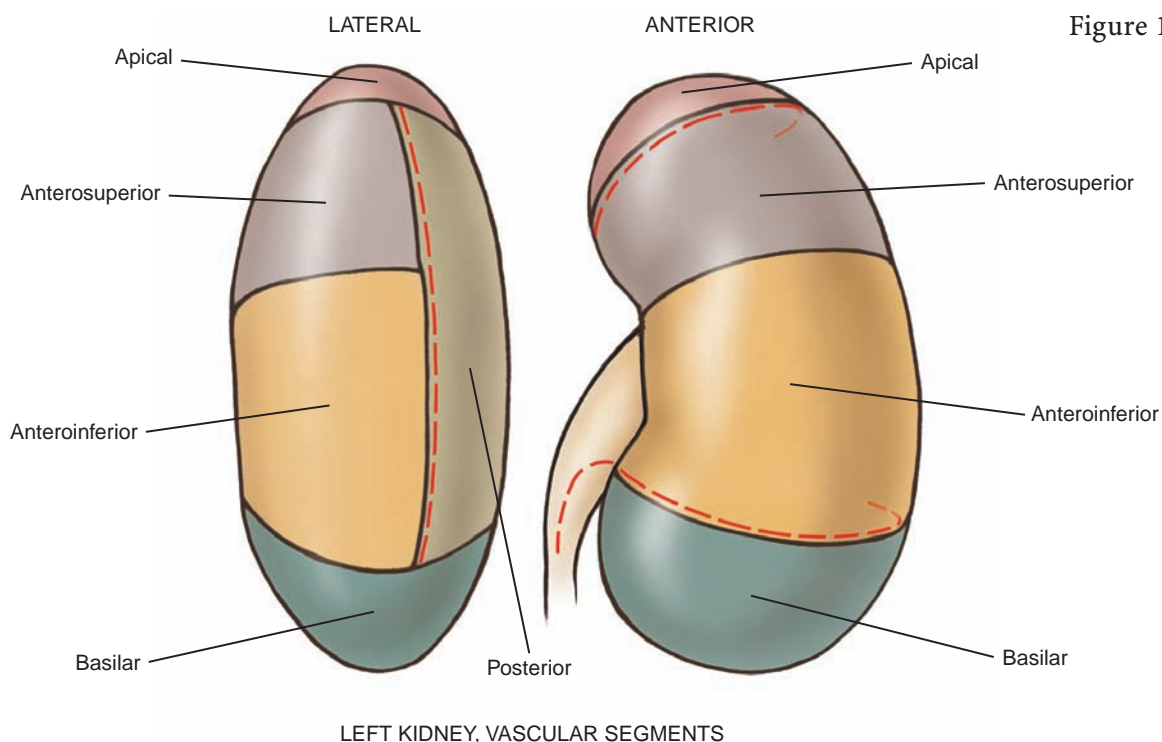
Figure 18.5



occlusion will lead to segmental renal ischemia and infarction. The first branch is the posterior artery, which arises just before the renal hilum and passes posterior to the renal pelvis to supply a large posterior segment of the kidney. The main renal artery then terminates into four anterior segmental arteries at the renal hilum: the apical, upper, middle, and lower anterior segmental arteries. Both the apical and inferior arteries supply the anterior and posterior surfaces of the upper and lower poles of the kidneys, respectively. The upper and middle arteries supply two corresponding segments on the anterior surface of the kidney.

The segmental arteries course through the renal sinus and branch into the lobar arteries, which are usually distributed one for each pyramid. Each lobar artery divides into two or three interlobar arteries that pass between the renal pyramids to the corticomedullary junction, where they become the arcuate artery. The arcuate arteries, as their name implies, arch over the bases of the pyramids and give rise to a series of interlobular arteries, which in turn take a straight course to the renal cortex, with some terminal, small branches anastomosing with the capsular arteries. This anastomosis can enlarge to supply a significant amount of blood to the superficial cortical glomeruli, particularly in cases of gradual narrowing of the renal arteries.

Of importance to the urologist is the relatively avascular plane on the posterior surface of the kidney, located approximately one third the distance between the posterior and anterior surfaces, although there is variation in the location of this plane. Incision through this line is unlikely to traverse any major vessels. This approach is utilized during anatomic nephrolithotomy for removal of large staghorn renal calculi that cannot be managed endoscopically. Similarly, transverse incisions are usually



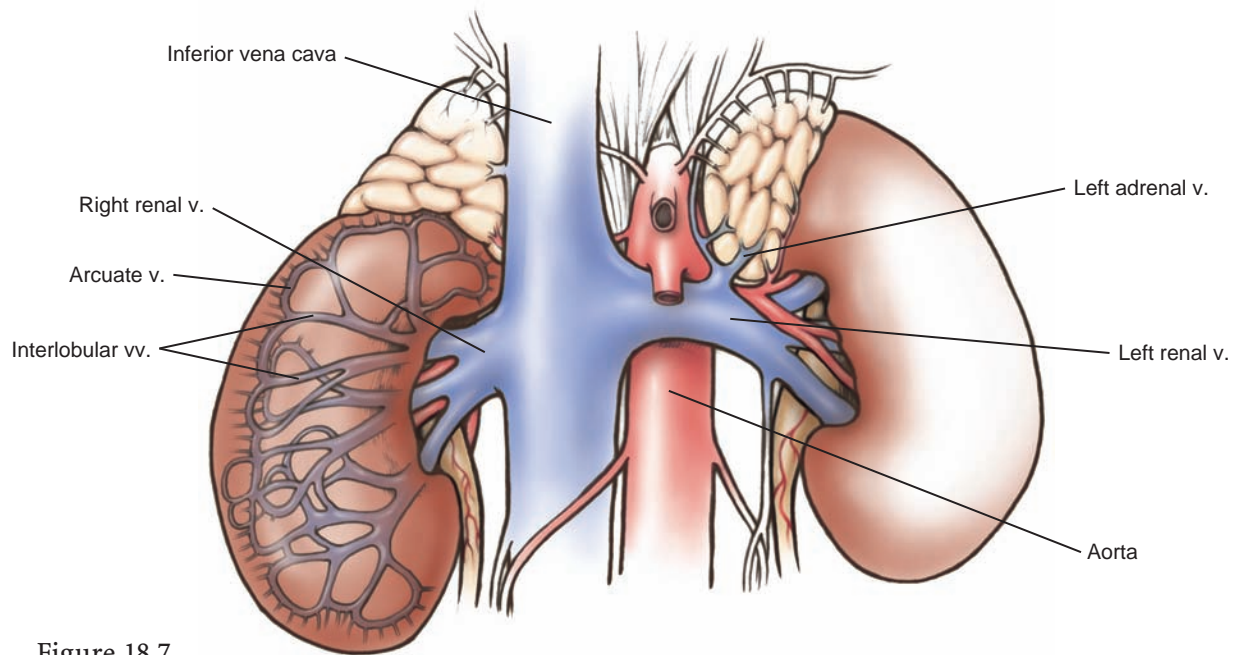


Figure 18.7

possible between the posterior segmental circulation and the polar segments, supplied by the apical or lower segmental arteries of the anterior circulation, to gain access to the upper or lower pole calyces.

The renal cortex is drained by the interlobular veins, which, unlike the renal arteries, anastomose freely with the arcuate veins at the base of the medullary pyramids and with the capsular and perirenal veins on the surface of the kidney. Unlike its renal arterial counterpart, occlusion of a segmental vein has little effect on venous outflow. The arcuate veins drain through the interlobar veins to the lobar veins, which join to form the renal vein. The right renal vein, 2–4 cm long, joins the lateral aspect of the inferior vena cava, usually without receiving any tributaries. The left renal vein, 6–10 cm long, crosses anterior to the aorta and ends in the left aspect of the inferior vena cava. It receives three tributaries lateral to the aorta: the left adrenal vein superiorly, left gonadal vein inferiorly, and a lumbar vein posteriorly. Intraoperatively, lumbar vein injury can cause massive hemorrhage, which may be difficult to control. Computerized tomography angiography (CTA) has been recommended for preoperative evaluation of renal vascular anatomy. At the renal hilum, the renal vein usually lies anterior to the renal artery. However, passing more posteriorly, the renal artery may be a centimeter or more, higher or lower than the vein.

Lymphatic Drainage

Lymphatic vessels within the renal parenchyma consist of cortical and medullary plexuses that follow the renal vessels to the renal sinus and form several large lymphatic trunks. The renal sinus is the site of numerous communications between lymphatic vessels from the perirenal tissues, renal pelvis, and upper ureter. Initial lymphatic drainage runs to the nodes present at the renal hilum lying close to the renal vein. These nodes form the first station for the lymphatic spread of renal cancer.

On the left side, the lymphatic trunks from the renal hilum drain to the para-aortic lymph nodes from the level of the inferior mesenteric artery to the diaphragm. The para-aortic nodal region is confined between the midline of the IVC and the left ureter. Lymphatic vessels from the right kidney drain into the lateral paracaval and interaortocaval nodes from the level of the common iliac vessels to the diaphragm. The interaortocaval and paracaval regions extend from the midline of the IVC to that of the aorta and the midline of the aorta to the right ureter, respectively. Lymphatic vessels from both sides may extend above the diaphragm to the retrocrural nodes or directly into the thoracic duct.

The kidneys have both sympathetic and parasympathetic innervation, yet the function of these nerves is poorly understood. Sympathetic preganglionic nerves originate from the eighth thoracic, through the second lumbar spinal levels. Sympathetic fibers are derived from the greater and the lesser splanchnic nerves, which link the celiac and superior mesenteric ganglia. Both sympathetic and parasympathetic fibers travel around the renal artery to the renal pelvis. The pain associated with ureteral obstruction, from causes such as ureteral calculi, is secondary to the stretch of the renal capsule. The activated nociceptors transmit a signal via myelinated A and unmyelinated C fibers. Pain might be referred over the distribution of the subcostal, iliohypogastric, ilioinguinal, genitofemoral nerves.

Nerve Supply

Ureters

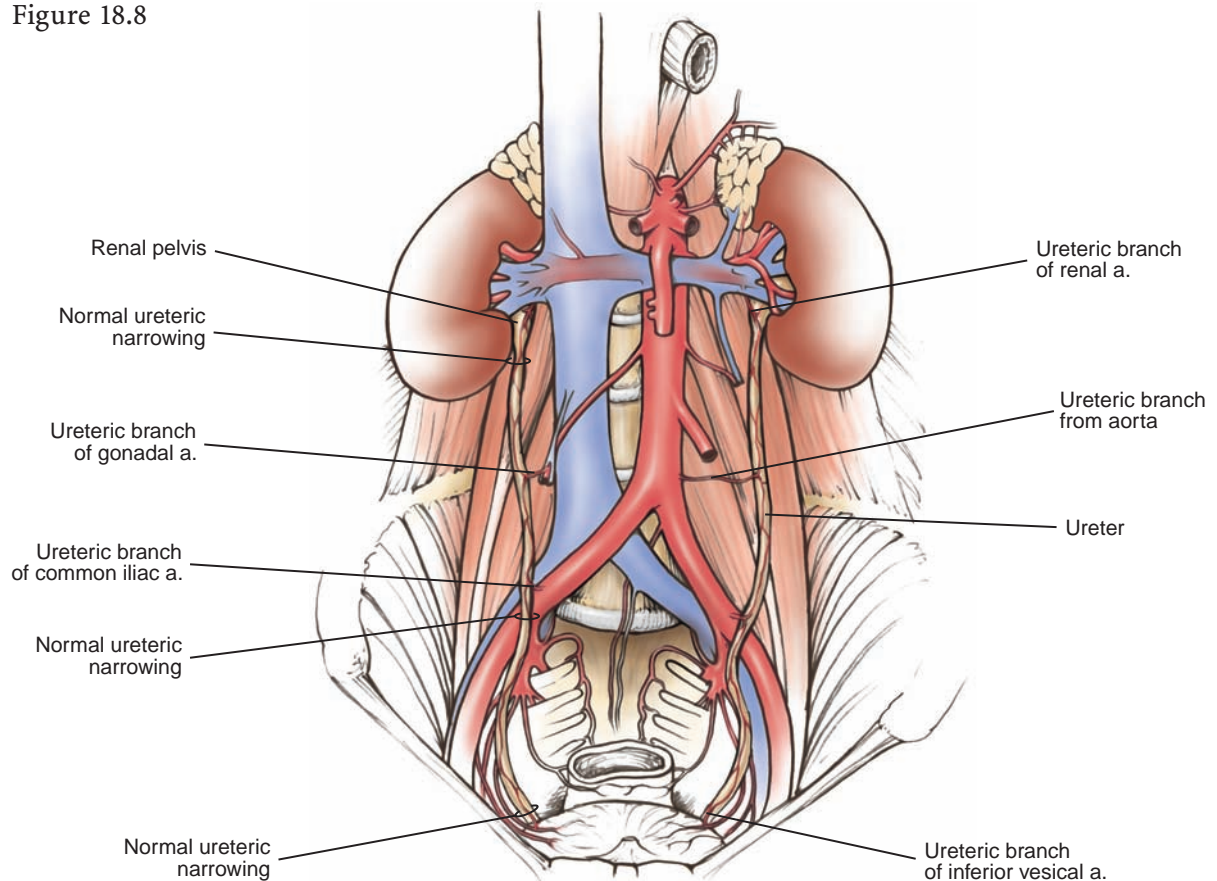
The ureter is a muscular tube that follows a gentle S-shaped course in the retroperitoneum. The muscle fibers are arranged in three separate layers: inner and outer longitudinal and middle circular. The length of the ureter in the adult is 28–34 cm, varying in relation with the height of the person. The average diameter of the ureter is 10 mm in the abdomen and 5 mm in the pelvis.

However, three areas of physiologic narrowing in the ureter should not be considered abnormal unless the proximal ureter is significantly dilated: the ureteropelvic junction, the point where the ureter crosses over the iliac vessels, and the ureterovesical junction. These are the common points where the ureteral calculi may cause obstruction during the passage down the ureter.

Both the ureters have the same posterior relations, lying on the medial aspect of the psoas major muscle and traveling downward adjacent to the transverse processes of the lumbar vertebrae. Retroperitoneal tumors or lymphadenopathy may distort the ureteral course. They enter the pelvis medial to the sacroiliac joints, cross over the bifurcation of the common iliac vessels, and follow the internal iliac (hypogastric) artery in a gentle lateral curve on the pelvic wall. At the level of the greater sciatic foramen, they turn medially again to enter the bladder obliquely and course submucosally for 2–3 cm, ending in the ureteral orifices.

Topography

Figure 18.8



Just proximal to their midpoints, both ureters cross behind the gonadal vessels. The right ureter passes behind the second part of the duodenum, lateral to the inferior vena cava, and is crossed by the right colic and ileocolic vessels. The left ureter passes behind the left colic vessels, descends parallel to the aorta, and passes under the pelvic mesocolon. In the male, the ureter crosses under the vas deferens in close proximity to the upper end of the seminal vesicle before entering the urinary bladder. In the female, the ureter travels in the posterior border of the ovarian fossa, passes forward under the lower part of the broad ligament lateral to the cervix, and underneath the uterine artery. This area is a common site for ureteric injury during hysterectomy.

Blood Supply

The upper ureter derives its blood supply from a ureteric branch of the renal artery. During their course in the abdomen, the ureters receive blood from the gonadal vessels, aorta, and retroperitoneal vessels. In the pelvis, they receive additional branches from the internal iliac, vaginal, middle rectal, uterine, vaginal and vesical, arteries. The abdominal portion of the ureter has a medial vascular supply while the pelvic portion receives its blood vasculature laterally. This should be taken into consideration during partial mobilization of the ureter to preserve as much blood supply as possible.

Venous drainage follows the arterial blood supply.

Lymphatic drainage of the ureters follows the arterial blood supply.

Lymphatic Drainage

The ureteric muscle fibers contain both α -adrenergic (excitatory) and β -adrenergic (inhibitory) receptors. However, peristaltic contractions occur in denervated ureters and can be altered by sympathomimetic or sympatholytic medications. This indicates that the role of the nerve supply to the ureter is to modulate the peristaltic activity and not to initiate it. Alpha-blocker medical therapy has been shown to be effective in augmenting spontaneous ureteral stone passage by inhibiting uncoordinated ureteral peristalsis.

Nerve Supply

Surgical Applications

The kidneys can be approached through various incisions: anterior transperitoneal, retroperitoneal flank, thoracoabdominal, and posterior lumbar. Factors that should be taken into consideration before selecting an incision include type of operation, pathologic condition, body habitus, and pulmonary or spinal deformities.

Operations for benign kidney disease (e.g., simple nephrectomy, partial nephrectomy, deroofting of a renal cyst, stone extraction) can be performed through an extraperitoneal flank incision. This approach has the advantages of being extraperitoneal, with a shorter period of ileus, and in obese patients most of the panniculus falls away from the kidney. This incision can be performed above the twelfth or eleventh rib, either extrapleural or intrapleural, to expose the adrenal gland or the upper pole of the kidney, and can also be extended downward to expose the ureter. This approach may not be suitable for patients with thoracic and lumbar musculoskeletal abnormalities such as scoliosis and cardio-respiratory compromise.

For good exposure of the renal vessels, particularly for vascular procedures or operation for advanced tumors, an anterior transperitoneal approach is preferred. It can be performed through an anterior subcostal, midline, chevron, or a paramedian incision. The midline incision is faster to perform and to close, but the incidence of incisional hernia is higher than with paramedian incisions. Posterior lumbar incisions are easy to perform and are easier on the patient, but the exposure is limited, particularly with respect to renal vessels. However, good access is provided to the renal pelvis and upper third of the ureter for stone surgery, but this approach is not recommended for malignancies.

After the induction of general anesthesia and endotracheal intubation, the patient is placed in the lateral decubitus position on the operating table so that the center of the kidney rests on the table brake is just below the tip of the twelfth rib. The kidney rests

Lumbar Subcostal Approach

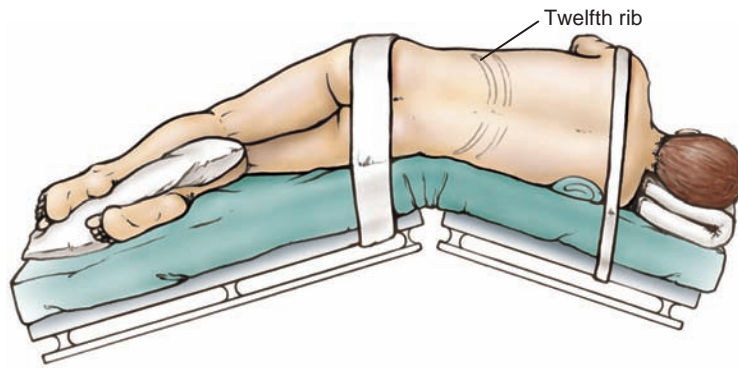
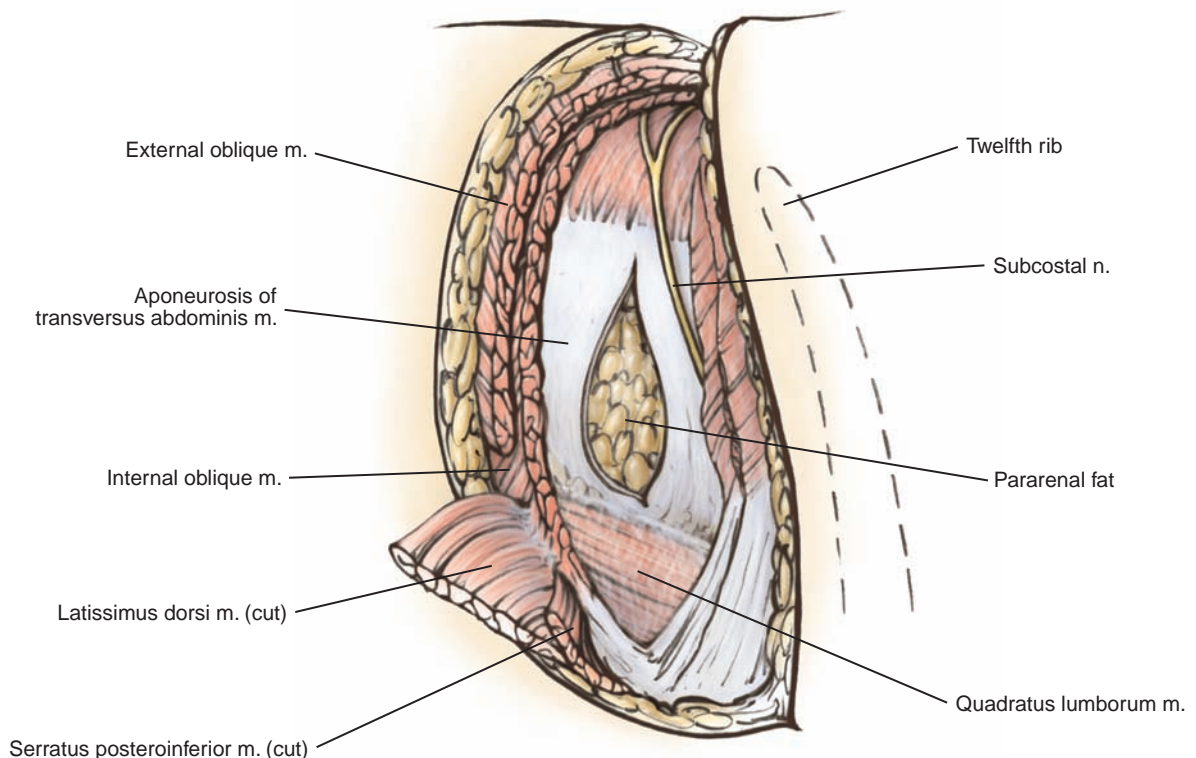


Figure 18.9

is elevated and the table is flexed to place tension on the incision site and increase the space between the costal margin and the iliac crest. Both the arms should be supported in a horizontal position on well-padded armrests or Mayo stand to prevent pressure injuries to the vessels and nerves. A soft pad or wrapped towel should be placed under the lower axilla to support the weight of the body away from the axillary vessels and nerves. The lower knee and hip are flexed, and the upper limb is fully extended. A soft pillow is placed between the knees. Prophylaxis against deep venous thrombosis with pressure stockings or pneumatic compression devices should be considered if the operation is expected to be lengthy. Large adhesive tape can be applied to the upper shoulder and thigh to secure position.

The skin is incised two fingerbreadths below the distal half of the twelfth rib and carried over the flank towards the umbilicus, where it can be extended as far as the

Figure 18.10



opposite rectus abdominis muscle. The incision is deepened through the subcutaneous fat to the first fascial layer, which is incised to expose the external oblique muscle anteriorly and the latissimus dorsi muscle posteriorly. These muscles are sharply divided to expose the fibers of the internal oblique muscle anteriorly and the serratus posterior muscle, which is sometimes seen below the latissimus dorsi muscle. These muscles are incised sharply in the line of the wound to expose the transversus abdominis muscle.

The subcostal nerve runs between the internal oblique and the transversus abdominis muscles, and care should be taken during incision of the internal oblique muscle to identify the nerve, dissect it free, and retract it away. Injury to the subcostal nerve can lead to numbness in a small area of the skin in the suprapubic region and weakness of the lower segment of the ipsilateral rectus abdominis muscle.

The transversalis (thoracolumbar) fascia in the depth of the wound is sharply incised to allow entrance into the retroperitoneal space. A finger is passed in this space, and the peritoneum is dissected medially away from the undersurface of the transversus abdominis muscle. The fibers of the transversus abdominis muscle can then be separated or incised to expose Gerota's fascia covering the perirenal fat.

The transcostal approach can be performed through the tenth, eleventh, or twelfth rib. However, the higher the level, the more risk for pleural injury.

Transcostal Approach

The patient is positioned as for the subcostal approach. The rib chosen for the incision is palpated and may be marked before the skin is incised. The skin and subcutaneous fat are incised as done for the subcostal incision approach. However, the incision should pass over the outer surface of the rib. The latissimus dorsi and external oblique muscles are incised to expose the outer surface of the rib. The periosteum is incised sharply over the whole length of the rib. A periosteal elevator is used to strip the periosteum of the rib on the outer surface, followed by the upper and lower borders. This removes the attachments of the abdominal and the intercostal muscles from the rib. Care should be taken not to injure the intercostal vessels when dissecting the lower edge of the rib.

A Doyen rib elevator is passed between the posterior surface of the rib and the periosteum and is moved backward and forward to free the rib from its attachments. A rib cutter is used to cut the rib posteriorly as far as the dissection allows.

The muscular slips of the corresponding crus of the diaphragm, still attached to the periosteum, are sharply incised, and the transversalis fascia is dissected to expose Gerota's fascia.

In contrast to the transcostal approach, the supracostal incision provides a good exposure to the adrenal gland and the upper pole of the kidney without the need for rib excision.

Supracostal Approach

The patient is positioned as for the subcostal or transcostal approaches. The skin is incised from the posterior axillary line, passing over the eleventh or tenth intercostal space to the rectus sheath. Subcutaneous fat and fascia are divided.

The latissimus dorsi and the serratus posterior inferior muscles are incised to uncover the intercostal muscles, which can be freed from the upper border of the rib

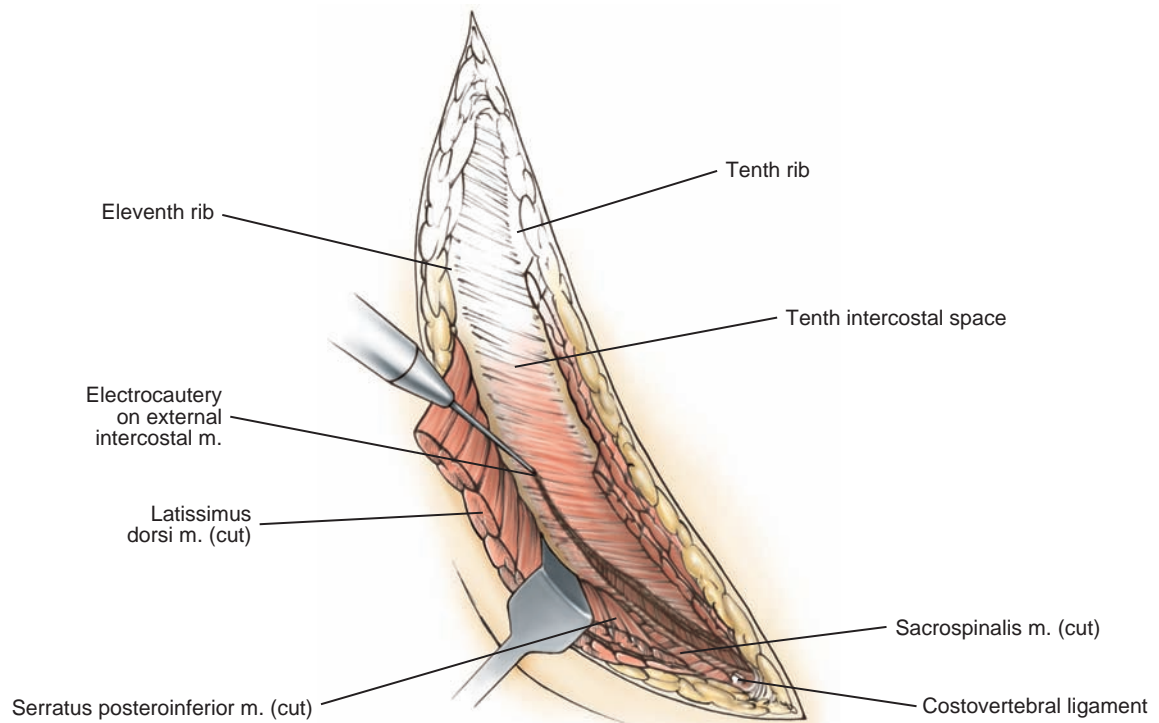


Figure 18.11

with an electrocautery. Great care should be taken while dissecting the intercostal muscles to prevent pleural injury or damage to the more cephalad intercostal vessels and nerve. The sacrospinalis muscle, covering the intercostal muscle in the posterior part of the wound, should be mobilized or divided to enable complete dissection of the intercostal muscles. The costovertebral ligament is divided to allow hinge-like movement of the rib so that it can be retracted without breaking.

The diaphragmatic fibers attached to the posterior part of the periosteum are divided and the pleura is mobilized superiorly. Then the transversalis fascia is incised sharply to display Gerota's fascia.

Downward Extension of Lumbar Incision

Lateral lumbar incisions, both subcostal and transcostal, can be extended downward to the suprapubic region. This is particularly useful for the exposure of the ureter and kidney, as for nephroureterectomy utilizing the same incision. However, this approach is difficult in obese patients, and two separate incisions may be needed.

Positioning is similar to that of the lumbar approach, but the patient is tilted backward and a long towel is rolled under the back to give access to the suprapubic area, where the incision will be carried out. The incision is similar to the typical lumbar approach, cutting toward the umbilicus and then gently curving towards the lateral border of the rectus abdominis muscle to the pubis. The abdominal wall muscles are cut in the direction of the wound, and the extraperitoneal space is entered as in the subcostal approach. The transversalis fascia is incised, and a blunt dissection is used to mobilize the retroperitoneal fat and display the ureter.

Thoracoabdominal Approach

The thoracoabdominal incision offers a good exposure of the kidney and the adrenal gland in cases of upper pole kidney tumors, adrenal tumors, or large renal tumors in a highly positioned kidney. The morbidity with this incision may be higher than that with other approaches because the pleural cavity is opened and a chest tube may be necessary, postoperatively.

The patient is placed in a semioblique position with the involved flank elevated 30–45° with rolled towels or sandbags. The operating table is extended to put the abdominal wall muscles under stretch. A soft pillow or a fluid-filled bag is placed under the contralateral axilla, and the arms are supported on armrests.

The incision is started at the angle of the ninth, tenth, or eleventh rib and continued downward and anteriorly towards the midpoint of the ipsilateral rectus muscle. It can be extended to the contralateral rectus muscle or to the pubis, if necessary.

The subcutaneous fat and fascia are incised. The latissimus dorsi muscle overlying the serratus posterior muscle will be seen in the posterior part of the wound, while the external and internal oblique muscles will be seen covering the anterior part of the wound. The muscles are sharply incised in the direction of the wound to uncover the rib and the intercostal muscles. The intercostal muscles are divided sharply, and the costal cartilage of the corresponding rib is also divided. The posterior end of the rib should be freed posteriorly by dividing the costovertebral ligaments to facilitate retraction, or the rib can be excised.

The pleura is usually opened during the dissection of the intercostal muscles, which is completed to expose the thoracic surface of the diaphragm. Care should be taken to avoid injuring the lung. With two fingers inserted under the diaphragm anteriorly, blunt dissection is carried out to separate the abdominal surface of the diaphragm from the upper surface of the liver on the right, and the spleen on the

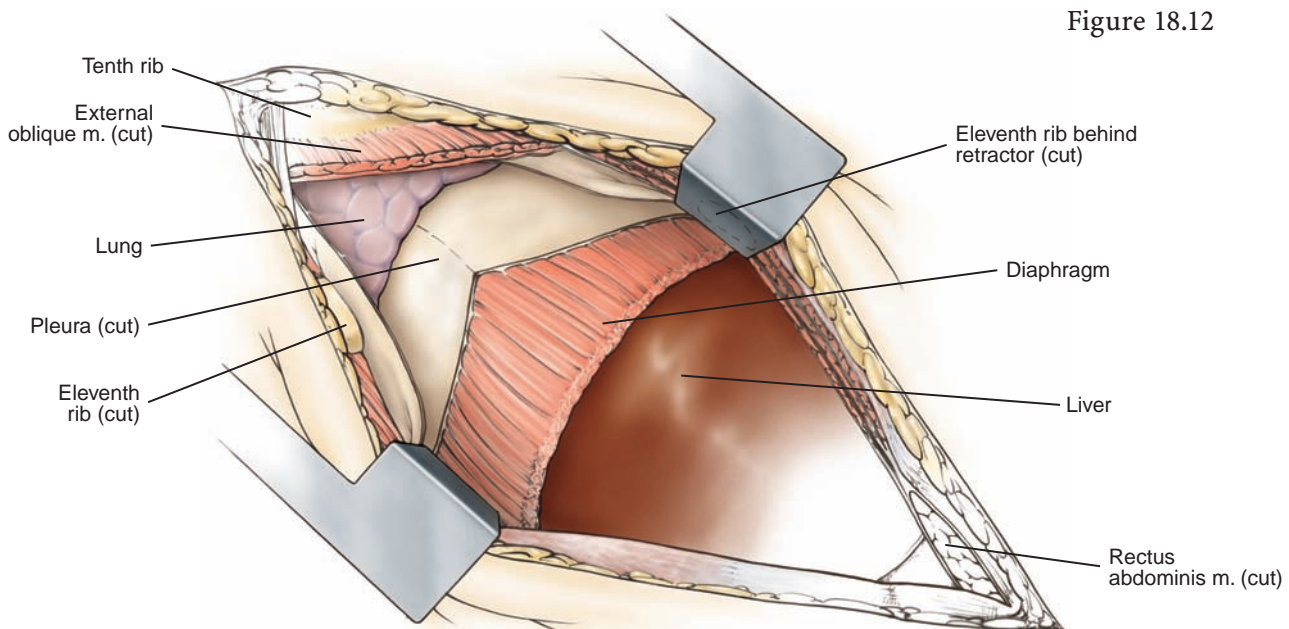


Figure 18.12

left. The diaphragm is divided from its thoracic surface, taking care not to injure the phrenic nerve. The internal oblique and transversus abdominis muscles, which pass medially to the ribs, are also divided.

If the procedure is to be performed extraperitoneally, the peritoneum is mobilized medially and freed from the undersurface of the diaphragm, transversalis fascia, and anterior rectus fascia. This allows the liver on the right side, and the spleen and the pancreas on the left side to be moved medially away from the dissection.

Anterior Midline Approach

The anterior midline incision is usually transperitoneal. While this approach is associated with a longer period of postoperative ileus, it is required when careful inspection of intra-abdominal viscera is needed, for bilateral procedures, or when access to the renal vessels is desired before manipulating the kidney. This incision is usually chosen for the exploration of urologic trauma because it is quick to perform and enables simultaneous exposure of the upper and lower urinary tracts, in addition to good exposure of the abdominal vasculature. This approach predisposes to intra-abdominal adhesions, which are a risk factor for bowel obstruction.

The patient is placed supine. Exposure of the kidney is improved by placing a cushion or a sandbag under the ipsilateral flank, extending the table, and tilting it in slight Trendelenburg position.

A complete midline incision is started at the xiphoid and carried down to curve around the umbilicus, usually on the left side to avoid the falciform ligament, and is continued to the symphysis pubis. If the surgery is limited to the kidney or upper ureter, the incision can be extended only to the umbilical level. Similarly, incision from the umbilicus to the symphysis pubis is adequate for the exposure of the lower part of the ureter and the pelvic organs.

The incision is deepened through the subcutaneous fat and fascia to expose the decussating fibers of the linea alba. In patients without previous history of abdominal surgery, the safest area at which to enter the peritoneal cavity is 5 cm above the umbilicus. The linea alba is incised at this level, the transversalis fascia is incised, and the fat is cleared. Then the peritoneum is grasped with two hemostats and incised sharply with a scalpel.

A finger is passed into the peritoneal cavity to palpate for bowel or omentum, adherent to the abdominal wall. Once this is cleared, two fingers are passed in the incision, and the abdominal wall is opened to the full length of the skin incision. If adhesions to the anterior abdominal wall are encountered, the wound is opened in a stepwise fashion and adhesions are divided by sharp dissection.

Anterior Paramedian Approach

The anterior paramedian incision, an alternative to midline incision, has the theoretical advantage of producing a stronger scar and less chance of incisional hernia, but it is time consuming, and close. It is preferred in operations where a stoma is created so that the subsequent scar will not interfere with the adhesive part of the urinary appliance.

The patient is placed supine. The skin is incised on the ipsilateral side 2–5 cm lateral to the midline. The incision can be carried from the costal margin to the pubis.

The anterior rectus fascia is incised along the length of the wound. The rectus muscle is dissected from its attachment to the fascia and displaced laterally. The posterior rectus sheath and the peritoneum are then incised about 2–3 cm from the midline.

The anterior subcostal incision provides good exposure of the adrenal gland and the upper pole of the kidney, in addition to adequate access to other upper abdominal organs such as the liver on the right and the spleen and pancreas on the left. Bilateral subcostal incision (Chevron incision) is an excellent approach when simultaneous exposure of both kidneys or adrenal glands is required.

The patient is placed supine with a rolled sheet or sandbags under the ipsilateral flank, shoulder, and pelvis. The table is flexed to about 20° to put the abdominal wall muscles in stretch. If bilateral incision is planned, the patient is placed supine with a rolled sheet beneath the upper lumbar spine, and the table is flexed.

The skin incision starts at the midaxillary line at the tip of the twelfth rib and is carried medially in a gentle curve about 2–3 cm below the costal margin. It is usually ended at the lateral border of the rectus muscle, but can be extended to the midline or the contralateral side as required. The incision is deepened through the subcutaneous fat and fascia, and the external oblique muscle and the anterior rectus sheath are incised.

An electrocautery is used to cut the rectus abdominis, internal oblique, and transversus abdominis muscles. Care should be taken to identify and ligate the branches of the superficial epigastric artery, which lies on the posterior rectus sheath. The posterior rectus sheath, transversalis fascia, and the peritoneum are picked up in layers between two hemostats and are incised with the knife carefully to avoid injuring the abdominal organs. The opening is widened, and the surgeon's finger is used to palpate for adhesive structures to the abdominal wall. Then the peritoneal cavity is opened to the full length of the incision.

Anterior Subcostal Approach

Kidney Tumors

Renal cell carcinoma is a relatively rare tumor, accounting for approximately 3% of malignancies in adults, but is the most common tumor of the kidney and the third most common tumor seen by urologists. The classic symptom triad of pain, hematuria, and flank pain is certainly a reliable clinical symptom complex. However, more recently, the majority of renal cell carcinomas are diagnosed incidentally at earlier stages during radiologic investigation done for other reasons.

Indications

Renal cell carcinoma is refractory to most traditional oncologic treatment, including chemotherapy, radiation therapy, and hormonal therapy. Therefore radical nephrectomy, which removes all the contents of Gerota's fascia, is considered the standard

Radical Nephrectomy

treatment for localized tumors. Unlike many tumors, in the setting of metastatic RCC, cytoreductive nephrectomy has been shown to improve the overall survival in patients receiving postoperative immunotherapy compared to those who receive immunotherapy alone. Local extension into the renal vein or inferior vena cava is not considered as a contraindication to radical nephrectomy. However, tumor extension beyond Gerota's fascia involving other organs is associated with poor prognosis, and nephrectomy should be considered only for palliation or as part of an adjuvant therapy protocol.

Preoperative Evaluation

Due to the recent advances in sophisticated radiologic studies, the surgeon can now make an accurate preoperative assessment of the nature and extent of kidney tumors. The diagnosis of renal cell carcinoma is generally made with computed tomography (CT), showing a solid contrast-enhancing mass in the parenchyma of the kidney. Fewer than 5% of all renal cell carcinomas have a cystic appearance with septations, irregular borders, dystrophic calcification, or other features that distinguish it from a simple renal cyst.

The differential diagnosis of solid kidney masses includes oncocytoma (granular oncocytes on histologic analysis, with a central scar in the tumor), angiomyolipoma (contains fat, seen on CT scans), xanthogranulomatous pyelonephritis (usually in patients with diabetes, with a concurrent stone in a poorly functioning kidney), fibromas, or metastasis. In spite of the diagnostic clues seen at radiologic investigation, the histologic nature of these masses cannot be confirmed without tissue biopsy, which is generally avoided because of the risk of seeding malignant cells through the needle track and the inherent risks of false negative results with percutaneous renal tumor biopsy. Accordingly, in most patients, radical nephrectomy is performed without prior tissue biopsy.

CT and magnetic resonance imaging (MRI) are the imaging studies which are most commonly used to stage renal tumors. Abdominal/pelvic CT is used to determine the local extension of the tumor, the presence of enlarged retroperitoneal lymph nodes, and the presence of abdominal/pelvic metastasis. MRI is superior in determining the extent of vena caval thrombi. Chest radiography or chest CT is routinely done to rule out pulmonary metastasis; bone scanning is required only in the presence of a large tumor or if clinical evaluation suggests metastasis to bone.

Incision

The eleventh or twelfth rib supracostal incision, with attempt to remain extrapleural, is recommended for most cases. It provides good exposure of the kidney, renal pedicle, and adjacent organs. Thoracoabdominal incision is preferred in patients with large upper pole tumors or tumors that extend into the inferior vena cava, although median sternotomy is an option for high caval thrombi. Unilateral anterior extraperitoneal incision provides adequate exposure in noncomplicated cases. Bilateral

tumors can be approached with a midline or Chevron incision; however, such lesions are best approached in a staged fashion.

Right Radical Nephrectomy

Once the peritoneum is entered, the intra-abdominal contents, mainly the liver, are inspected for unrecognized metastasis, and the tumor is carefully examined for resectability. The diaphragm is retracted superiorly with a self-retaining retractor, and counter traction is applied to the superior border of the rib below, after releasing the costochondral ligament. The liver is kept out of the way by gentle retraction to prevent hepatic injury. During extensive inferior vena cava mobilization, care must be taken not to injure the short caudate veins.

Attention should be given to the renal pedicle, which can be approached ventrally by retracting the ascending colon and dividing the lateral paracolic peritoneum. The hepatic flexure and the duodenum are mobilized medially to expose the renal pedicle and the renal veins lying in front of the artery. As an alternative, with the dorsal approach to the renal pedicle, the renal artery is readily accessible for ligation and division. This maneuver significantly reduces potential blood loss. It can be performed by dissecting the kidney and surrounding tissues free from the posterior abdominal wall and rotating it medially, after which the renal artery can be identified, ligated, and divided.

The ureter, gonadal vessels, and periureteral fat are dissected free of the posterior peritoneum and divided into two or three separate bundles. The dissection is then

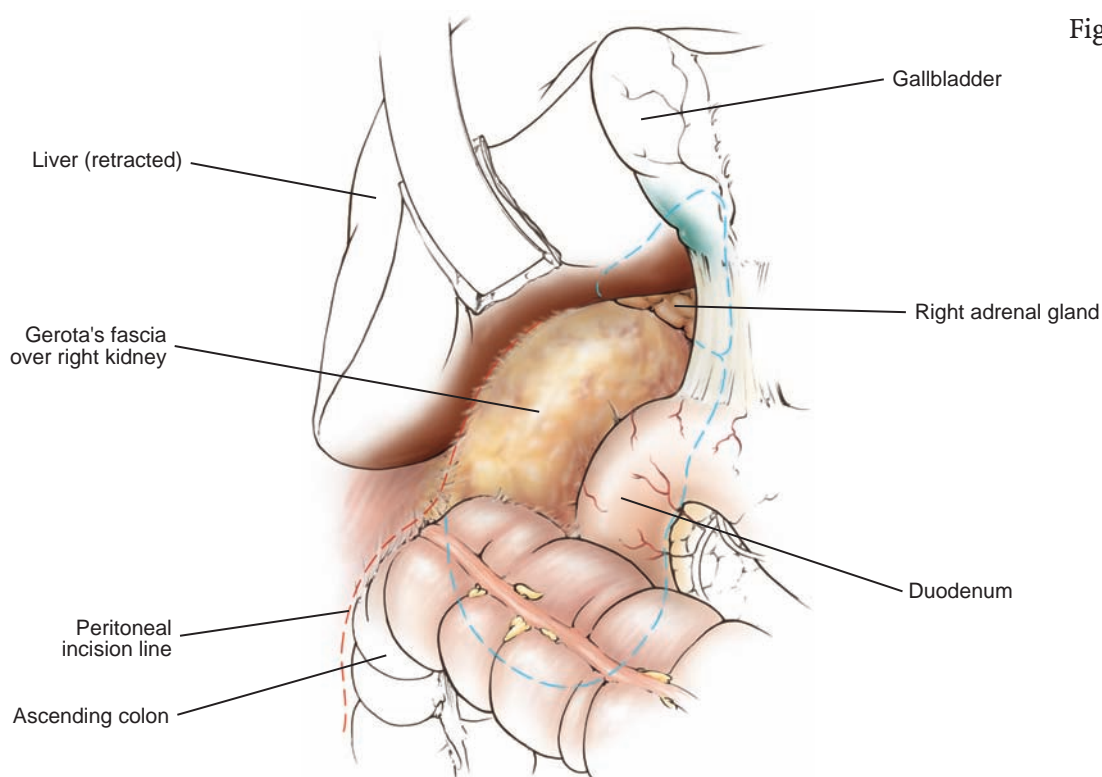


Figure 18.13

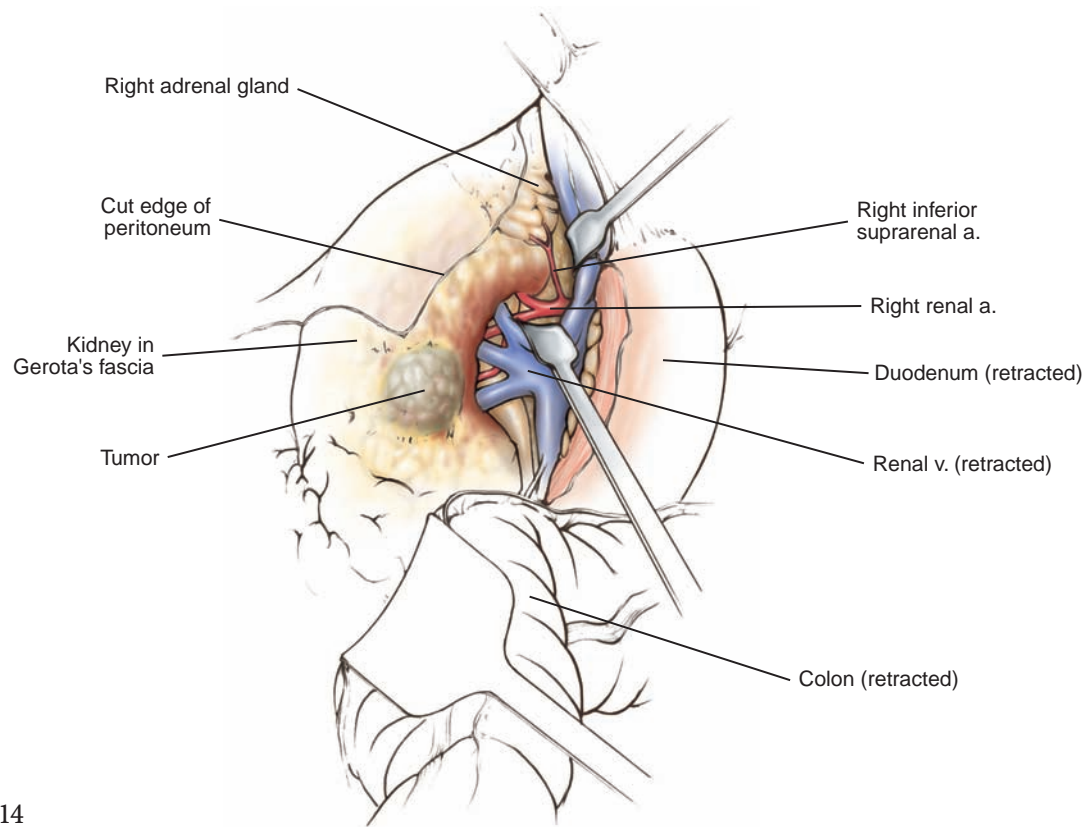


Figure 18.14

carried out superiorly along the inferior vena cava on its anterior surface, where there are few, if any, significant branches.

Superior to the renal vessels, the peritoneum fans out laterally, and the dissection is carried out at the lateral border of the peritoneum. In most larger tumors and some smaller tumors, the peritoneum cannot be dissected free of Gerota's fascia, and the surgeon is forced to remove a window of peritoneum with the specimen. Care should be taken to avert injury to the bowel, especially the C portion of the duodenum.

The superior portion of the specimen, including the adrenal gland, should be dissected free of the retroperitoneum and liver. As there may be branches of the phrenic and other vessels, a series of large hemoclips with tissue division below the clips is generally used to enhance hemostasis.

The specimen should be free at this point except for the venous structures. The adrenal vein is short and easily avulsed, and drains directly into the inferior vena cava. It should be identified and ligated carefully. The renal vein should be collapsed because the renal artery is divided. If the renal vein is still full, awareness of the branch arteries that may still be perfusing the specimen is necessary. The vein should be palpated for possible unsuspected thrombi, divided, and ligated. The specimen is then removed and the wound is closed, without a drain in most cases. Recent evidence suggests that the adrenal gland can be spared if preoperative imaging studies show no adrenal involvement and the adrenal gland does not demonstrate evidence of gross disease intraoperatively.

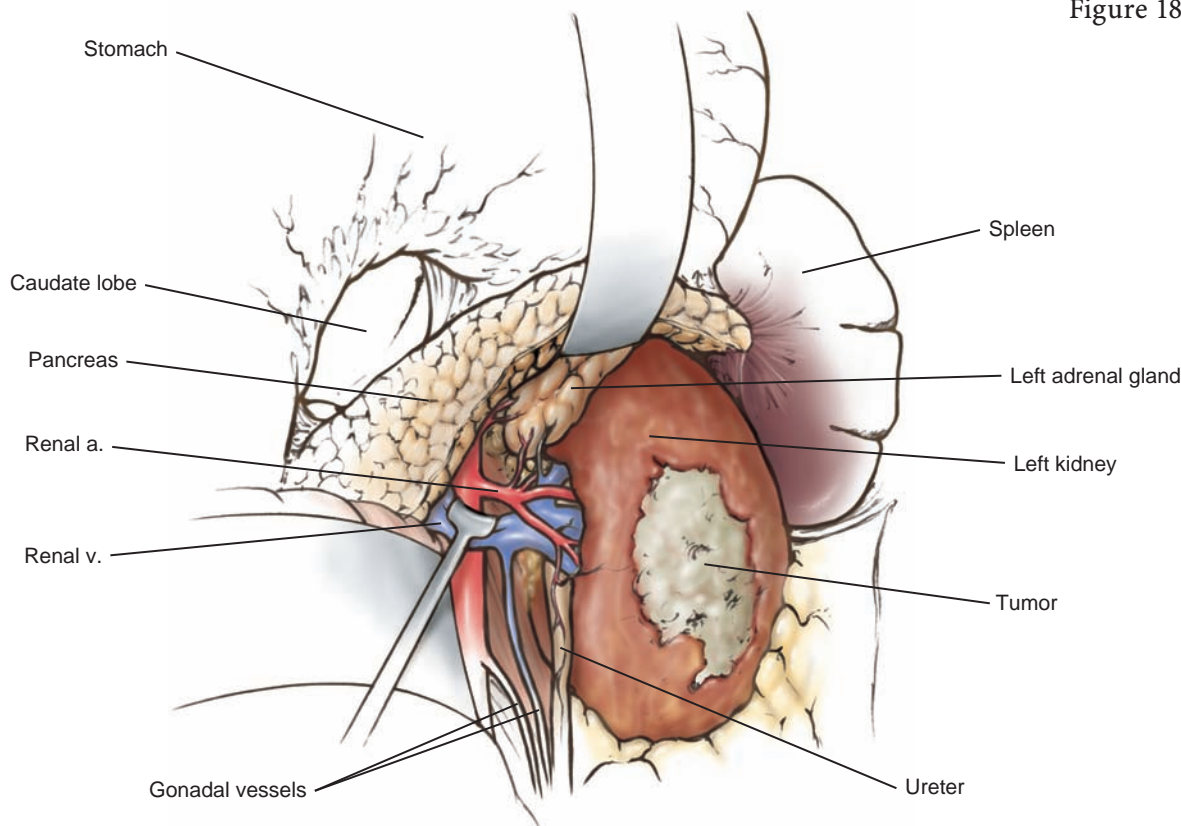
Left Radical Nephrectomy

The intra-abdominal contents are inspected for unrecognized metastasis, and the tumor is carefully examined for resectability. The diaphragm is then retracted superiorly with a self-retaining retractor.

The descending colon is retracted medially, and the lateral reflection of the peritoneum is incised. The mesentery is dissected bluntly from the anterior surface of Gerota's fascia. Care should be taken to prevent injury to the tail of the pancreas, which is mobilized medially. If the tumor extends into the colonic mesentery, this part of the mesentery can be resected with the specimen without great risk of colonic ischemia, as long as the marginal artery is not disrupted. The kidney and surrounding tissues are dissected free from the posterior abdominal wall and rotated medially, and the renal artery is identified, ligated, and divided. In bulky tumors, the superior mesenteric artery might be displaced laterally; therefore great care should be taken to distinguish the superior mesenteric artery from the renal artery on either side.

The ureter, the gonadal vessels, and the periureteral fat are dissected free of the posterior peritoneum and divided into two or three separate bundles. The dissection is then carried out superiorly along the aorta on its anterior surface, where there are few significant branches. The splenorenal ligament is identified, ligated, and divided, to avert splenic injury during mobilization of the kidney. The superior portion of the specimen should be dissected free of the retroperitoneum.

Figure 18.15



The specimen should be free at this point except for the venous structures. The left adrenal vein drains into the renal vein and is ligated and divided. The back surface of the renal vein should be carefully inspected for any lumbar veins, which if present should be ligated and divided. Then the renal vein should be palpated for possible unsuspected thrombi, divided, and ligated. Large tumors on either side frequently develop parasitizing vessels, which are abnormal in structure and can frequently lead to troublesome bleeding, if not ligated or clipped with great care. In some cases where it is difficult to identify the renal artery, the vein may be ligated and divided first, accepting the fact that the kidney will quickly become engorged, but identification of the artery will be much facilitated. The specimen is then removed, and the wound is closed without a drain in most cases.

Management of Tumor Extension in the Vena Cava

The presence of a solid mass in the vena cava might represent tumor extension into the lumen, blood thrombus, or less commonly, tumor invasion of the vena cava wall. Tumor extension into the vena cava occurs in 4–10% of the cases. The renal neoplasms resulting in tumor thrombus are usually aggressive. There are four levels of tumor thrombus depending on its location.

Level I thrombus extends less than 2 cm and level II more than 2 cm relative to the renal vein. Level III extends into the subdiaphragmatic and level IV into the supradiaphragmatic vena cava.

Complex cases may involve multiple disciplines including vascular, cardiothoracic and liver surgeons in addition to the urologist. When a high level of tumor thrombus is expected, the preoperative work up may include echocardiography, esophageal ultrasonography and MRI.

Total cardiovascular bypass with hypothermia with or without circulatory arrest and liver transplant techniques such as femoro-axillary (veno-veno) bypass are the options available for thrombus management. Intraoperative ultrasonography has been reported as an aid. Exploration of the vena cava is a major procedure, and a complete set of vascular instruments should be available. The extent of the tumor extension into the vena cava should be delineated preoperatively to help in planning the surgical approach. Right-sided renal tumors with limited vena caval extension can be approached with a right flank incision. A thoracoabdominal incision is utilized for high right-sided tumor extension, whereas a midline incision with a median sternotomy extension is frequently required for patients with left renal tumors and vena caval extension to the level of the hepatic veins or above.

Exposure of the retrohepatic vena cava is initiated by dividing the right triangular and coronary ligaments and ligating of the small hepatic (caudate) veins. The liver is then mobilized medially to expose the vena cava, and a cardiac tourniquet is applied around the vessel for temporary occlusion. The contralateral renal vein and the infrarenal vena cava are also occluded with a Rumel tourniquet. Since about one fourth of the venous return in the vena cava comes from the liver, clamping the porta hepatis through the foramen of Winslow with a noncrushing vascular clamp reduces the blood loss remarkably. A cavotomy is made adjacent to the hepatic veins and extended inferiorly to the origin of the affected renal vein. A 20 Fr Foley catheter

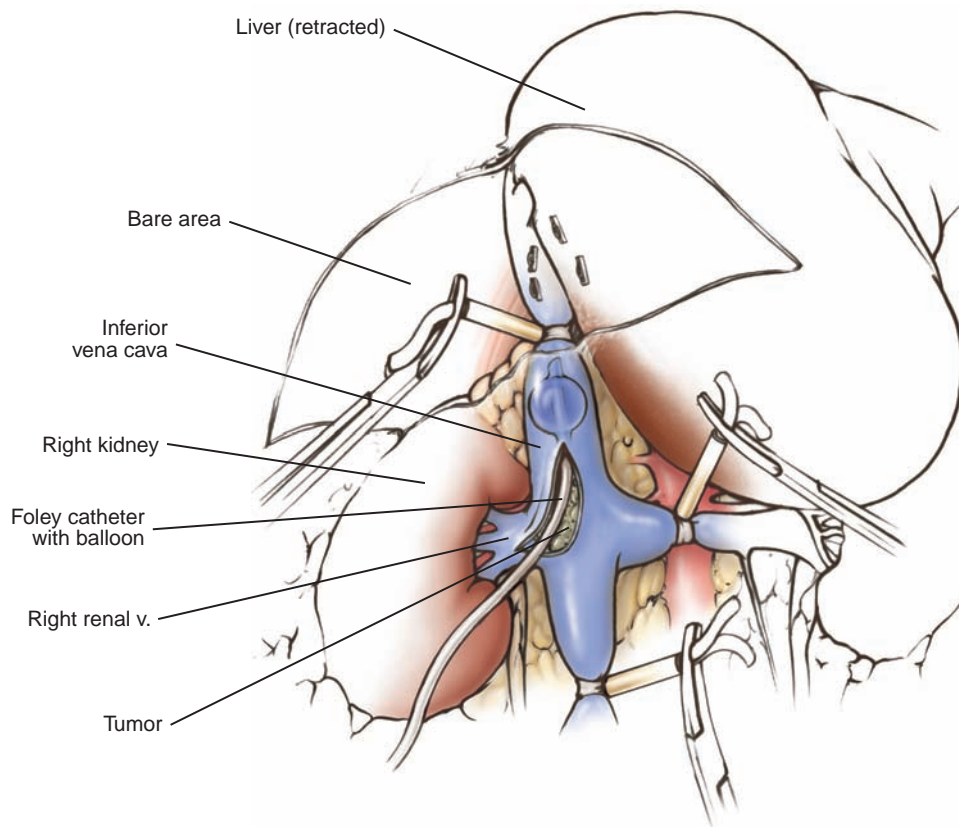


Figure 18.16

with a 30-mL balloon or a Fogarty catheter is introduced into the vena cava, and the balloon is inflated above the level of the thrombus and is withdrawn gently to extract the thrombus out of the vena cava. However, using this technique has been associated with tumor embolization. When the tumor invades the wall of the vein, partial or complete resection of the vein is considered.

Air should be evacuated from the vena cava before closure. A Satinsky clamp is applied to the cavotomy, and the edges of the vena cava are approximated gently with Allis clamps. The tourniquet on the contralateral renal vein and infrarenal vena cava and the clamp on the porta hepatis are released, leaving the tourniquet on the suprahepatic vena cava in place. The Satinsky clamp is briefly vented to allow the air in the vena cava to be evacuated, then the clamp is closed again, and the last tourniquet on the vein is released. The affected renal vein is transected flush with the vena cava. The entire cavotomy is then closed with a continuous 5-0 polypropylene suture.

The prognosis of renal cell carcinoma is greatly affected by the presence or the absence of nodal metastasis. Due to the position of the kidney just inferior to the cisterna chyli, tumor spread from the renal lymphatic vessels to the cisterna chyli and widespread dissemination of the disease is common. Therefore, curative lymphadenectomy is not possible in most cases, and the value of lymphadenectomy is limited to the diagnosis of lymph node involvement. Limited dissection of the tissue around the junction of the renal vessel to the nearest great vessel and the resection

Lymphadenectomy

of the visible or palpable nodes is usually sufficient. Conversely, some investigators have argued that lymphadenectomy may affect cancer-specific survival, thus more investigation needs to be done to determine its ultimate role.

Nephroureterectomy

Transitional cell carcinoma of the calyces, pelvis, or ureter is usually treated with nephroureterectomy, provided the contralateral collecting system is normal and no evidence of distant metastasis exists. In properly selected patients with small low grade tumors, segmental ureterectomy or endoscopic treatment may be warranted. Preoperative evaluation should include cystoscopy and bilateral retrograde pyelography for better evaluation of the collecting system. The operation can be performed through a flank incision with downward extension, or alternatively two separate incisions or a midline incision can be made. The technique of nephrectomy is the same. The ureter is mobilized with blunt and sharp dissection down to its insertion in the bladder. A cuff of the bladder must be removed with the lower ureter because this is the most common site for tumor recurrence after nephroureterectomy. The bladder is then closed in two layers with 2-0 chromic catgut sutures. A Foley catheter is left in the bladder for drainage, as well as a drain in the pelvis next to the suture line.

Partial Nephrectomy

In the past, partial nephrectomy (nephron sparing surgery) was reserved for tumors in a solitary functioning kidney, bilateral tumors, or unilateral tumors in patients with pre-existing azotemia. More recently, partial nephrectomy has been applied to all patients with small (<4 cm) renal tumors, as long-term results have demonstrated similar cancer specific survival rates compared to radical nephrectomy in this cohort of patients. Full preoperative evaluation should be carried out to confirm the localization of the disease. The arterial anatomy of the affected kidney and the tumor location relative to the collecting system should be carefully studied with preoperative three-dimensional CT or MRI.

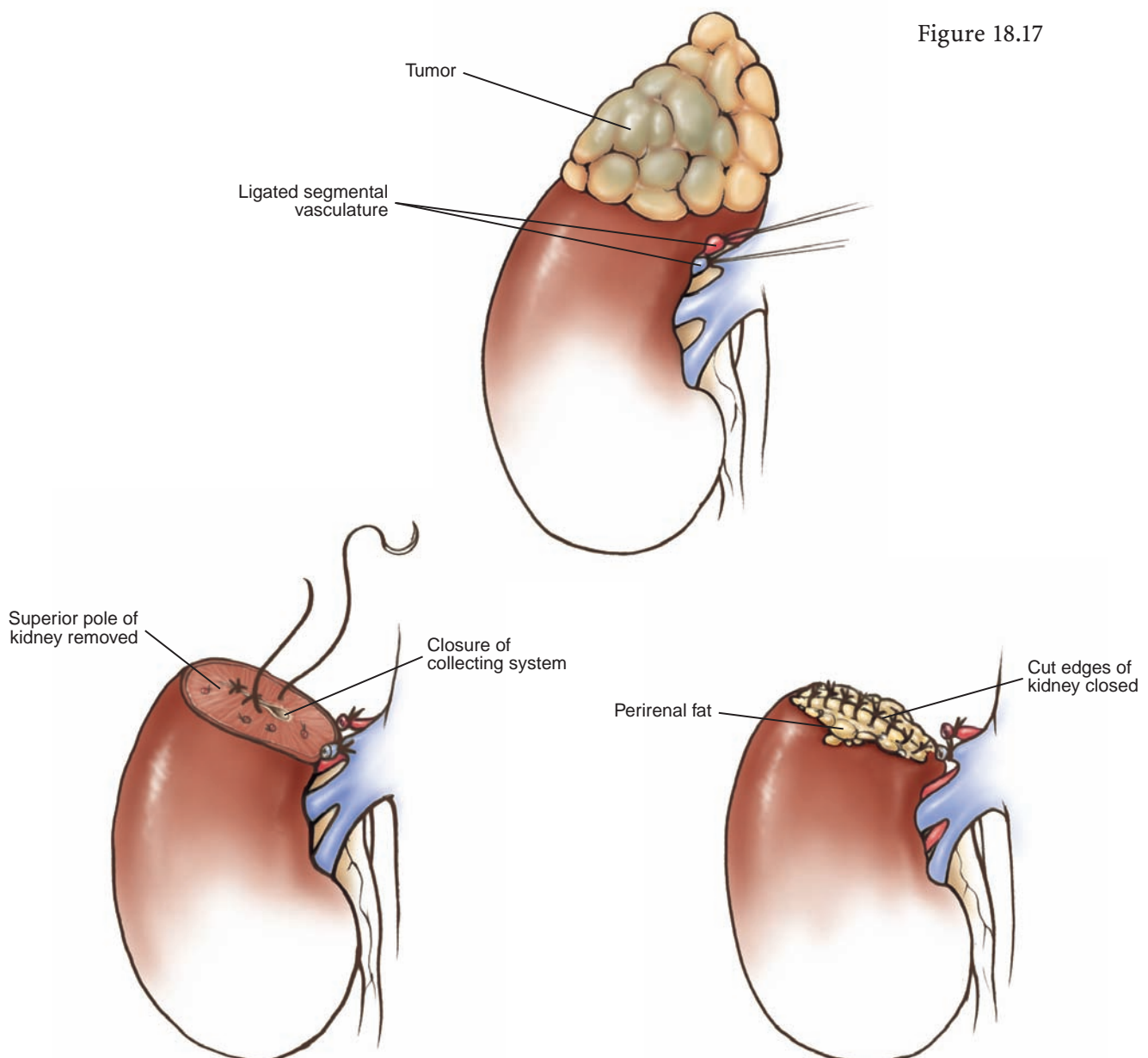
Adequate renal perfusion is secured with preoperative hydration and mannitol administration prior to renal artery occlusion. Flank incisions through the bed of the eleventh or twelfth rib, with attempt to stay extrapleural and extraperitoneal, provide an excellent exposure of the peripheral renal vessels. Then the kidney is mobilized within Gerota's fascia. Renal dissection can be performed under warm, cold or no ischemia. The decision for occluding the renal artery is dependent on tumor location, size, difficulty of dissection and reconstruction of renal parenchymal and collecting system; renal vessel occlusion creates a blood-free field. Temporary occlusion of the renal artery (warm ischemia) will allow 30 min of operating time without significant ischemic injury to the kidney. If a surgeon anticipates the renal dissection and collecting system reconstruction to last longer than 30 min, then surface cooling (20–25°C) of the kidney (cold ischemia) with iced slush during the procedure is warranted. Renal hypothermia with ice slush increases renal protection from ischemic injury for at least 90 min. Alternatively, perfusing the kidney with cold solution through an arterial catheter or via the ureter in a retrograde fashion has been reported. However, small polar or peripheral renal tumors may not require renal artery occlusion, and instead the segmental artery can be identified and divided. Simple enucleation for

malignant lesions should be avoided even if the tumor looks well defined, because of the probable presence of microscopic extensions of these tumors beyond the pseudo-capsule. Tumors of the upper or the lower pole of the kidney are best resected by polar nephrectomy (guillotine resection), whereas mid-renal tumors are resected with wedge resection. Intraoperatively, tissue biopsies taken from the resection base following tumor removal are sent for frozen section analysis to confirm adequate margins. Intraoperative sonographic imaging is useful for tumor localization and delineation. If the collecting system is violated during the resection, retrograde ureteral injection of indigo carmine or methylene blue is used to identify openings that are then subsequently closed.

After the mobilization of the kidney, the renal artery and the vein are dissected free from the surrounding structures. Dissection of the branches of the renal artery will

Polar Nephrectomy

Figure 18.17



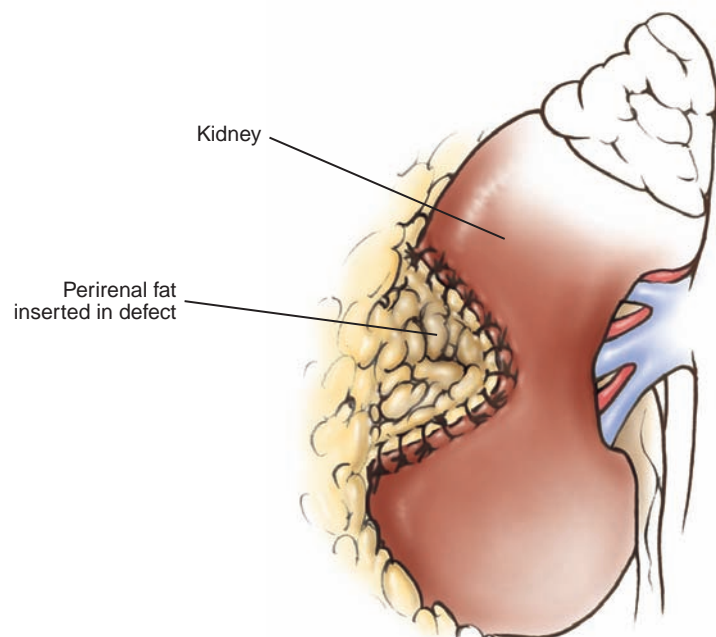
delineate the segmental artery of the affected pole of the kidney, which is ligated and divided. Often a corresponding venous branch is present, which is similarly ligated and divided. The kidney is inspected for the ischemic line of demarcation, which outlines the segment of the kidney to be excised. If this area is not obvious, injection of a few milliliters of methylene blue in the distal part of the apical artery gives a better outline of the area to be resected. This segment of the kidney and the covering Gerota's fascia is then excised by sharp and blunt dissection, making sure that the incision is at least 1–2 cm from the visible edge of the tumor. However, a margin as little as 1 mm has been shown to be adequate.

The collecting system is then closed with interrupted or continuous 4-0 chromic catgut sutures to ensure a watertight closure. Small vessels are identified and controlled with figure-of-eight 4-0 chromic sutures. The edges of the kidney are then approximated with 2-0 chromic sutures, passing through the capsule and superficial parenchyma, with some perirenal fat applied to the edge of the kidney, and the sutures are tied on top of it. A drain should be left in the perirenal space, particularly if the collecting system is opened.

Wedge Resection

Temporary renal artery occlusion and surface cooling are usually required for wedge resection. A wedge of Gerota's fascia and renal parenchyma is resected with 1–2 cm of surrounding grossly normal renal parenchyma. The collecting system and the vessels are closed with 4-0 chromic sutures. Portions of the perirenal fat are mobilized and inserted in the defect, and the edges are closed with interrupted 2-0 or 3-0 chromic sutures. Alternatively, if the defect is small, the edges can be approximated with insertion of fat with a small piece of oxidized cellulose (Oxycel) placed at the base of the

Figure 18.18



defect for hemostasis. Other hemostatic adjuncts like bovine derived gelatin matrix and thrombin may also be used to aide in hemostasis. There should be no tension on the sutures, and the renal vessels should not be significantly kinked after closure.

Laparoscopy can be performed via a transperitoneal or retroperitoneal approach depending on size and location of the tumor and surgeon's preference. Additionally, hand-assisted laparoscopy can be utilized for more complex cases and when surgeons are initially learning laparoscopic surgery.

Laparoscopic Nephrectomy

Transperitoneal Approach

It is similar to open transabdominal nephrectomy. The patient is positioned in an oblique lateral decubitus position. A 1-cm infraumbilical incision is made and a Veress needle is used to obtain a pneumoperitoneum. A 10-mm blunt tipped trocar is inserted under direct visualization into the peritoneal cavity. The laparoscope is used to inspect the abdomen and to visualize the placement of additional trocars (typically a 10-mm trocar is placed two-thirds the distance from the umbilicus to the anterior superior iliac crest, and a 5-mm trocar is placed midway between the umbilicus and xiphoid). With standard laparoscopic techniques, the colon is reflected medially. Renal colic ligaments are divided to access the kidney. The ureter and gonadal are retracted anteriorly and dissection is carried out towards the renal hilum. While the renal vessels can be ligated with sutures or clips, they are mostly divided separately using laparoscopic stapling devices. Once the kidney is freed, it is placed in a retrieval endoscopic bag. The renal specimen is removed from the abdomen either intact or by morcellation.

Retroperitoneal Approach

A 1–2-cm incision is made just anterior to the twelfth rib tip. The thoracolumbar fascia is incised and digitally dilated. A space is created within the retroperitoneum for the placement of a balloon dilator. The balloon dilator is gradually distended and removed, and a pneumoretroperitoneum is created. Two secondary trocar ports are inserted under manual guidance: one anterior to the anterior axillary line and the other at the midaxillary line. The lower renal pole and/or ureter are usually identified first, and then further dissection exposes the middle, and then the upper poles. Access to the renal hilum is expedited with this approach. However, there is limited working space and close proximity of ports. An individual with prior multiple abdominal surgeries can benefit from this approach, if tumor location allows.

Hand-Assisted Approach

Laparoscopic nephrectomy has its challenges despite its benefits of better cosmesis, quicker recovery and lower postoperative pain. Direct digital manipulation is replaced with visually directed instrumentation. In order to combine the benefits of both open and pure laparoscopy, hand-assisted laparoscopy was introduced. The

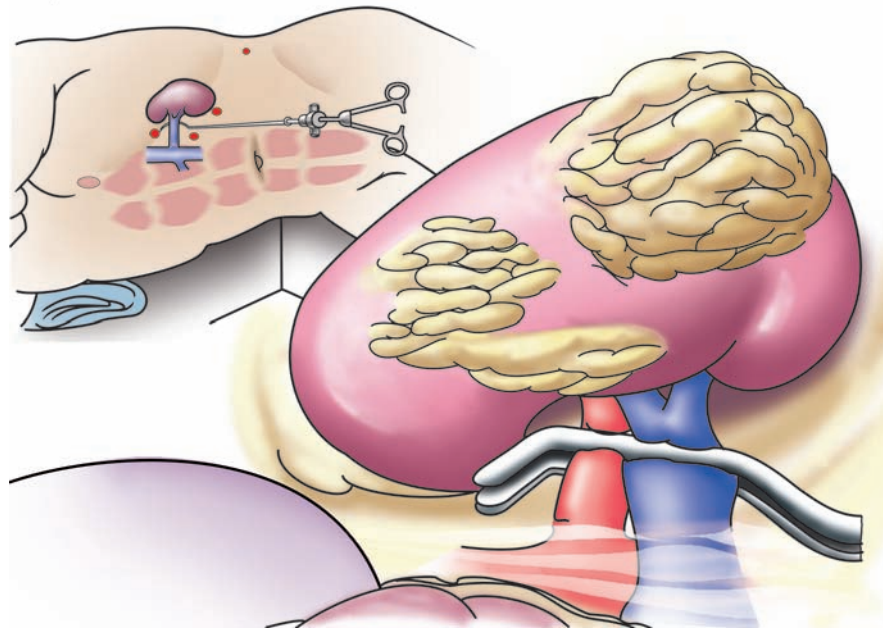


Figure 18.19

technique is similar to the transperitoneal laparoscopic approach but includes a hand port. This port allows intra-abdominal insertion of the surgeon's hand while maintaining the pneumoperitoneum. With this technique, the specimen is removed intact without morcellation.

Laparoscopic Partial Nephrectomy

Partial nephrectomy, whether open or laparoscopic, is technically demanding; however, the challenge is much greater laparoscopically and therefore should be reserved to experienced laparoscopic surgeons. Preoperatively, a ureteral catheter is placed and standard transperitoneal/retroperitoneal laparoscopic techniques are performed. The renal hilum is either clamped en bloc with a Satinski clamp or the renal vessels are individually occluded with bulldog clamps. A laparoscopic sonographic probe delineates the tumor. After the tumor with a margin of normal parenchyma is removed, the transected vessels are secured with intracorporeal sutures. The pelvicaliceal system is tested for leakage with retrograde ureteral indigo carmine infusion. If leakage from the collecting system is appreciated, then repair is completed with running sutures. Hemostatic bolsters (Surgicel) are cinched down in the renal defect with parenchymal sutures. The hilar clamp is removed and the resection site is observed for hemostasis. If ischemia time is expected to exceed 30 min, then renal cooling should be undertaken with ice slush.

Renal Cryoablation and RadioFrequency Ablation

Minimally invasive ablative procedures (cryoablation and radiofrequency ablation) have become an option for patients with significant comorbidities. These treatments can be administered via a percutaneous, open or laparoscopic approach. This discussion will focus on laparoscopic-assisted treatment. Tumors can be approached transperitoneally or retroperitoneally based on tumor location, body habitus and

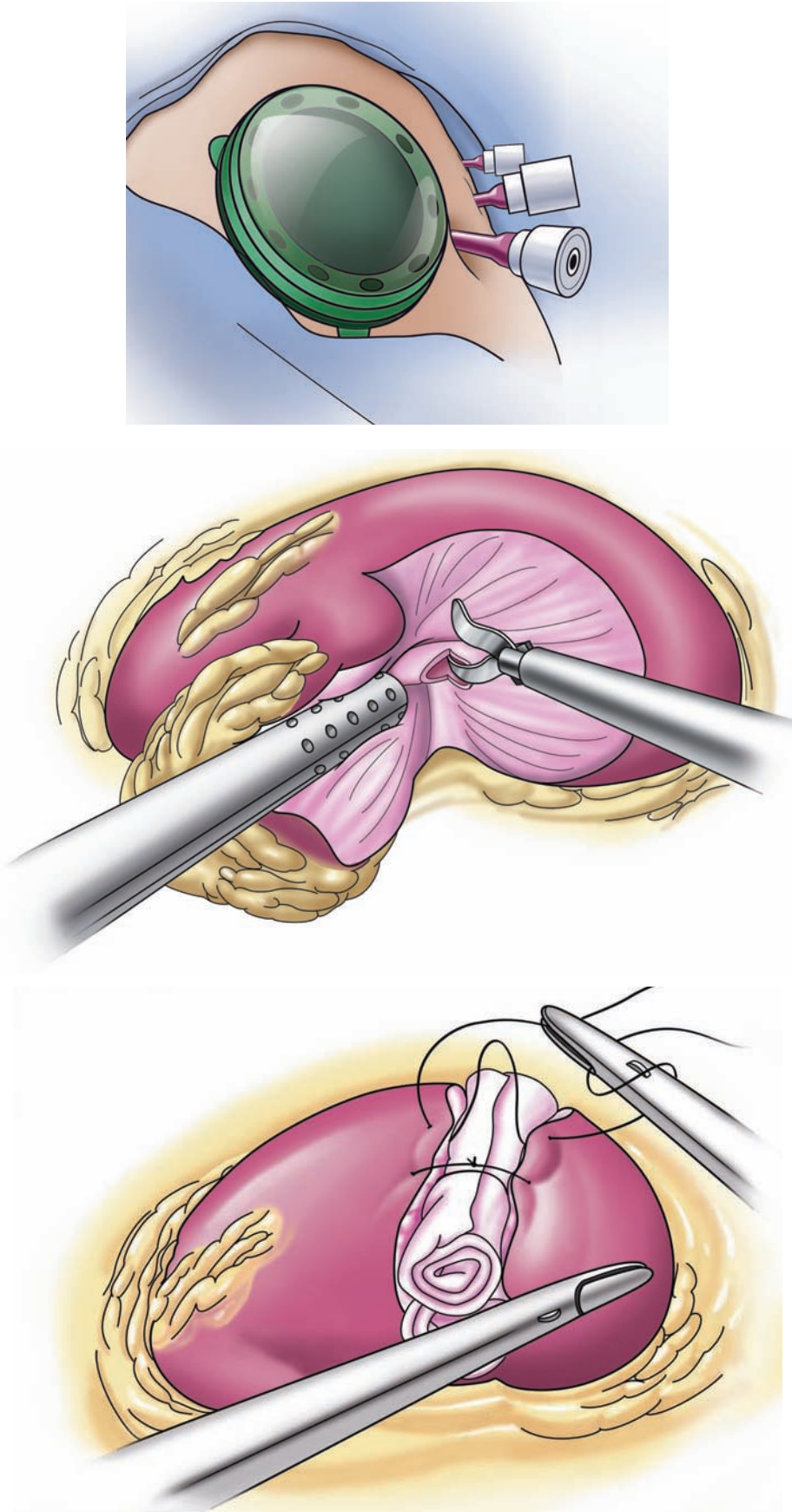


Figure 18.20

surgeon's comfort and skills. Typically, anterior and posterior lesions are managed transperitoneally and retroperitoneally, respectively.

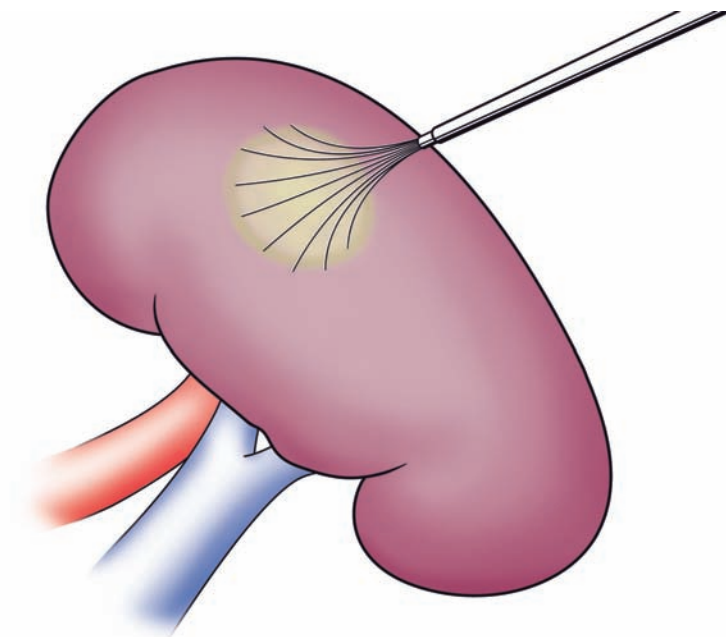
Laparoscopic Cryoablation

With standard laparoscopic techniques, the kidney is exposed and Gerota's fascia is opened. The perirenal fat is dissected off of the kidney, exposing the tumor. A laparoscopic ultrasound probe is used for tumor margin delineation. A biopsy of the tumor is taken for diagnosis confirmation. Percutaneous cryoprobes are positioned perpendicularly into the tumor(s) under visual and sonographic guidance. Colon, liver, spleen or other adjacent structures are moved away from the cryoprobes. These cryoprobes are rapidly cooled and the ice ball is visually and sonographically followed. Cryoablative temperature goal recommendation is -20°C for optimal tumor necrosis. The ice ball has to extend at least 1 cm beyond the tumor margin. The tumor(s) undergo a few freeze-thaw cycles. The cryoprobes are removed and renal parenchymal insertion sites are observed for hemostasis; adjunctive hemostatic agents such as fibrin glue and oxidized cellulose are applied as needed.

Laparoscopic Radiofrequency Ablation

As with cryoablation, once the tumor is exposed, the radiofrequency probes (tines) are inserted perpendicularly in the tumor, percutaneously. The temperature goal recommendation is 105°C for 3–8 min depending on tumor size. As opposed to cryablation, radiofrequency ablation cannot be monitored in real time with ultrasonography. The ablative cycle is repeated a few times. Bleeding following probe removal is rare as cell death is accomplished by coagulative necrosis.

Figure 18.21



The robotic-assisted approach consists of a master-slave system with a surgeon at a remote console controlling 3–5 laparoscopic robotic arms. The added benefits compared to standard laparoscopic techniques are 3 dimensional vision, intuitive robotic movements and enhanced degrees of freedom. Robotic-assisted laparoscopic radical, partial nephrectomy and nephroureterectomy are still being evaluated. The limited data available suggest no additional benefit of robotic-assisted laparoscopy over pure laparoscopic surgery.

Robotic-Assisted Laparoscopy

Ureteral Tumors

Transitional cell carcinoma accounts for more than 95% of ureteral tumors and has the worse prognosis compared to other urothelial tumors. The surgeon should be aware that this tumor is commonly multicentric, and careful search for other tumors in the urinary tract should always be considered. Squamous cell carcinoma, adenocarcinoma, and sarcoma account for less than 5% of ureteral tumors.

Total ureterectomy is most frequently done in combination with nephrectomy (radical nephroureterectomy) for treatment of renal pelvic or ureteral neoplasms. Localized solitary tumors of the ureter can be treated with partial ureterectomy or endoscopically.

Gross hematuria is the most common symptom of ureteral tumors. Most patients have hematuria throughout urination, and passage of vermiform clots. Gradual ureteral obstruction by tumor may lead to dull flank pain in about a third of patients. However, the passage of blood clots might cause severe ureteral colic, and care should be taken not to summarily diagnose stone disease, particularly if the patient has a history of bladder urothelial tumors.

The majority of ureteral tumors are demonstrated as a filling defect on excretory urograms. CT is useful for diagnosis and staging, but small tumors can be missed due to volume averaging. Ureteral stones are opaque on CT scans and can be easily differentiated from tumors. Cystoscopy should be performed in all patients with ureteral tumors to rule out bladder tumors which is found in approximately 40% of the patients. Retrograde urography provides better visualization of the upper urinary tract and can be performed in patients with deteriorated renal function. Urine should be collected at the lesion level endoscopically for cytologic analysis. Additionally, ureteroscopy and biopsy can be used to establish the diagnosis. Abdominal CT, chest radiography, bone scan, and liver function tests should be considered to rule out metastasis.

Preoperative Evaluation

With the advances in endoscopic instrumentation, ureteroscopy or percutaneous renal surgery with tumor resection or laser ablation of ureteric tumors have been described as an alternative conservative management to nephroureterectomy. Tumors

Endoscopic Treatment

should be low grade, localized, solitary, superficial, and accessible. Other indications include solitary kidney, bilateral renal disease, and renal insufficiency. Potential complications are ureteral perforation, extravasation, and stricture formation. The next step in management if recurrence is detected is complete nephroureterectomy with the excision of ipsilateral orifice and a bladder cuff.

Partial Ureterectomy

Indications

Conservative treatment of localized ureteral tumors is especially indicated in patients with a solitary kidney, bilateral tumors, and renal insufficiency. Upper and middle third ureteric tumors should be treated with segmental resection if they are solitary and low grade, and with nephroureterectomy if they are multifocal or high grade. Distal ureteric tumors should be treated by distal ureterectomy, removing a cuff of tissue from the bladder around the ureteral orifice.

Incision

Surgical approaches to the ureter depend on the part of the ureter to be operated on. Upper third tumors can be accessed with a subcostal flank incision; middle third tumors can be removed through a muscle-splitting incision in the appropriate position; and lower third tumors can be approached through a lower midline, paramedian, or Gibson incision. The decision whether the incision should be transperitoneal or extraperitoneal, depends on whether exploration of the abdominal viscera is necessary and on the type of urinary reconstruction planned.

Technique

Extraperitoneal exposure of the ureter is achieved by incising the abdominal muscles and the transversalis fascia. It is important to enter the plane between the transversalis fascia and the parietal peritoneum. The peritoneum is mobilized medially with blunt dissection, and the ureter should be looked for, in the retroperitoneal space. Sometimes, the ureter is mobilized with the parietal peritoneum and can be palpated as a cord-like structure on the surface of the peritoneum. It is important to know that the femoral nerve and the tendon of the psoas minor muscle, if present, can be palpated as a cord-like structure in the pelvis and can be confused with the lower third of the ureter. Careful observation for peristaltic activity is helpful in these situations. The ureter enters the pelvis medial to the sacroiliac joint, and in front of the bifurcation of the common iliac artery this anatomic landmark may prove helpful in identifying the ureter more readily.

Once the ureter is identified and the tumor is palpated, a decision is made on the length of segment to be removed. The ureter is then closed with noncrushing vascular clamps both proximal and distal to this segment to prevent spillage of tumor cells. This segment is then excised.

Primary anastomosis of the ureter should be considered only if the segment removed is short enough to allow a tension-free anastomosis. Both the ends of the

ureter should be spatulated to prevent anastomotic strictures. Absorbable interrupted sutures (e.g., 4-0 Vicryl) should be used.

If the resection is limited to the lower third of the ureter, ureteral reimplantation into the bladder with or without a psoas hitch and anterior bladder wall flap (Boari flap) should be attempted. In some situations, the segment removed precludes reimplantation. In these circumstances, the ureter can be brought under the mesocolon and anastomosed to the contralateral ureter (transureteroureterostomy) or the ureter can be replaced with a segment of the ileum (ileal ureter). Alternatively, autotransplantation may be necessary for large ureteral resections.

Whenever the ureter is incised, a stent should be left in situ to allow the anastomosis to heal. It is recommended that a drain be left near the anastomotic site. Whenever the ureter is mobilized, consideration must be given to its blood supply and the alternating directions from which it is derived, depending on which area of the ureter is involved. In the abdomen, the ureteral blood supply is medial and in the pelvis, it is lateral.

Radical nephroureterectomy is the gold standard for upper tract transitional cell carcinoma. Both open and laparoscopic techniques have resulted in equivalent oncologic outcomes. Laparoscopic nephroureterectomy can be performed via the transperitoneal (with or without hand assistance) or retroperitoneal approach.

Open nephroureterectomy has been performed with either a large incision or two separate incisions. For advanced tumors (pT3) and nodal involvement, open surgery remains the standard of care and lymphadenectomy is necessary.

Laparoscopic nephroureterectomy has been commonly used for lower and intermediate stage and grade neoplasms. The lauded advantages of laparoscopy are lower blood loss, decrease in pain, shorter hospital stay, and shorter convalescence. Different techniques for ureter and cuff resection have been described; however, there is not a standardized ureterectomy technique. Cases of port site metastases (incidence 1.6%) have been observed. Thus, it is important to prevent tumor spillage by strict tumor removal within a retrieval bag (“no-touch technique”). Surveillance consists of cystoscopy and imaging of the contralateral upper urinary tract.

Open and Laparoscopic Nephroureterectomy

Urinary Bladder

Surgical Anatomy

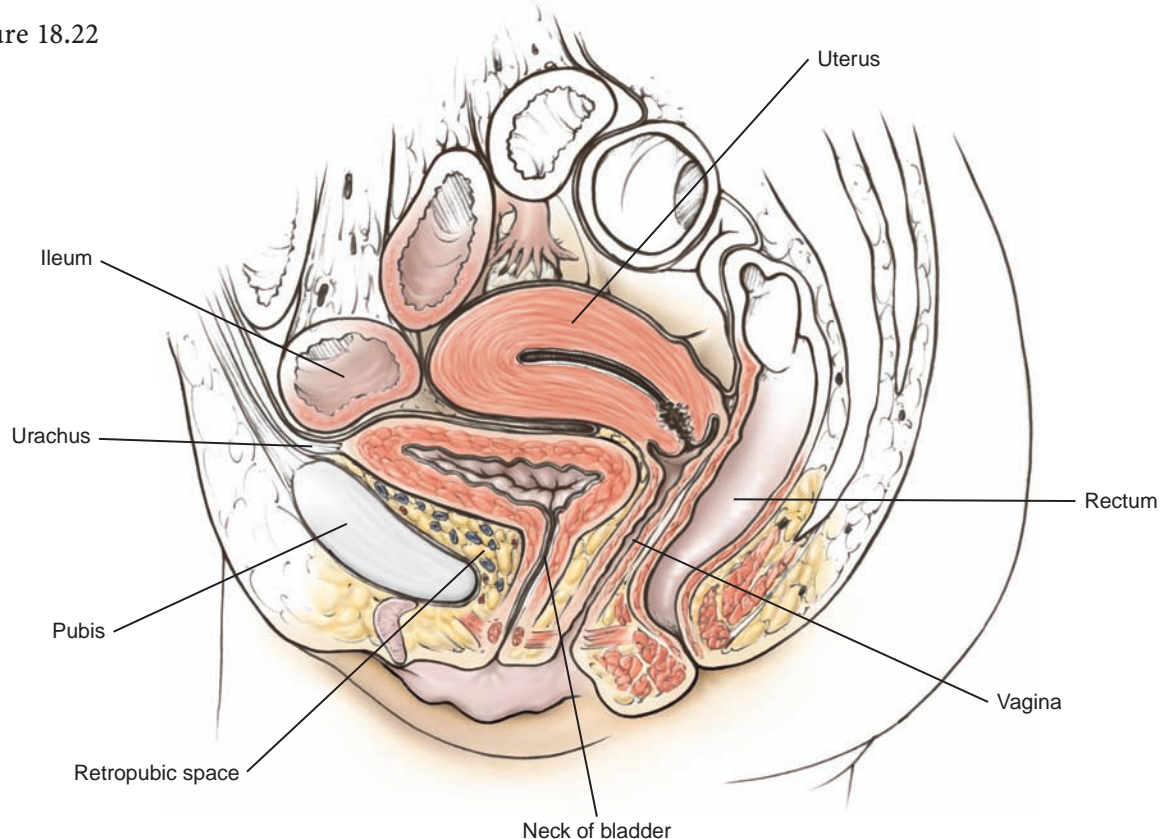
The bladder is a hollow muscular organ that functions as a reservoir. When empty, the bladder is situated in the pelvis, behind the pubic symphysis. As the urine content increases, the bladder rises above the pubic ramus and, in cases of urinary retention,

Topography

can be palpated above the umbilicus. The bladder has a number of areas or surfaces that enable the position of lesions or abnormalities to be accurately documented. There are two anterolateral, a superior, and a posterior (base) surface. Other named areas include the apex (dome) of the bladder and the neck. At the apex, a short fibrous cord is present, which is the remnant of the urachus; this structure originally connected the allantois to the bladder. This cord runs from the apex to the umbilicus between the transversalis fascia and the peritoneum, raising a ridge of peritoneum called the median umbilical ligament. The urachus should be removed in continuity with the bladder during radical cystectomy for bladder cancer. It can also be the original site of malignancy, in which case the lesion is usually an adenocarcinoma as opposed to a transitional cell lesion. The superior surface of the bladder is the only surface covered by the peritoneum, except for a small part of the base in the male.

In the female, the ileum and uterus lie against the superior surface of the bladder, whereas in the male the ileum and pelvic colon occupy this area. The anterolateral surfaces are related to the pubic bone and the levator ani and obturator internus muscles. The bladder is separated from the pubis by the retropubic space (Retzius space), which contains vessels and abundant fat. The base of the bladder is posteriorly separated from the rectum by the uterus and vagina in the female, and the vasa deferentia, seminal vesicles, and ureters in the male. The most inferior part of the bladder is the neck, which leads directly into the urethra. The neck remains fairly constant in

Figure 18.22



position as the bladder fills, except when the supporting structures have been damaged, such as in complicated childbirth, when the entire organ can prolapse as a result of variations in position and intra-abdominal pressure.

The mucosal surface of the bladder is composed of layers of transitional epithelium. The underlying connective tissue allows considerable stretching of the mucosa except in the trigonal area; thus when empty, the bladder has numerous mucosal folds, whereas when full, the mucosa is stretched flat. The trigonal area, which stretches from the bladder neck to both ureteric orifices and the area in between, is always flat.

The muscles of the bladder are arranged in crude muscle bundles with no particular layering arrangement except in the area of the bladder neck and outlet. In other areas, the bundles interdigitate freely without orientation, varying from circular to longitudinal. At the neck of the bladder, a circular layer of muscle is sandwiched between two longitudinal layers; these layers rapidly intermingle as they move cranially, with muscle bundles from an inner to middle to outer level and back again to form a definite mesh pattern. The overall impression of the bladder musculature, with the exception of the bladder neck, is of one large muscle with component bundles weaving in and out of varying planes and directions.

Condensations of loose subserous fascia, which is continuous superiorly over all pelvic organs, form attachments between the bladder and the anterior abdominal wall and lateral pelvic wall. Dorsolaterally, this condensation is called the dorsolateral ligament, and through it the main vascular and neurologic supply enters the bladder base. The median umbilical ligament connects the bladder to the umbilicus

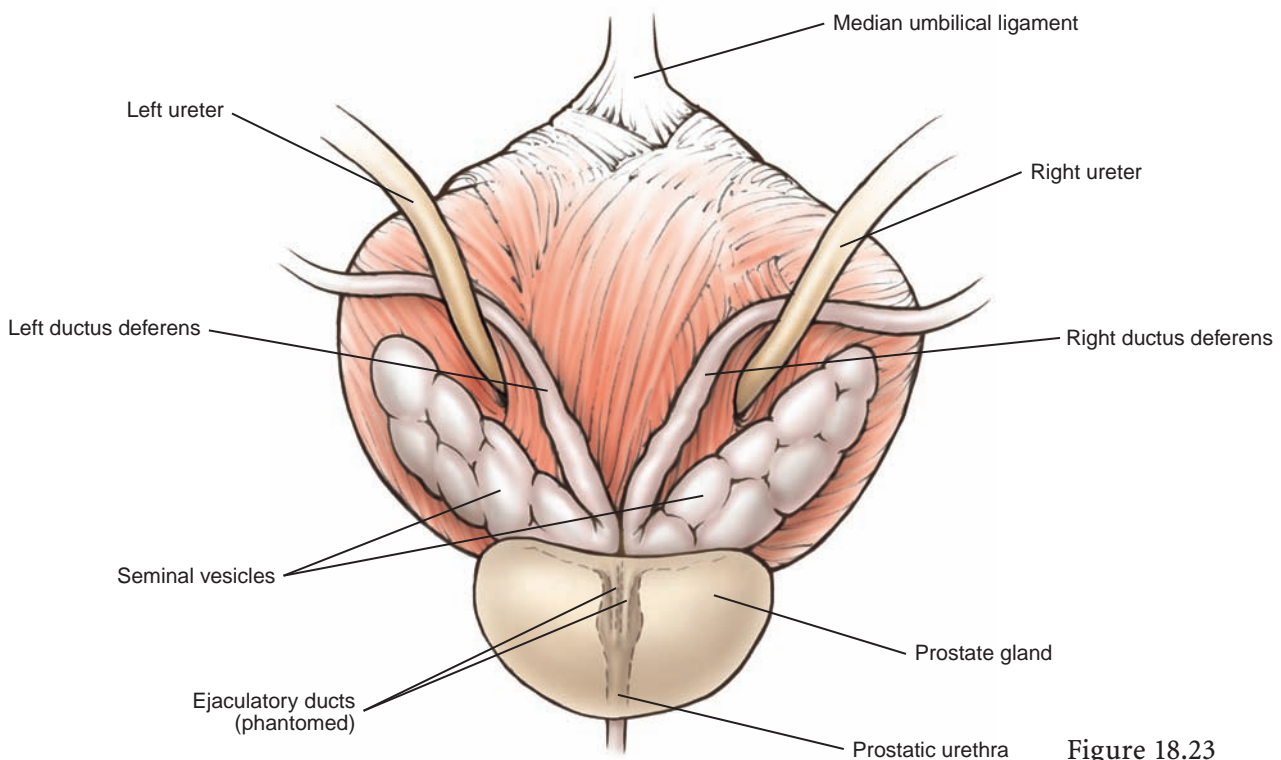


Figure 18.23

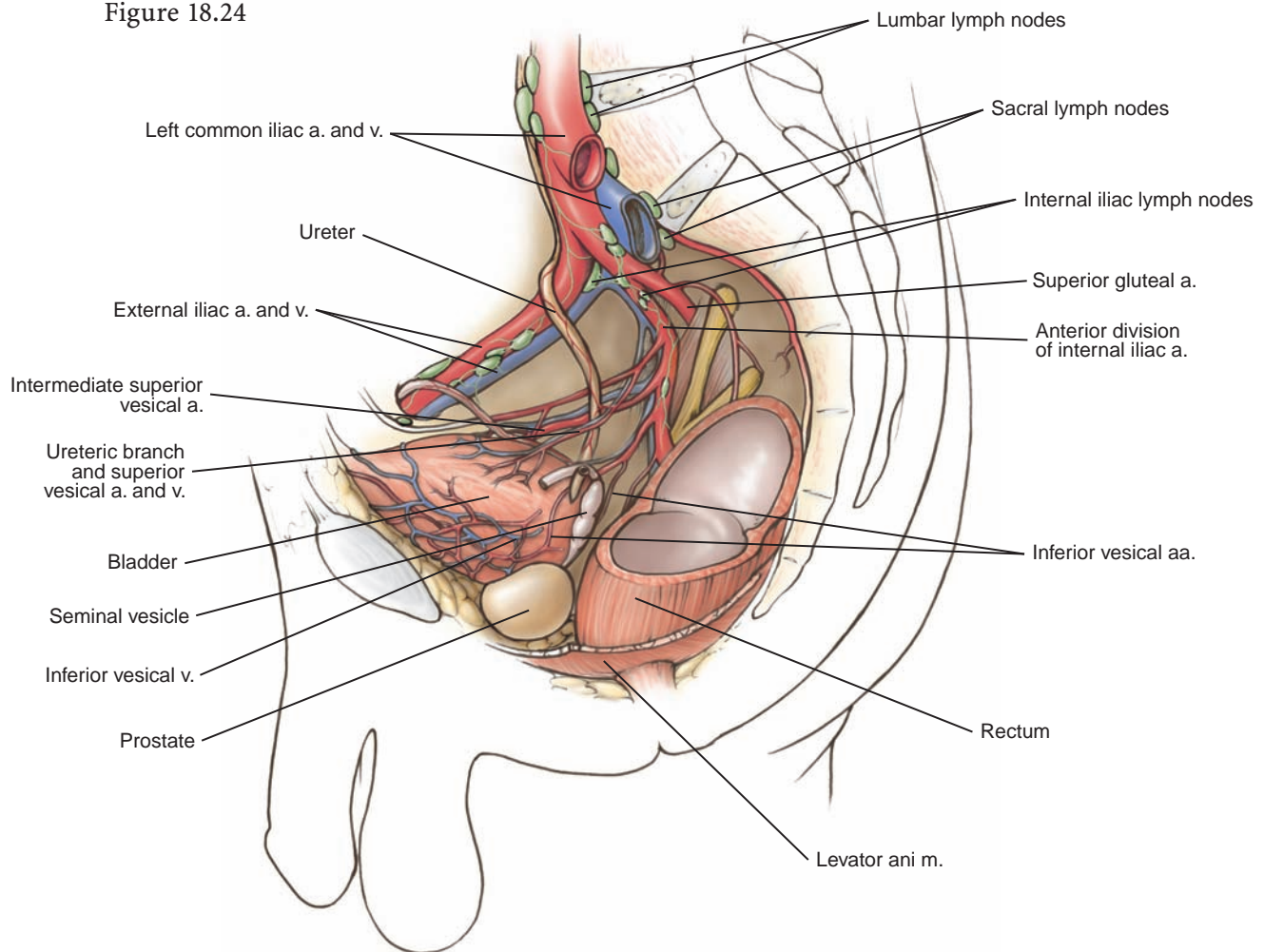
via the urachal remnant. The inferior condensations in the male are the puboprostatic ligaments, and in the female the pubovesical ligaments. These attachments run from the levator ani muscle and the pubic bone to the bladder.

Blood Supply

Arterial branches come from the superior, middle, and inferior vesical arteries, which are branches of the anterior division of the internal iliac artery. During cystectomy, care should be taken to prevent high ligation of the anterior division, which may result in buttock claudication secondary to ligation of one of the main gluteal arteries, which also originate in this area. Excessive bleeding can be temporarily controlled by placing a vascular clamp on the main internal iliac trunk. Smaller branches from the obturator and inferior gluteal arteries also supply the bladder. In the female, the uterine and vaginal vessels also contribute to the rich blood supply.

The bladder is drained by a rich plexus of veins situated between the bladder wall and its adventitial covering. These vessels drain into the internal iliac veins after coalescing into main trunks, some of which run with accompanying arteries. In the male, the vesical plexus communicates with the plexus of Santorini (retropubic) and can cause significant bleeding, if not adequately secured.

Figure 18.24



The external and the internal iliacs, and the common iliac lymph nodes constitute the primary lymphatic drainage of the bladder. There is an extensive lymphatic anastomosis between the pelvic, genital, and lower intestinal organs.

Lymphatic Drainage

The neural supply to the bladder is composed of two components of the autonomic system. The sympathetic supply originates primarily from T11 to L2 and L1 to 2. These fibers run via the sympathetic trunk to the lumbar splanchnic plexus and the superior hypogastric plexus, which divides into the right and left hypogastric nerves. These nerves then run inferiorly to join the pelvic plexus of parasympathetic fibers and innervate the bladder and urethra. The parasympathetic nerve supply arises from S2 to 4 and forms the pelvic parasympathetic plexus. After mixing with the sympathetic fibers to form the pelvic plexus, vesical branches run towards the bladder base. These fibers reach the lateral sides of the bladder to innervate the bladder and urethra. The prostate gland receives a segment to form the prostatic plexus, from which runs the cavernous nerves responsible for penile erection and clitoral erection. These nerves are combined motor and sensory. The vesical plexus gives many branches to the bladder that intermingle in the adventitia and penetrate the muscular wall to supply the entire bladder. Ganglia are formed along the nerve trunks of the vesical plexus and in its deeper branches. These nerves continue to branch and ultimately are distributed throughout the muscular coat. The ratio of nerve fiber to muscle fiber varies, roughly 1:1 for parasympathetic cholinergic fibers and considerably lower for the sympathetic fibers, which in contrast to the parasympathetic fibers are unevenly distributed throughout the bladder, with maximal concentration in the bladder base and proximal urethra. Since the nerves branch frequently and run a tortuous course, they are not damaged by bladder filling (stretching) except at extreme volumes. The majority of the bladder muscle (detrusor) is innervated primarily by parasympathetic fibers (stretch and fullness), and the trigone, bladder neck, and lower end of the ureters are innervated mainly by sympathetic fibers (pain, touch, and temperature). Nerve damage may occur during any radical pelvic procedure, with varying clinical manifestations ranging from hyperreflexia (frequency, nocturia, urgency) to hyporeflexia (decreased stream, retention), depending on the fibers damaged.

Nerve Supply

Surgical Applications

Indications

Bladder cancer is the fifth most common malignancy in men and the second most common tumor, after prostate adenocarcinoma, treated by urologists. The most common histologic pattern of bladder cancer in the United States is transitional cell carcinoma. Less common are adenocarcinoma, squamous cell carcinoma, anaplastic carcinoma, and sarcomatous tumors. Superficial bladder tumors (carcinoma

Radical Cystectomy

in situ, Ta and T1 transitional cell carcinoma) can be treated with transurethral resection, with or without adjuvant intravesical immunotherapy or chemotherapy. However, invasive bladder cancer, in the absence of metastasis, is best treated with radical cystectomy with or without neoadjuvant chemotherapy. More than half of muscle-invasive transitional cell carcinomas and 20–30% of tumors penetrating the perivesical fat are cured with radical cystectomy.

Preoperative Evaluation

Cystoscopy should be performed and bladder biopsy specimens should be taken with cup forceps or a resectoscope. Care should be taken to obtain representative samples from the tumor and from bladder muscle to determine the depth of tumor invasion. Samples should be taken from any abnormal area in the bladder, which might represent secondary tumors or carcinoma in situ.

Upper urinary tract evaluation should be performed to define the anatomy of the upper urinary tract and to rule out the presence of any filling defects that might represent coexisting tumors. A radiograph of the chest, CT scan of the pelvis and abdomen, and bone scan should be obtained to rule out distant metastases. A sterile urine culture should be documented before hospital admission.

The type of urinary diversion should be discussed with the patient before surgery. Multiple techniques of continent urinary diversions have evolved over the past decade, with good results. However, in patients with decreased kidney function (serum creatinine >2 mg/dL) an ileal conduit is necessary because of less postoperative electrolyte abnormalities. The proper site for the abdominal stoma should be marked on the day before surgery and a urinary collection device, half filled with water, should be fitted to the site for trial on the night before surgery.

The day before surgery, patients undergo a mechanical and antibiotic bowel preparation. Prophylaxis against deep venous thrombosis should be considered, particularly in patients at increased risk. The patient should be kept well hydrated, particularly with the bowel preparation and increased fluid loss. Intravenous prophylactic antibiotics should be administered just before surgery. Two to four units of blood should be available because blood loss is common, especially if previous pelvic surgery has been performed or radiation has been delivered to the pelvis.

Technique in Male Patients

The patient is placed supine with the legs in a modified lithotomy position with foot stirrups. The abdomen, perineum, and genitalia are prepared and draped, and a catheter is inserted into the patient's bladder.

A midline incision is made from the symphysis pubis to a point several centimeters above the umbilicus or to the xiphoid, if necessary, and is carried through the midline fascia.

The bladder is reflected medially with blunt dissection to develop a plane between the bladder and the lateral pelvic wall, and then the retropubic fat is mobilized with a sharp and blunt dissection to display the puboprostatic ligaments. This dissection

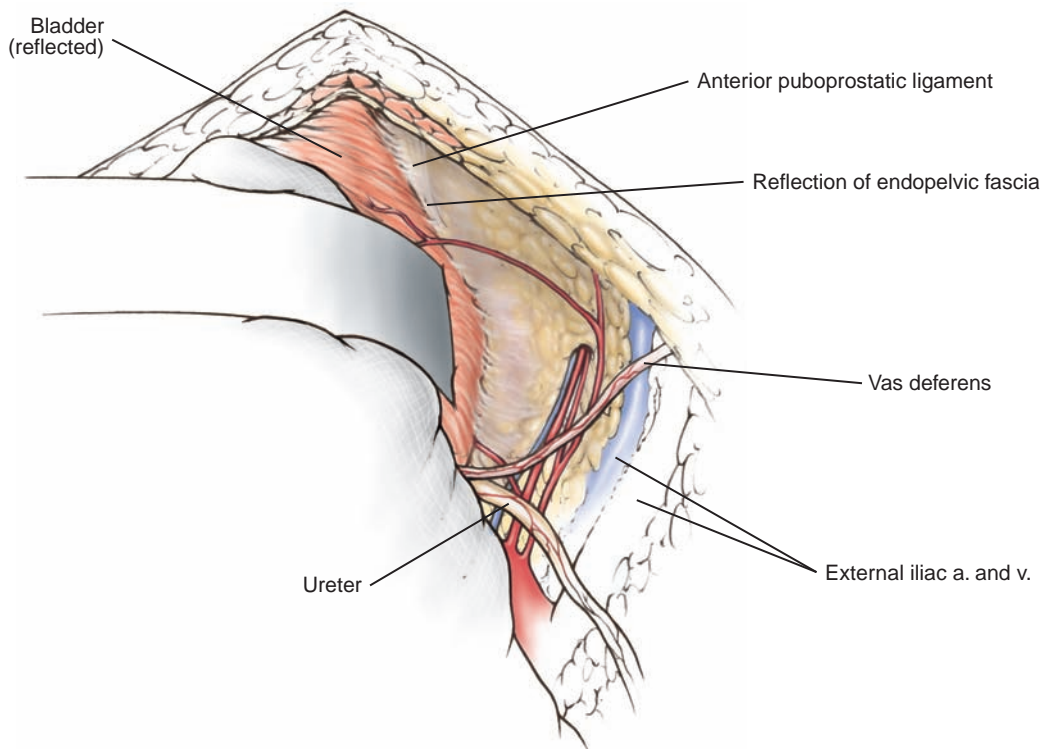


Figure 18.25

is performed on both sides of the pelvis because it is easily done before the peritoneal cavity is opened. The external iliac vessels are seen on the lateral pelvic wall, and the fat and the lymph nodes in the obturator fossa can be palpated for any enlarged lymph nodes. The obturator nerve should be palpated or viewed in the depth of the obturator fossa, and care should be taken during lymph node dissection to prevent injury to this nerve that supplies motor fibers to the adductor muscles of the thigh. The bladder is examined carefully to evaluate the extent and resectability of the tumor. The peritoneal cavity is then opened through the whole length of the incision, and the intra-abdominal contents are examined for any metastasis. The vas deferens and gonadal vessels are encountered during lateral dissection. The vas is divided and the pelvic segment is excised with diathermy; the gonadal vessels are mobilized laterally.

Once the resectability of the tumor and the absence of metastasis are confirmed, the bladder dissection is started by dividing the urachus between two clamps and freeing the apex of the bladder off the abdominal wall. The peritoneal reflection on the lateral walls of the bladder is then incised in the depth of the wound on each side of the umbilical ligament to free the lateral sides of the bladder from the pelvic wall.

Pelvic lymphadenectomy is performed to remove the lymphatic tissues related to the iliac vessels and obturator fossa. The dissection is started by incising the areolar tissue on the external iliac artery and extending the dissection to the bifurcation of the common iliac artery proximally, the internal iliac artery medially, and the femoral canal distally. Alternatively, lymphadenectomy can be performed following cystectomy.

The wound is retracted with a self-retaining retractor. The peritoneal reflection on the posterior wall of the bladder is incised, and the small bowel and the ascending

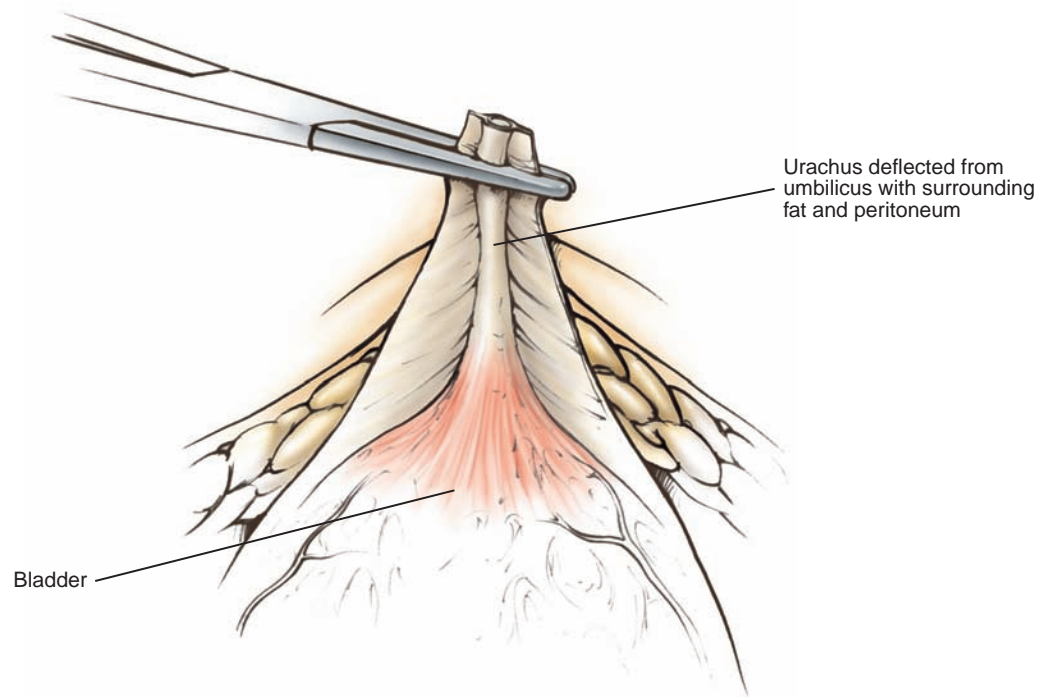


Figure 18.26

colon are retracted superiorly and kept in position with moist abdominal packs and the malleable arm of the self-retaining retractor. On the left side, the sigmoid colon is mobilized medially to display the ureter where it crosses the bifurcation of the common iliac artery, which is tied several centimeters proximal to the bladder and incised above the tie. A specimen from the proximal end of the ureter is excised and sent for frozen-section analysis to confirm the absence of tumor extension. The same procedure is repeated for the right ureter. Devascularization of the ureter can be prevented by mobilizing it within the periureteric fat and by remembering that the ureteric blood vessels in the pelvis enter the ureter from the lateral side. Good ureteral length is important to facilitate subsequent reconstruction.

The anterior branches of the internal iliac artery are then divided in sequence, beginning with the obliterated umbilical artery. Each pedicle is isolated and divided, with the artery being divided prior to division of the vein. This includes the superolateral vesical pedicle, middle lateral vesical pedicle, and inferolateral vesical pedicle. A plane is then developed bluntly between the rectum, the seminal vesicles, and the prostate gland to enable identification of the posterior pedicles, which are serially clipped and divided. Alternatively, a laparoscopic stapler can be used to divide the pedicles, especially for large tumors when there is limited space. The isolation of individual vessels is time consuming and unnecessary. Branches of the pelvic plexus that innervate the corpora cavernosa required for erection are usually injured during the division of the anterolateral vascular pedicle or the internal pudendal artery, which arises from the distal internal iliac artery. If a nerve-sparing technique is attempted, care should be taken to prevent injury to the inferior branches of the internal iliac artery, which form the pudendal artery. As the dissection is carried down to the

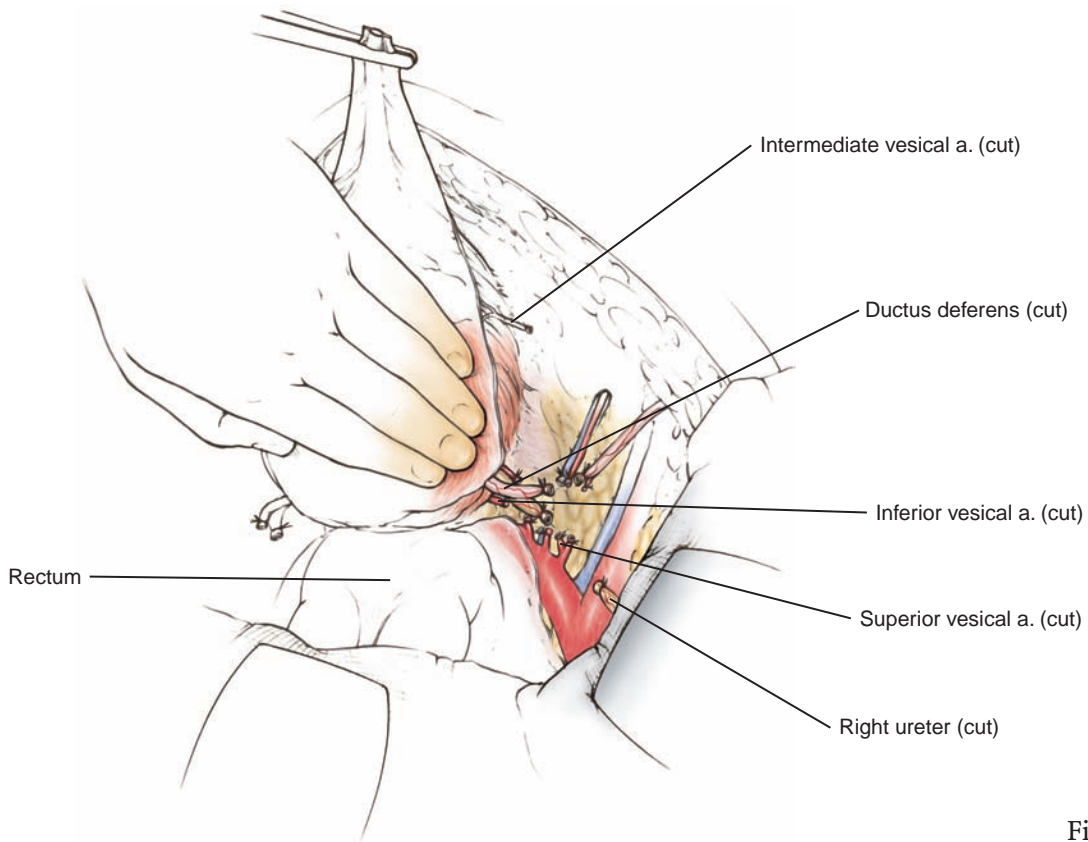


Figure 18.27

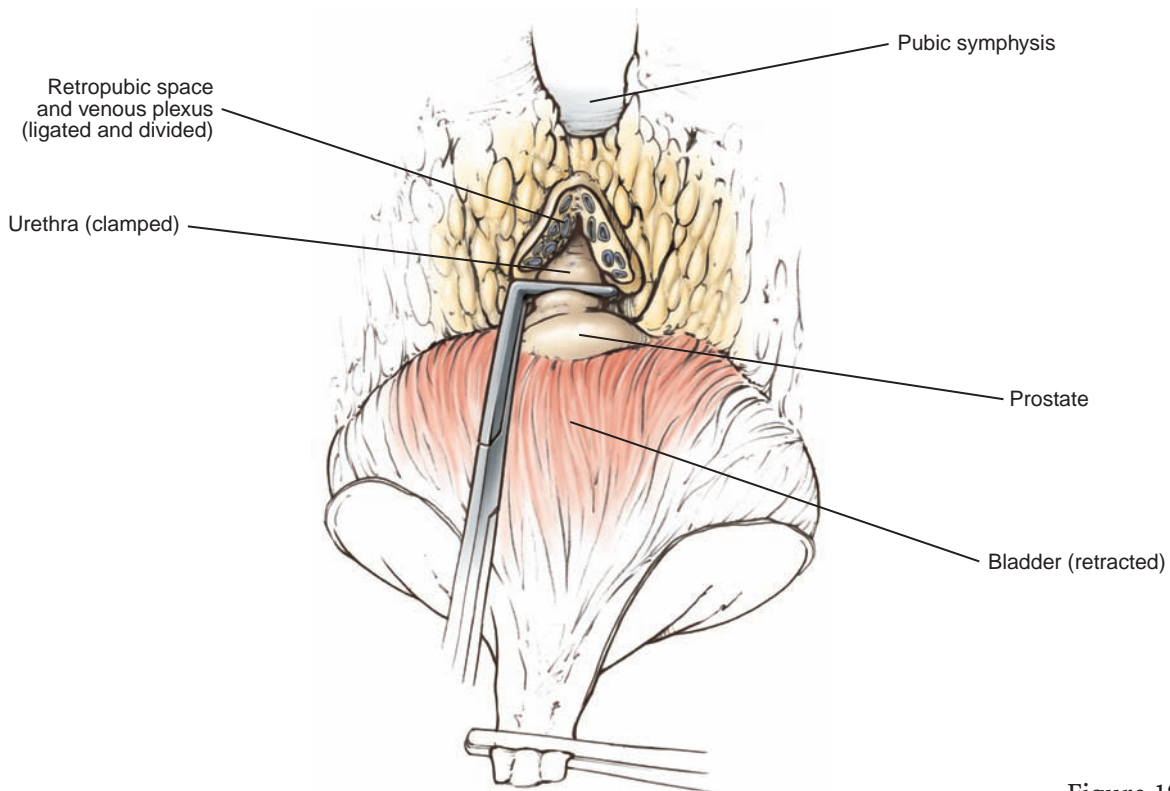


Figure 18.28

prostate gland it enters the plane between the two layers (parietal and visceral) of Denonvilliers' fascia to the apex of the prostate. The prostatic pedicles are divided and ligated.

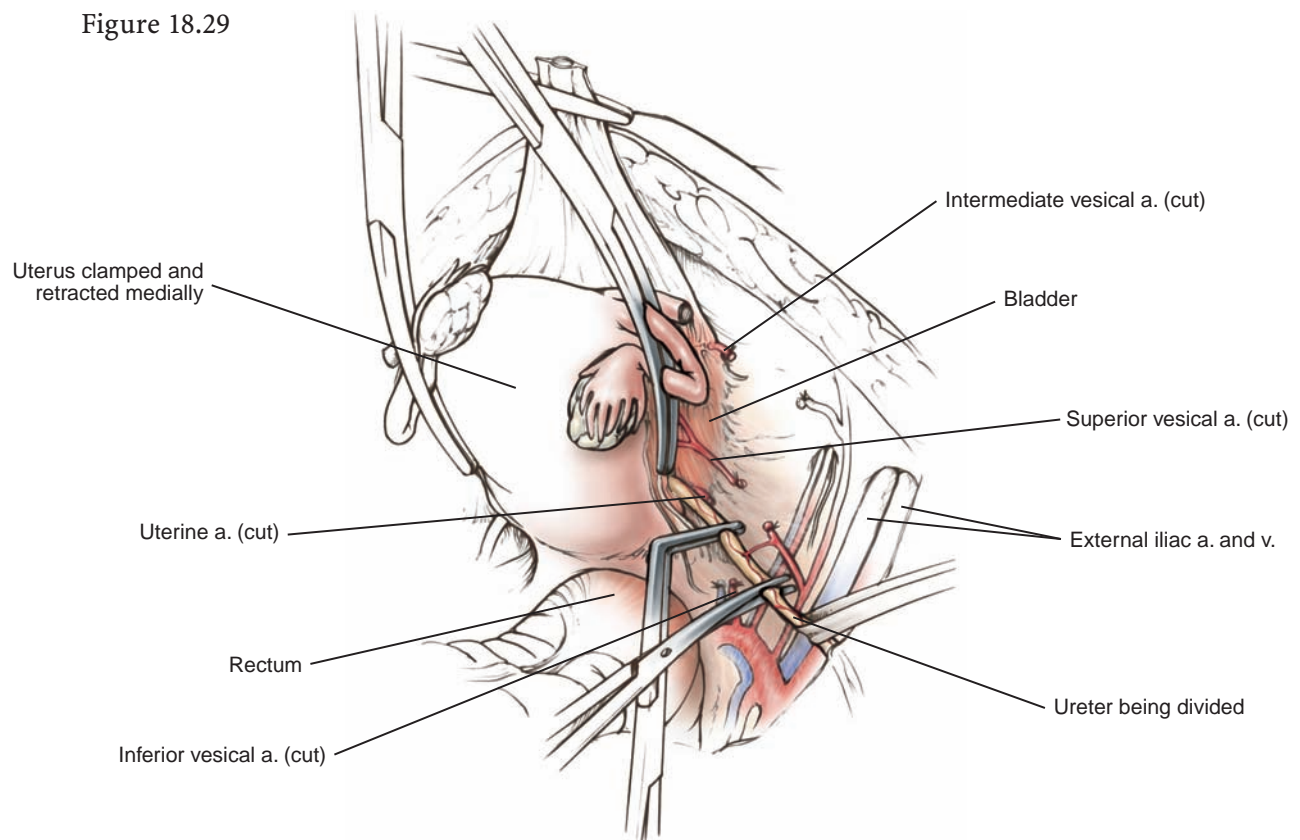
The endopelvic fascia is identified superolateral to the prostate gland and incised to expose the puboprostatic ligaments. The ligaments are divided at the posterior surface of the symphysis pubis to enable identification of the venous plexus, which drains the deep dorsal veins of the penis (plexus of Santorini). The venous plexus is then tied with heavy nonabsorbable sutures and divided. The urethral catheter is removed, and the urethra is retracted from the urogenital diaphragm, clamped with a large clamp beyond the apex of the prostate to prevent tumor spillage, and divided, if no concomitant urethrectomy is planned.

Hemostasis is secured, and the pelvis is packed with moist packs. Attention is then given to the urinary diversion.

Technique in Female Patients

The positioning, abdominal incision, and the management of the ureters is similar to that in the male patient. If the patient has not had a prior hysterectomy, the ovarian arteries and veins are divided and the fallopian tubes and ovaries retracted medially on both sides. The round ligament is also divided and retracted medially. The superior, middle, and inferior vesical pedicles are divided, as in cystectomy in male patients, and the peritoneal incision is carried across the midline at the fornix of the vagina.

Figure 18.29



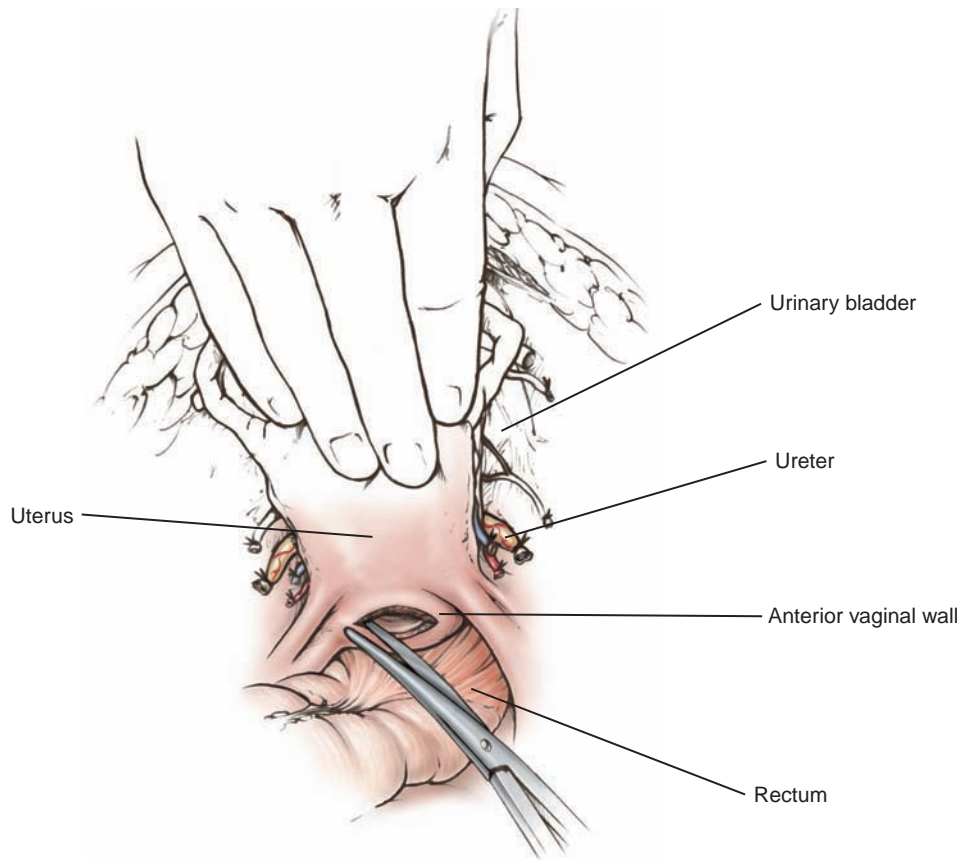


Figure 18.30

The uterine pedicles are divided and ligated. A swab on a stick is inserted into the vagina, and the vagina is entered at the fornix. With a sharp dissection, the anterior vaginal wall is excised with the specimen to the urethra. At the urethra, the anterior vaginal incisions are carried medially to encircle the urethral meatus, and the specimen is removed. Allis clamps are placed along the incision in the vagina to provide temporary hemostasis, which is usually obtained as part of the vaginal reconstruction with 2-0 Vicryl running sutures.

Certain advantages such as the sparing of potency in male patients, retention of a functioning urinary reservoir, and the ability to achieve full-thickness resection of bladder tumors and sample perivesical nodal tissue makes partial cystectomy an attractive procedure in selected patients. Partial cystectomy in the treatment of bladder cancer has been associated with tumor recurrence rates, which range from 40 to 80% in reported series. However, overall survival and survival by stage are equivalent when compared to radical cystectomy.

Partial Cystectomy

Indications

There are certain criteria which must be met before a patient can be considered for partial cystectomy. First, the tumor must be a solitary primary lesion located in a part of the bladder that allows for complete excision with adequate margins of at least 1 cm.

Second, in patients who are not candidates for endoscopic resection due to a combination of body habitus, hypomobility of the hips secondary to osteoarthritis, or a fixed prostatic urethra, partial cystectomy may be required for complete diagnosis. Third, it has been recommended that tumors which are located in bladder diverticula can be managed with partial cystectomy because bladder diverticula have attenuated walls that may be easily perforated with transurethral resection, allowing tumor spillage into the perivesical space. Finally, other indications for partial cystectomy include management of genitourinary sarcomas, urachal carcinomas involving the dome of the bladder, involvement of the bladder by tumors in adjacent organs, and palliation of severe local symptoms.

Contraindications to partial cystectomy include patients with multiple lesions, recurrences or tumors located on the trigone, where adequate excision is not possible due to the proximity of the ureteral orifices and bladder neck. In addition, patients must have biopsy-proven absence of cellular atypia or carcinoma in situ in the remainder of the bladder and prostatic urethra. If there is evidence of fixation of the tumor to adjacent pelvic structures, or if segmental resection of the tumor would require removal of so much of the bladder as to necessitate augmentation cystoplasty, then a partial cystectomy should not be performed.

Technique

The patient is placed on the operating room table in the supine position with the break of the table at the anterosuperior iliac spine, which allows adequate flexion and elevation of the bladder into the wound. The sterile field includes the penis in men and the vulva and vagina in women to allow sterile insertion of a Foley catheter into the bladder after resection of the tumor and before closure of the incision.

A lower midline incision or a transverse suprapubic incision can be utilized. The rectus abdominis muscle is divided in the midline and the space of Retzius is entered. The patient is then placed in the Trendelenburg position to elevate the abdominal contents out of the pelvis. Depending on the location of the tumor in the bladder, an extraperitoneal or intraperitoneal approach can be performed. For tumors on the dome or anterior part of the bladder an extraperitoneal approach is optimal, whereas for tumors on the posterior aspect of the bladder, an intraperitoneal approach is preferred.

Extraperitoneal Partial Cystectomy

The anterior surface of the bladder is exposed through the space of Retzius, and the peritoneum is mobilized where it is easily separated from the bladder. A bilateral pelvic lymph node dissection is performed. The bladder is freed laterally and posteriorly well beyond the site of the tumor. The superior vesicle pedicle can be divided if necessary. The fat over the site of the tumor is left attached to the bladder.

Several stay sutures are then placed in the bladder at a site, known from cystoscopy to be distant from the tumor. The wound edges are packed away from the bladder with laparotomy pads or plastic drapes, and the bladder is entered between

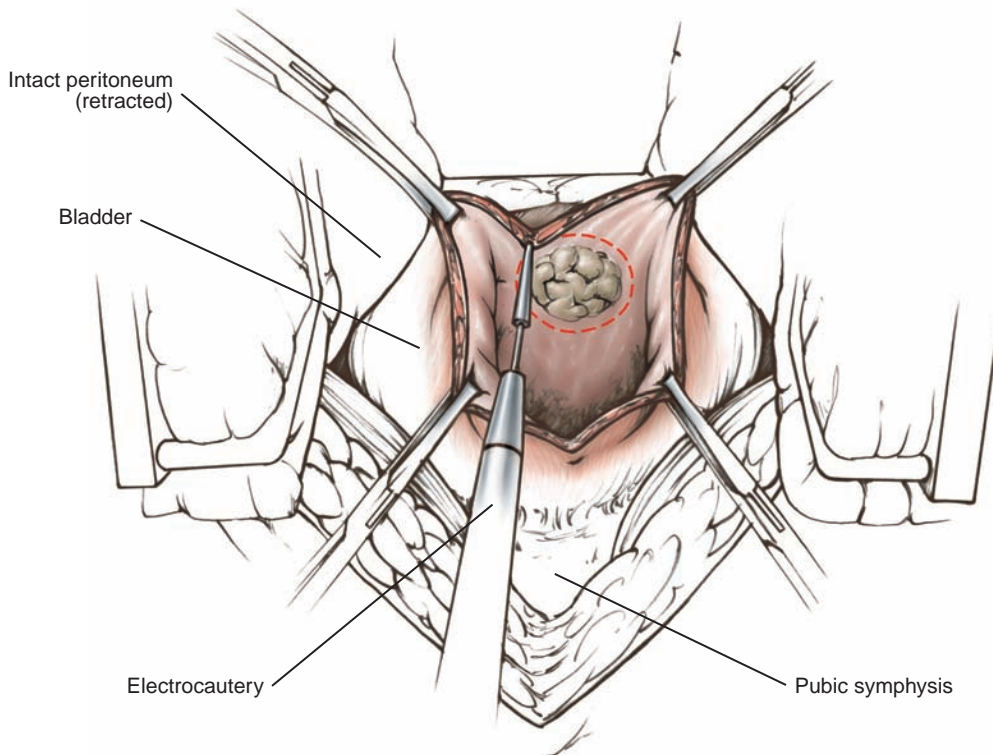


Figure 18.31

the stay sutures with an electrocautery, taking care to minimize the amount of urine spillage in order to reduce the risk for tumor implantation. The incision is extended several centimeters anteriorly and posteriorly to allow adequate visualization of the tumor and its relationship to the ureteral orifices and bladder neck.

The tumor is then excised, taking care to leave a 1-cm margin of normal-appearing bladder around the tumor. The tumor should be removed en bloc with the overlying perivesical fat and peritoneum, with an electrocautery or with sharp dissection. If the tumor lies less than 1 cm from the ureteral orifice, the orifice should be resected and the ureter reimplanted elsewhere. If excision of the tumor involves the bladder neck, it is possible to excise the bladder neck and the surrounding prostatic capsule after enucleation of the prostate gland. However, it is probably safer to perform radical cystectomy in such a situation. The bladder neck should not be resected in female patients because of the high risk of incontinence.

After the removal of the tumor, frozen sections are obtained from the resection site to assess margins. The bladder is subsequently closed in two layers with 3-0 Vicryl sutures to close the urothelium and 2-0 Vicryl sutures to close the muscular layer. A suprapubic cystostomy catheter is contraindicated because of the risk of tumor spillage and so it is essential that a wide-bore Foley catheter is used. The perivesical space is drained for 3–4 days or until drainage is minimal. The abdominal wall is then closed in the standard fashion.

Postoperatively, the urethral catheter should be left in place for 7–10 days. If there is any doubt as to the integrity of the repair, gentle gravity cystography may be performed.

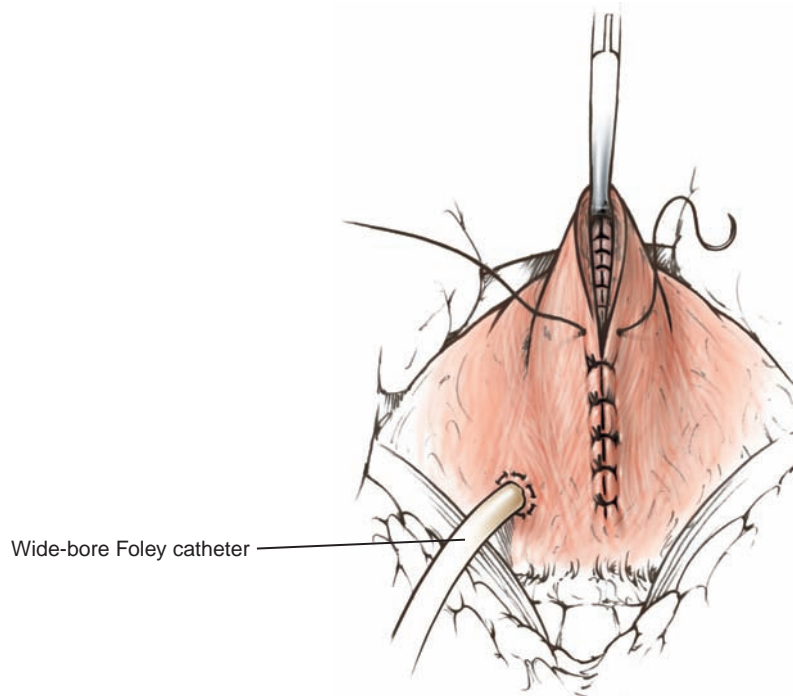


Figure 18.32

Intraperitoneal Partial Cystectomy

After the rectus abdominis muscles are divided in the midline, the peritoneum is opened in the midline. The peritoneum over the iliac vessels is incised, and bilateral pelvic lymph node dissection is performed. The obliterated umbilical artery is followed to the point of takeoff of the superior vesical artery, which is divided. The bladder is then freed posteriorly as needed, stay sutures are placed, and the bladder is opened.

Removal of the bladder tumor, including the perivesical fat and the peritoneum, reimplantation of the ureters, closure of the bladder, management of urethral catheters, and perivesical drains and wound closure, are the same as described for extraperitoneal partial cystectomy.

Laparoscopic and Robotic Radical Cystectomy

The first laparoscopic cystectomy was performed more than a decade ago. Urinary diversion is difficult to perform laparoscopically, thus in most cases it is performed extracorporeally. Hand assistance is an option in laparoscopic radical cystectomy and some of its advantages include direct palpation, shorter surgical time and manual retraction. It also creates some technical ease which is not present in strict laparoscopy.

Surgical specimens can be removed transvaginally for females and transrectally for males or through a mini laparotomy incision which can be used for extracorporeal urinary diversion construction. To date, no port site metastasis cases have been reported after laparoscopic cystectomy, but one case after robotic assisted cystectomy.

As with laparoscopic cystectomy, there is a limited experience with robotic radical cystectomy and only short-term follow up is available. The technical difficulty

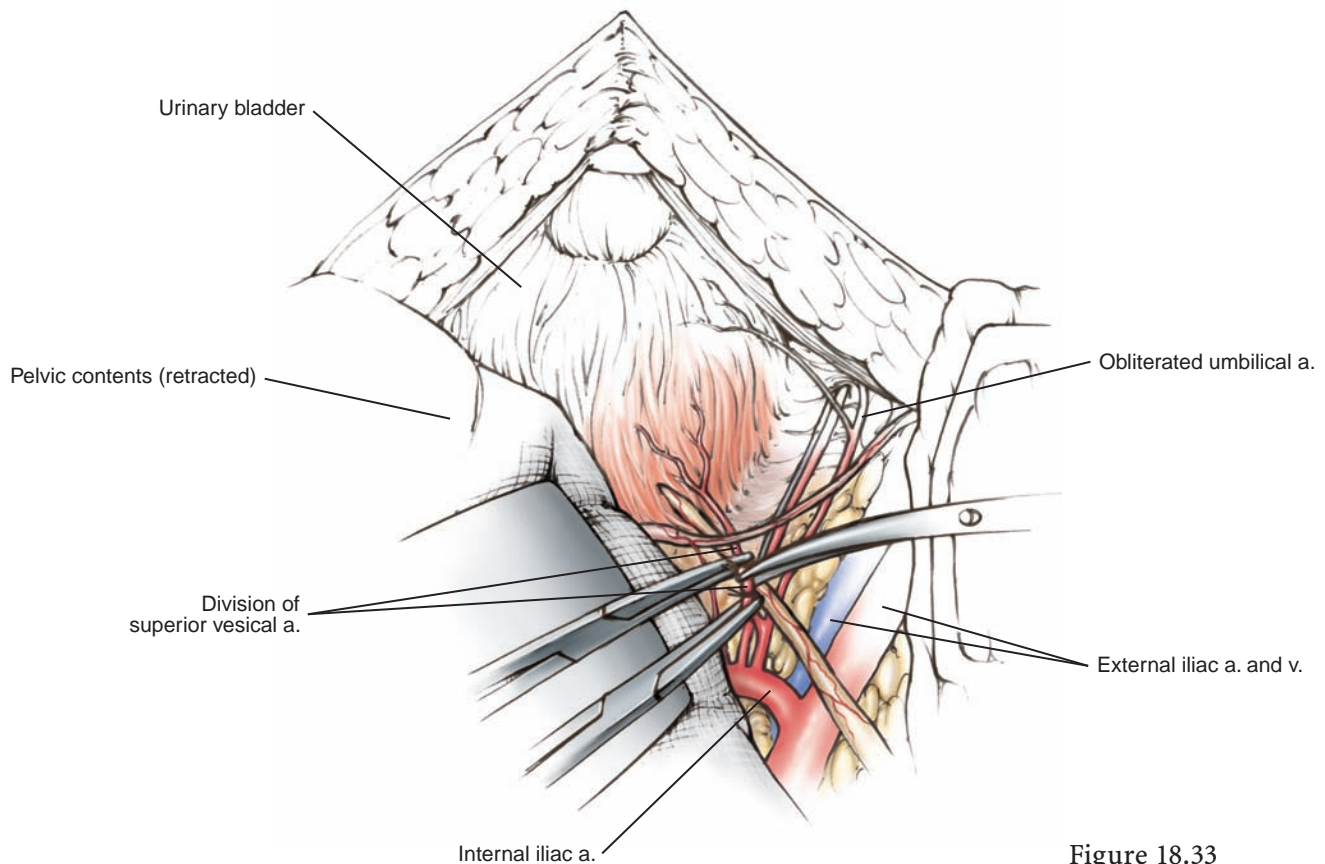


Figure 18.33

associated with this procedure, combined with the potential aggressiveness of bladder cancer has limited the wide acceptance of laparoscopic and robotic cystectomy.

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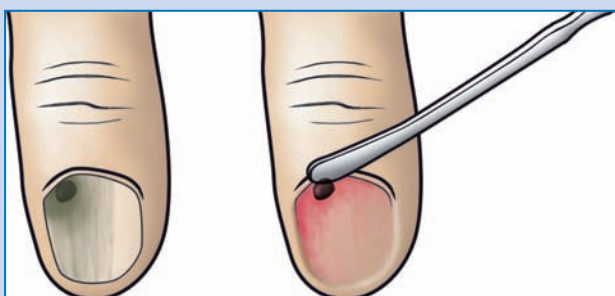
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Tumors of the Skin

Keith A. Delman
Grant W. Carlson



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Introduction

Cancers of the skin are the most common neoplasms diagnosed in the United States annually. They are a heterogeneous group with a widely varying prognosis. Despite this stark contrast, the principles of anatomy applied to the surgical treatment of these entities are remarkably similar. Cancers of the skin range in clinical behavior from indolent, such as BCCs, to highly aggressive, as is the case with some melanomas and merkel cell carcinoma.

The relatively new technique of sentinel lymph node biopsy has revolutionized the approach to these entities, allowing for the early detection of regional metastases in patients with lesions at risk to metastasize. Although, like many novel interventions, sentinel lymph node biopsy for cutaneous malignancies has its opponents, it has been widely accepted as standard care in the United States and is broadly applied in melanoma and merkel cell carcinoma as well as in many adnexal carcinomas. Sentinel lymph node biopsy is highly accurate and in patients with metastatic disease, it appears to offer a survival benefit when early lymphadenectomy is performed.

While the technique of sentinel lymph node biopsy has changed the overall management of patients with skin cancers, the mainstay of the therapy remains the wide local excision, with margins defined by the malignant potential of the lesion. The extent of margins for melanoma has been extensively evaluated through several prospective, randomized trials all of which have advanced the treatment of this disease. Although a direct comparison between 1 and 2 cm margins has never been performed, most clinicians have accepted an inter-trial comparison implying an equal overall survival, with only a minimal increased risk of local recurrence with the smaller margin of excision for lesions that are between 1 and 2 mm in Breslow thickness.

The treatment of cutaneous lesions is predominantly surgical. As these entities can occur anywhere on the body, an in-depth understanding of the anatomy is imperative. A thorough understanding of the techniques of excision, simple and complex repair, and working familiarity with more advanced plastic surgical techniques, including rotational flaps and skin grafts, are of considerable importance to the individual who treats melanoma, merkel cell carcinoma and other cutaneous lesions. An in-depth understanding of the biology of these lesions is imperative, as it helps to guide the treatment of the patient and often defines the extent of intervention needed to appropriately manage the disease.

Biology of Skin Cancers

Basal Cell Carcinoma

BCC is the most common of all skin cancers. The incidence of skin cancer, particularly BCC, continues to rise. It is predicted that nearly 1 in 6 Americans will develop skin cancer in their lifetime, a figure which is likely underestimated because BCCs

are not recorded on cancer registries. BCC arise from hair follicles and therefore, the distribution is limited to hair-bearing areas. BCC is associated with a low mortality, with a metastatic potential of less than 0.5% of the cases.

Risk factors for BCC are similar to those of other cutaneous malignancies and include, light hair, light eyes and light skin, smoking, exposure to ionizing radiation, use of tanning bed and ultraviolet light exposure. There is an associated risk with certain genetic disorders such as albinism and xeroderma pigmentosum and most significantly, there is a considerable increase in risk in patients who are immunosuppressed – such as in transplant recipients.

There has been considerable progress in recent years in the genetic understanding of BCC. Dysfunction of the sonic hedgehog pathway is the primary focus of the molecular pathogenesis of BCC. This pathway has been implicated in rhabdomyosarcoma and medulloblastoma as well. In 30–40% of sporadic BCCs, the hedgehog pathway is defective in its interaction with the tumor suppression protein patched homologue-1. While defects in the sonic hedgehog pathway are considered as the major abnormality leading to the development of BCCs, mutations of the p53 gene have been found in 50% of sporadic lesions as well.

The mainstay of treatment for BCC is complete excision and this, along with other considerations, are discussed subsequently. Despite adequate excision, there are risk factors associated with recurrence and poor prognosis. These include, a lesion larger than 2 cm, perineural or perivascular involvement, and those lesions which have been long-standing and those located on the central part of the face or ears.

Squamous cell carcinoma (SCC) is significantly less common than BCC, which accounts for approximately one-fourth to one fifth of the number of skin cancer cases annually. Like BCC, SCC is rising in incidence, but in contrast to BCC, SCC has a higher metastatic potential, with an estimated incidence of metastasis reaching 2–3%. SCC arises from keratinocytes and can be found in association with chronic wounds such as nonhealing venous stasis ulcers and chronic burn wounds. Cutaneous SCC behaves differently than SCC of the oropharynx and anorectum, which are tumors of the mucous membranes, and are also associated with verrucous disease.

Risk factors for SCC are similar to those of BCC and other cutaneous malignancy, and include light hair, light skin and, most significantly, damage from sun exposure. Actinic keratoses also serve as precursor lesions in up to 60% of patients. There is a remarkably increased risk of SCC in patients who are immunosuppressed, such as those infected with HIV, and transplant recipients. In this subgroup of patients, the risk of SCC is higher than the risk of BCC; the ratio of 4:1 is inverse in this group, with SCCs being four to five times more common than BCC.

Like BCC, there are genetic associations in SCC also. Mutations in the *TP53* gene and *CDKN2A* have been associated with SCC as well as abnormalities in *p53*, which are seen in immunosuppressed patients but not in those who are immunocompetent. Furthermore, *HRAS* and *KRAS* mutations have also been characterized in SCCs.

The mainstay of treatment for SCC, like BCC, is complete excision, but ablative techniques and topical therapy have been utilized in specific circumstances.

Squamous Cell Carcinoma

Recently, some authors have suggested that there might be a role for sentinel lymph node biopsy in certain “high-risk” groups of patients, but this has not been routinely employed. The prognosis from SCC is good for the general population, but in patients who are immunosuppressed, the disease tends to be considerably more aggressive and the prognosis is considerably more grave. Location may also be associated with prognosis, with SCCs of the lips and ears conferring a worse prognosis than those located elsewhere. In patients with clinically identified metastases, surgical excision is reasonable, however, multimodality therapy inclusive of systemic chemotherapy and radiation therapy should be considered.

Merkel Cell Carcinoma

Merkel cell carcinoma (MCC), in stark contrast to BCC and SCC, is extremely rare and highly aggressive. In contrast to the nearly 100% 5-year survival observed in patients with BCC, the 5-year disease specific survival in MCC is estimated at approximately 64%. Unfortunately, due to the rare incidence of MCC, there is little comprehensive, prospective data on the management of this entity. The incidence of MCC has not significantly changed historically, although sunlight has been associated with the development of the disease and therefore, with increases in societal sun-exposure, it may increase in incidence over the next several years. MCC arises from the pressure receptors in the skin, which are located in the basal layer of the epidermis. The average age of diagnosis is 69 and there is a slight predilection (2–3:1) to occur in males over females.

MCC is associated with sun-exposure as a causative factor, but has also been associated with exposure to toxins such as arsenic. Immunosuppression has also been implicated as a risk factor, with the incidence of MCC increasing to a greater extent, than that seen in the general population, in individuals with HIV or transplant recipients. The most confounding factor about MCC is the difficulty in diagnosis. Histologically, it is a neuroendocrine tumor, and at biopsy, other sources of similar histologies (such as small cell carcinoma of the lung) must be ruled out, as they are much more common. The most difficult quandary about MCC is the fact that it is relatively innocuous on clinical evaluation. MCC will often be nothing more than a raised erythematous nodule. Clinical suspicion for MCC of any new, persistent, nodule must be entertained for the astute diagnostician. It is rare though, that this entity is suspected at biopsy.

Genetically, information about MCC is known to harbor abnormalities in the MAP kinase pathway. This includes both failure of activation as well as deactivation abnormalities, and may involve genetic alterations in any of the components. It is significant to note that while B-Raf mutations are common in melanocytic nevi and in many melanomas, this does not seem to be the source of the defect in MCC. In contrast, in MCC the primary abnormality appears to be due to the presence of Raf Kinase Inhibitor Protein as well as changes in the phosphorylation status of ERK (extracellular signal-regulated kinase).

The management of MCC is again found in a wide excision of the primary lesion. However, adjuvant treatment is routinely recommended due to the aggressive nature of this malignancy. The consensus guidelines from the National Comprehensive

Cancer Network advocate radiation to the primary site regardless of the margin status, although data are based on clinical experience and single center reports rather than prospective, randomized, multicenter (Level 1) analyses. Sentinel lymph node (SLN) biopsy is also advocated for MCC, with completion lymphadenectomy appropriate when a node is identified with metastatic disease. If a patient presents with clinical lymphadenopathy, an FNA is advocated followed by either SLN bx if negative, or therapeutic lymphadenectomy, if positive.

At SLN bx, if the nodes are positive only by immunohistochemical analysis, radiation in lieu of completion lymphadenectomy can be offered to the patient. At some centers, radiation alone is offered if there is no extranodal extension at SLN biopsy. If there is extranodal extension, or multiple involved nodes at completion lymphadenectomy, then radiation should be considered in addition to definitive surgical control. Most authors advocate that the radiation field be designed to include the primary site, in-transit lymphatics as well as the lymphatic basin, when this amount of disease is present. In patients with metastatic disease, and those with concerning (i.e. large) primary lesions, many clinicians consider the addition of chemotherapy as well. It should be evident that of all the cutaneous malignancies, MCC is among the most aggressive and therefore multimodality therapy is strongly encouraged.

Melanoma is the third most common cutaneous malignancy, affecting approximately 60,000 individuals in the United States in 2007. Melanoma has undergone a 650% increase in incidence and a 185% increase in melanoma related death since 1950. The median age of diagnosis for melanoma remains in the 50s but melanoma is also the most common solid-tumor in the age group 15–29, making this as much a disease of the young as that of the old, sun-damaged individual. Melanoma arises from the melanocytes, and although generally thought of as a disease of the skin, it can be found in the eyes, oral mucosa and intestines, particularly in the ano-rectum. Mucosal melanomas tend to behave much more aggressively than cutaneous melanomas and nearly 50% of ocular melanomas will metastasize, almost uniformly to the liver.

Risk factors for melanoma are identical to those of the other cutaneous malignancies, with light hair, light eyes and light skin increasing the risk of melanoma to a greater extent than that of the general population. However, the greatest controllable risk factor remains the intermittent exposure to ultraviolet light, such as the sun and tanning beds, especially before the age of 18. A personal history of melanoma is the single greatest risk factor for developing another melanoma, with the 5-year incidence of developing a second skin cancer in patients with a history of melanoma reaching approximately 8%. New insights have also provided information regarding the germline mutations and the increased risk of melanoma as well as detailed information with respect to genetic mutations present in melanoma, which may offer therapeutic targets in the future.

Among the most common genetic abnormalities identified in atypical melanocytic nevi and subsequently in melanomas, is a mutation in the *BRAF* gene. It is now proposed that melanomas develop through a progression, from atypical nevi through radial growth phase lesions to vertical growth phase lesions, with associated

Melanoma

genetic changes. Approximately 25–40% of familial melanomas will be associated with a genetic defect in *CDKN2A*, which encodes the p16 tumor-suppressor protein. Furthermore, and perhaps more significant for the treatment of melanoma, a significant percentage of acral and mucosal melanomas have been found to have a genetic mutation in the *cKIT* oncogene, with nearly 40% of the lesions of the mucosa or acral areas harboring a mutation. The potential clinical implications with this finding are obvious, as lesions harboring these mutations may be susceptible to targeted therapy with agents such as Gleevec. At present, the knowledge of the genetics of melanoma is expanding at an extraordinary rate, and the insight this new information may provide is boundless.

The management of melanoma serves as the foundation for the treatment of the more aggressive cutaneous malignancies, such as MCC, some high grade SCCs and even some high grade adnexal carcinomas (which are beyond the scope of this chapter). The basic treatment includes wide excision with or without SLN biopsy. As previously mentioned, the margins of excision for melanoma has been studied in a multitude of prospective trials and has become widely accepted as either 1 or 2 cm as defined by the depth of the primary tumor. The role of SLN biopsy has also been broadly accepted with only a few authors still arguing against its routine use. In general, SLN biopsy is recommended in patients with primary tumors greater than 1 mm in Breslow depth, and without evidence of regional or distant metastases, as well as in selected patients with lesions less than 1 mm thick and defined high-risk features, such as ulceration, lymphovascular invasion and high mitotic rate. The management of melanoma remains primarily surgical, although patients with metastatic disease are offered interferon alpha as an adjuvant. In individuals with multiple (4 or more) positive nodes in a regional basin or extracapsular extension, radiation therapy may be offered. Patients with widespread metastases are offered either interleukin-2 or biochemotherapy, but should generally be considered for a clinical trial, if available.

Summary

The treatment of cutaneous malignancies is focused on complete surgical extirpation of all known disease. Like all solid tumors, complete excision with negative margins is the goal of therapy, and the surgical planning is focused on achieving this endpoint with the most effective functional and cosmetic outcome. Assessment of the regional lymphatics is appropriate in high grade lesions without clinical evidence of metastases through the technique of SLN biopsy, and patients with distant metastases should be offered systemic therapy or a clinical trial. The understanding of the biology of the diseases we treat allows for sound surgical decision-making and, in conjunction with a fundamental knowledge of the anatomy discussed subsequently, should lead to the best outcome for treating patients with cutaneous malignancies.

Surgical Considerations in Primary Lesions

Clinical examination is vital to diagnosis and treat skin cancers. They typically arise clinically in two ways, as a single lesion in apparently normal skin and as multiple lesions arising in the background of abnormal skin. This distinction is extremely important in treatment planning.

General concepts

Biopsy Technique

The biopsy technique depends on the size, location, and suspected pathology. A *shave biopsy* is appropriate for superficial lesions suspected to be BCC or SCC. It is not ordinarily applicable to deeply seated lesions, particularly suspected melanoma. Tangential skin incisions are made with the scalpel, removing the specimen down to or below the skin surface. *Excisional biopsy* may be both diagnostic and therapeutic in some instances. It is the method of choice for lesions suspected to be melanoma. The biopsy is performed under local anesthesia and includes a 2-mm margin of grossly normal tissue extending into the subcutaneous fat which allows for complete pathological evaluation of the lesion. This is critical for determining the extent of additional surgery and possible SLN mapping. *Incisional or punch biopsy* should be used for large and fixed lesions. A punch biopsy instrument removes a small cylinder of tissue from the center of the lesion or from the area of deepest penetration. A three or four mm diameter punch is generally used, and the resultant defect is closed with a single catgut suture.

Incision Planning

Elective excisions of lesions are planned so that the final scars will parallel the relaxed skin tension lines. These allow tension free closure and produce the most cosmetically acceptable scars. Wrinkle lines are generally the same as relaxed skin tension lines and lie perpendicular to the long axis of the underlying muscle.

Skin incisions along the junction of the facial subunits are very inconspicuous. Skin excisions oriented in the pathway of lymphatic drainage such as the long axis of the extremities have been advocated to reduce local recurrence, but this has never been proven to be valuable. These incisions in the extremities run perpendicular to the relaxed skin tension lines resulting in wide scars.

Surgical Excision

Simple *elliptical excision* is the most commonly used technique to remove skin cancers. The length of the ellipse should be at least three times that of the width. Elliptical excisions of inadequate length may yield “dog-ears” which consist of excess skin and subcutaneous fat at the end of the closure. There are several ways to correct a dog-ear deformity as shown in Fig. 19.1. A *circular excision* is useful to preserve the skin and to reduce scar length. This allows the natural contraction of the remaining skin to

Figure 19.1

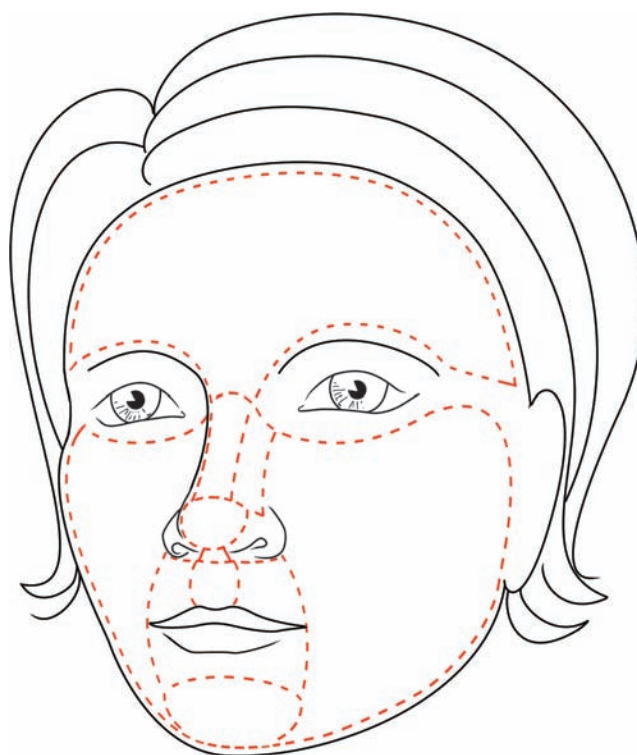
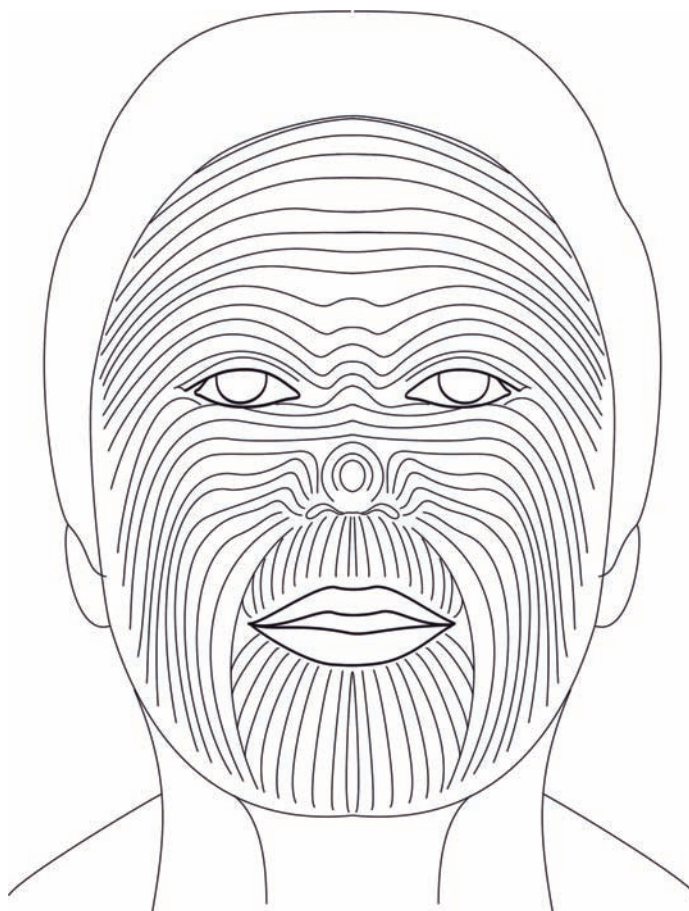


Figure 19.2

Table 19.1 The indications for Mohs surgery

Large invasive BCCs
Morpheaform BCC or others with aggressive histological features
High risk areas
Recurrent lesions especially after radiation
Tumors with Perineural invasion

form an ellipse which will parallel the relaxed skin tension lines. This is particularly useful in the face and on the scalp, where skin graft closure is used.

No general “rule of thumb” can be given for determining the size of excision margins because the growth characteristics and the behavior of tumors vary greatly with histological type and location. Large lesions (greater than 1 cm) and recurrent lesions require wider and deeper margins. Mohs micrographic surgery utilizes precise tangential tumor excision with immediate pathological margin assessment: It provides the best histological control and preservation of tissue for any treatment method. The indications for Mohs surgery are included in Table 19.1.

Wound Closure

Precise approximation of the skin edges without tension is essential to primary healing with minimal scarring. Wounds that are deeper than the dermis are closed in layers to eliminate dead space. Wound edge eversion produces the best coaptation of the skin which will flatten over time. Sutures should be placed in a manner that will not leave permanent suture marks. Prompt removal of permanent sutures can prevent this deformity. Sutures of the face should be removed in 3–5 days and on other areas of the body they should be removed in 7 days or less.

The *skin* is comprised of two basic layers: the epidermis and the dermis. The epidermis is the outer layer containing four major cell types: keratinocytes, melanocytes, Langerhans cells, and Merkel cells. The dermis is much thicker than the epidermis and contains noncellular connective tissue elements such as collagen, elastin, and ground substance. It also contains nerves, blood vessels, lymphatics, pilosebaceous, apocrine and eccrine units. The papillary dermis abuts the epidermis. It contains fibroblasts, mast cells, histiocytes, Langerhans cells, and lymphocytes. The reticular dermis is deeper and thicker than the papillary dermis and extends into the underlying fat. The reticular dermis contains loosely arranged elastin fibers interspersed with large collagen fibers. The *blood supply to the skin* comes from the dermal-subdermal plexus. It is supplied by direct cutaneous vessels or musculocutaneous and septocutaneous perforating blood vessels.

The *scalp* extends for the external occipital protuberance and superior nuchal lines to the supraorbital ridges. It consists of five layers: (1) the skin, which is thick in hair bearing areas and contains numerous sebaceous glands, (2) connective tissue, which is the superficial fascia containing nerves and blood vessels, (3) epicranial

Anatomic Considerations

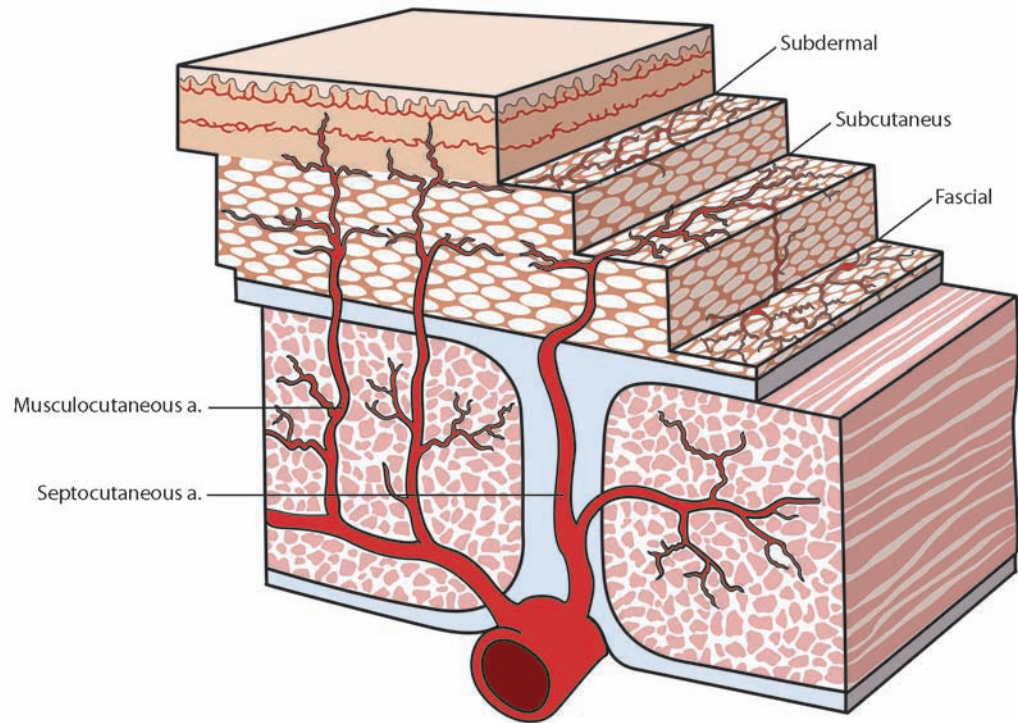


Figure 19

aponeurosis (galea), which extends from the muscles of the scalp, (4) loose areolar tissue, which is a natural avascular surgical plane, and (5) the pericranium, adherent to calvarium. The first three layers are bound together as a single unit below which is a good avascular plane for surgical dissection. It is in this plane, that most skin cancers are excised.

The skin of the *nose* and the lining of the mucus membranes are separated in its upper half by bony nasal skeleton and lower half by nasal cartilages. The skin over the bony skeleton and the lateral cartilages has a degree of mobility, whereas the skin over the alar cartilages is adherent, and has no mobility. The bone and the cartilage act as a tumor barrier.

Treatment by Disease Type

Basal Cell Carcinoma

There are several treatment methods that can be used depending on the tumor histology, size, location, and patient characteristics.

- Cryotherapy
- Electrodesiccation and curettage
- Radiotherapy
- Topical chemotherapy
- Surgical excision

Cryotherapy is frequently performed by dermatologists to treat small, less aggressive subtypes of BCC. Hypopigmentation, scarring, and injury to local nerves are associated with this form of treatment. *Electrodesiccation and curettage* is commonly

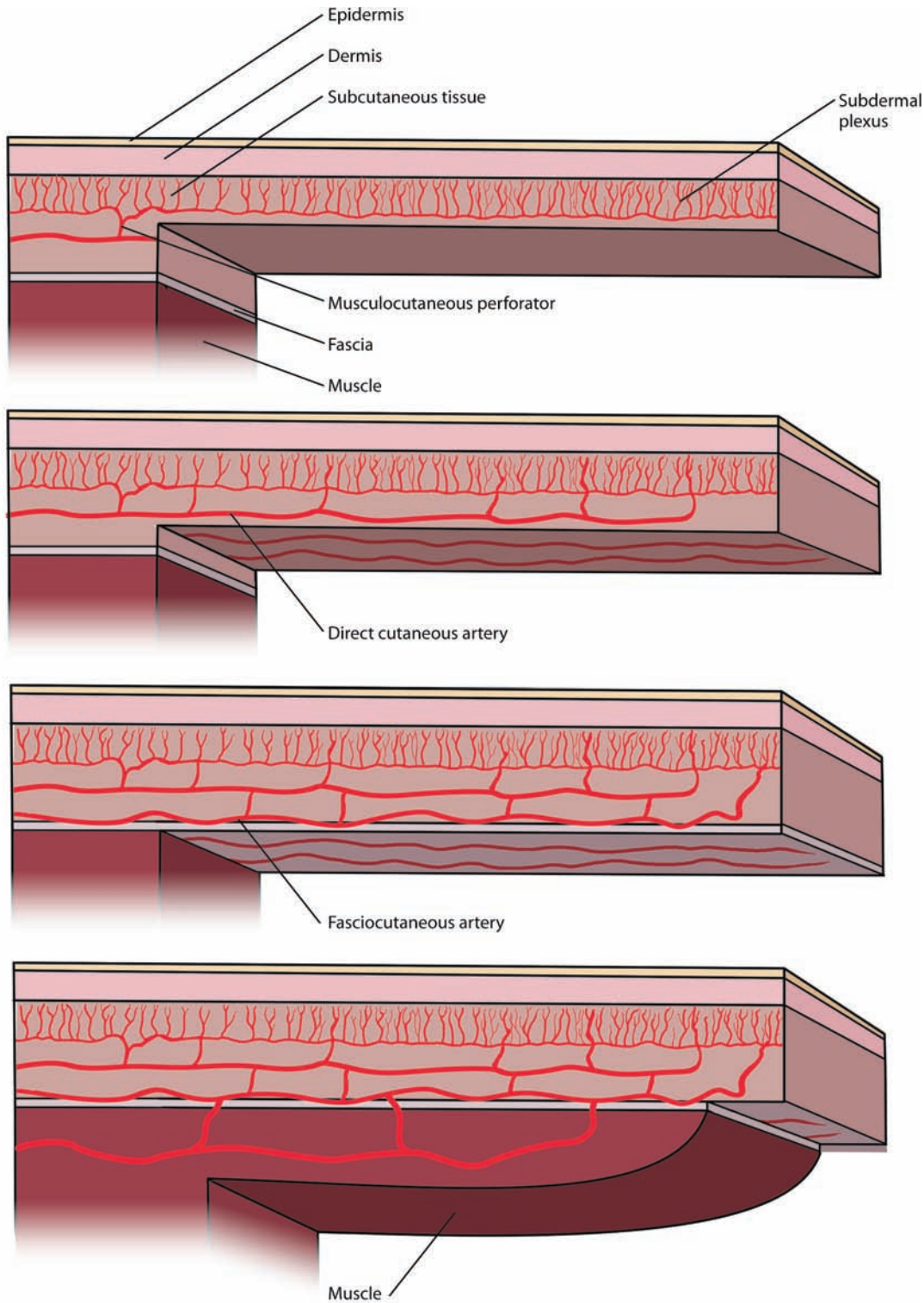


Figure 19.3b

employed in lesions that are less well-circumscribed. It may be primary treatment modality for nodular subtypes less than 2 cm and superficial variants of any size. *Radiotherapy* is reserved for patients who are at a high risk of surgical complications. It results in lower cure rates than other modalities. *Topical chemotherapy*

(5-fluorouracil) may be used to treat nodular and superficial subtypes (less aggressive). It is more often employed for premalignant lesions. *Surgical excision* of BCC results in a cure rate which is greater than 90%. The overall prognosis is related to size, location, and histological subtype. For well defined nodular BCCs which are 2 cm or less in diameter, margins of 2–4 mm would be adequate in most instances. It is unusual for BCC to penetrate the fat and so, the depth of excision should be carried into the fat to assure tumor clearance. Morpheiform BCCs, tumor size greater than 2 cm, tumors with aggressive histological growth pattern, and those that are recurrent, are best treated with Mohs micrographic surgery. This results in better tissue preservation and lower recurrence rates.

Squamous Cell Carcinoma

The incidence of lymph node metastases with SCC of the skin is reported to be 2%. The predisposition to regional nodal metastases is multifactorial with the etiology of cancer being important. SCCs arising in the following conditions have an increased risk of nodal metastases.

- Chronic wounds, Marjolin's ulcer, osteomyelitis
- Radiation induced
- Mucocutaneous areas: lip, penis, perianal, vulva
- Immunocompromised patients.

The incidence of nodal metastases in these high risk tumors can be 10–30% in some cases.

Merkel Cell Carcinoma

This rare neuroendocrine tumor has certain features which make the surgical management unique. As a primary concern, the head and the neck are the most common sites. Another important consideration is that one fourth of the patients present with regional or systemic spread (local 75%, regional 22%, and distant 3%).

The extent of the lesion is difficult to determine clinically and the risk of involved surgical margins is high. This makes it a good option to leave the wound open until final clear pathological margins are obtained. The wound should then be allowed to close by secondary intention or skin grafting.

The overall 5 year survival ranges from 35 to 75%. Because of the high incidence of regional spread, SLN biopsy is often performed in cases who present with localized disease. Radiation therapy is often administered to reduce locoregional recurrence.

Melanoma

Surgical excision margins in melanoma are based on tumor characteristics, which are described previously. Local recurrence of melanoma is defined as the recurrence within 2 cm of surgical incision. It is related to tumor stage, especially tumor thickness and ulceration. The etiology is multifactorial. It may represent retained primary

melanoma cells in the surrounding dermal lymphatics. It is probably a manifestation of systemic relapse, as the long term survival after local recurrence is very low.

There have been numerous randomized trials examining the impact of surgical margins on local recurrence.

Study	Tumor thickness	Margin (cm)	N	Local recurrence (%)
WHO	≤2 mm	1	305	2.6
		3	307	0.98
French	≤2 mm	2	161	0.98
		5	165	0.62
Swedish	≤2 mm	2	476	0.6
		5	513	1.0
Intergroup	1.0–4.0 mm	2	238	2.1
		4	230	2.6
UK	>2.0 mm	1	453	3.3
		3	447	2.8

These trials have shown a trend towards increased local recurrence with narrower margins of excision. None of the trials have shown a survival advantage for larger margins of excision. The current recommendation for excision margins are based on tumor depth and location. Thin melanomas warrant a conservation 1 cm excision margins. Thicker melanomas should be excised with a least a 1-cm margin. With tumors thicker than 2 mm, larger margins should be used having a 2-cm excision margin, if the surrounding tissue permits. The depth of incision includes the subcutaneous fat. The removal of muscle fascia has never been shown to reduce local recurrence.

Face

Special Situations

Incisions on the face should fall into the relaxed skin tension lines. Circular excision is often performed which allows the natural contraction of the remaining skin to form an ellipse, which will parallel the relaxed skin tension lines. Tumor location plays an important role in treating BCC of the face. The “H” zone depicts areas of the midface and preauricular areas, especially along embryonal fusion planes that have a potential for deep invasion. Tumors in this zone are often treated with Mohs micrographic excision to assure tumor clearance and maximum tissue preservation.

Scalp

The frequent problem with scalp neoplasms is deep margin clearance. Tumor mobility off the pericranium is usually a good indication that the bone is not invaded. Sometimes, it can be difficult to determine whether the tumor has breached the galea. Partial calvarial resection is difficult, lacks margin control, and generally is not recommended. Scalp excisions are generally not amenable to direct closure because of poor extensibility of the skin. Wide undermining generally gains little

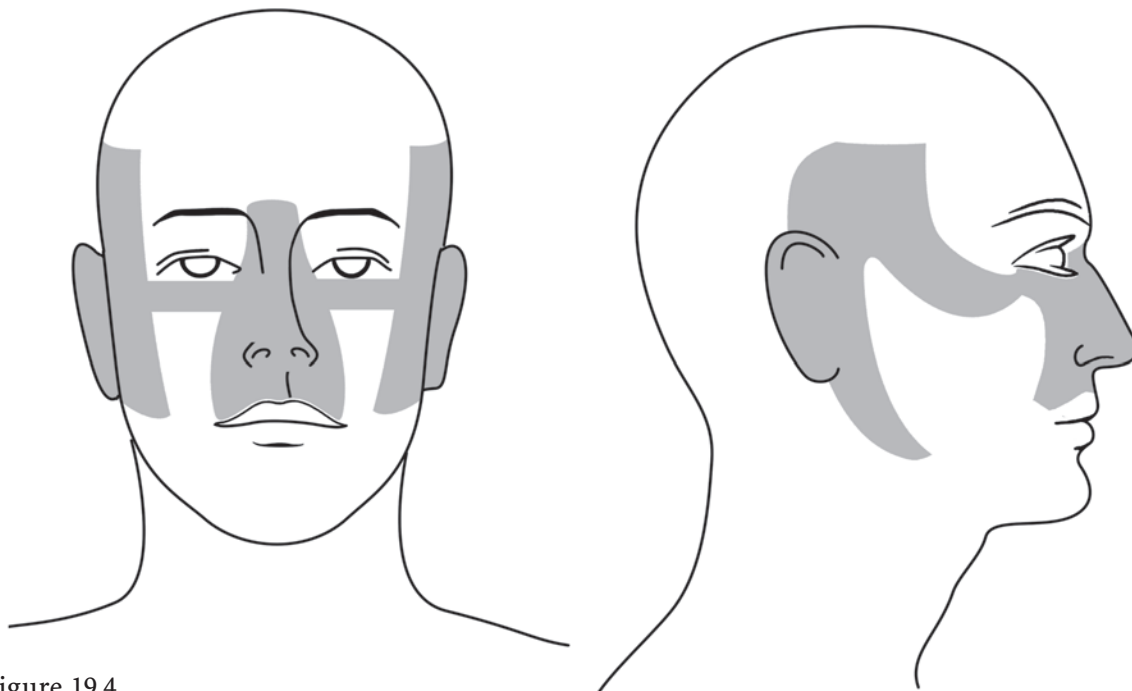


Figure 19.4

advancement to facilitate wound closure. Local scalp flaps require large area tissue advancement and generally are not recommended especially with uncertain margin control. These defects are best closed with skin grafts.

Hand

SCC of the skin is the most common tumor of the hand (75–90% of total). It is more common in men and typically occurs on the dorsal surface of the hand, fingers, and wrist. In some series, SCC of the hand is reported to be more locally aggressive and have higher rates of regional and distant metastases.

Pigmented lesions of the nail bed require special attention. It can be difficult to distinguish a traumatic subungual hematoma from a melanoma. A careful history is important. A hematoma will migrate towards the nail tip as the nail grows. For sus-

Figure 19.5



pected subungual melanomas, an incisional biopsy should be performed under digital block. A small window is made in the nail over the area which is then biopsied.

Ear

BCC is rare on the ear. It usually occurs around the external acoustic meatus and on the posterior surface. SCC is more common and often has an infiltrative growth pattern which spreads within the dermis and along the perichondrium. The specific anatomy of the ear, being composed of two layers of thin skin separated by auricular cartilage, makes surgical removal difficult. Prognosis of auricular cutaneous malignancies tends to be worse than other areas of the body

Melanoma of the ear is often treated with full thickness resection, most often a wedge resection. The surgical margins tend to be less owing to the anatomic site but the local recurrence rate is comparable to other sites. Wide excision of the skin down to perichondrium, and skin grafting has been suggested for thin melanomas with ulceration or invasion into the reticular dermis. The cartilage can be resected with the skin on the backside preserved to assist in reconstruction.

Reconstruction after skin cancer resection depends on many factors including the size, location and depth of the defect, availability of local tissue, tumor biology, margin status, and the experience of the surgeon. In the appropriate clinical setting, all methods may provide excellent cosmetic and functional results. No reconstruction may be appropriate in certain clinical situations especially with aggressive tumors involving the ear or nose. Prosthetic reconstruction can provide superior results in these settings.

Reconstructive Options

Methods

Allowing wounds to heal by *secondary intention* is useful in small superficial wounds. This method is also useful in cases of recurrent cancer or aggressive tumor biology. Location is an important predictor of the aesthetic outcome of secondary wound healing. Concave surfaces tend to heal better than convex surfaces. The alar and nasolabial folds of the nose, the medial canthal area, and the lower eyelid, produce satisfactory cosmetic outcome with this method.

Primary closure could be used in most skin cancer excisions. It is used in cases with high probability of complete tumor excision and in areas where adjacent tissue is available.

Skin grafts are useful in large defects, especially on the scalp and in cases of aggressive tumor biology with a high risk of local recurrence. Skin grafts are also utilized in skin cancer arising in the background of abnormal skin. They are classified as either split-thickness or full-thickness depending on the amount of dermis included. Split grafts contain varying amount of dermis whereas a full-thickness skin graft contains the entire dermis. All grafts contract after removal from the donor site because of the elastic fibers in the skin. This is called primary contraction. If more

dermis is harvested, more primary contracture will be experienced. Secondary contraction occurs after the revascularization of the graft. This is probably the result of myofibroblast activity.

Full thickness grafts exhibit more primary contraction but less secondary contraction than split-thickness grafts. This makes them useful especially in the face and on the hand. Grafts taken from above the clavicles have a better color match for defects of the face. The upper eyelid and the posterior sulcus of the ear can provide small amounts of very thin skin for full-thickness grafting of the face. These donor sites can be closed primarily.

The thin *split-thickness grafts* exhibit greater secondary contracture. They are harvested with a pneumatic or electric dermatome. Donor sites from thin split grafts (<10/1,000 of an inch) will heal in 7–10 days. Meshing either mechanically or with a knife can allow for expansion to increase graft size. It also allows for wound drainage of serum and blood. Mesh grafting can result in a “pebbled” appearance.

Flaps

Skin flaps have their own blood supply which is useful in covering recipient beds that have poor vascularity, and covering of vital structures. They are particularly useful in the head and neck reconstruction including: full thickness defects of the eyelids, lips, ears, nose, and cheeks. They can provide outstanding cosmetic results by “replacing like tissue with like tissue.”

Flaps that rotate about a *pivot point* are called rotation or transposition flaps. They have a rotation arc through which the flap is rotated. The radius of this arc is the line of greatest tension. *Rotation flap* is a semicircular flap of skin and a subcutaneous tissue that rotates about a pivot point into the defect to be closed. The donor site can generally be closed primarily. Occasionally, a back cut from the pivot point along the base of the flap can be used to release tension. This must be used with caution not to compromise the blood supply to the flap. A *transposition flap* in its classic form is a rectangle, which is raised and moved laterally into the primary defect. It leaves a secondary triangular defect which is at least equal in area. This usually requires graft closure. This flap is useful in the hair-bearing scalp.

Advancement flaps include single-pedicle, V-Y advancement, and bipedicle advancement flaps. These have a limited role in reconstruction and only the face has the necessary skin laxity to allow advancement flaps to be useful. In its simplest form, it comprises a wide undermining of the skin and subcutaneous tissue, above the underlying muscle fascia. This allows skin advancement to facilitate wound closure. *Distant flaps (free flaps)* should be considered in situations where there is extensive tissue loss and no local options remain. This is rarely needed in the treatment of cutaneous lesions and should only be performed in conjunction with a reconstructive team. Distant flaps are usually necessary only in recurrent disease and generally, after other reconstructive options have been used in prior settings.

Surgical Considerations in Sentinel Lymph Node Biopsy

Although regional lymphadenectomy and SLN biopsy are covered elsewhere in this text, certain considerations specific for melanoma and MCC require comment. As already mentioned, depending on the location of the primary lesion and the draining nodal basin, SLN bx may have as much as 98% accuracy in detecting metastases in patients with at-risk lesions. This accuracy decreases in the head and neck region, where rich lymphatic drainage and the close proximity of primary lesions to the draining nodes, often make this procedure more difficult.

The fundamentals of SLN biopsy are held across all disease types, that is, to identify the first draining lymph node associated with the tissue that gave rise to a given tumor. For melanoma and other cutaneous malignancies, this is determined routinely by the use of preoperative lymphoscintigram followed by intraoperative lymphatic mapping. Most melanoma surgeons utilize both radiotracer and blue dye, and we strongly advocate this “dual-technique.” Approximately 0.3–3% of the patients will have in-transit nodes (nodes outside a major draining nodal basin) which harbor occult metastases and it is imperative that surgeons performing SLN biopsy for melanoma do not overlook these nodes – hence the importance of preoperative lymphoscintigraphy.

The basic surgical approach is applied to all sites, regardless of location. The area of greatest radioactivity is identified using transcutaneous gamma probe detection and the smallest incision possible given the number of nodes, and the patient’s body habitus is mapped out in such a fashion as to allow the operating surgeon to return to a subsequent procedure and perform a complete regional lymphadenectomy. It is a practice to draw the incision that would be used to perform a complete regional lymphadenectomy and then to use the gamma probe to determine the segment of the incision that would serve for the SLN bx. In general, except in patients who are extremely obese or harbor several widely dispersed nodes which need to be removed, an incision of 2–4 cm is adequate.

There is one exception to this routine approach, which warrants mention. In the head and neck, exposure is critical and we strongly advocate the use of larger incisions, with complete exposure of the parotid gland, when nodes in the preauricular and cervical level II region are identified as part of the lymphatic drainage. Although we do not routinely use a full parotidectomy incision, an incision which will allow complete exposure of the gland, and if the nodes are identified in the cervical region as well, an in-continuity incision is utilized, rather than a “skip” incision.

The specific anatomy of the neck is discussed elsewhere in this text and we will therefore not discuss at length in this chapter, however certain highlights warrant mention. The neck contains several small nerve branches which can easily be injured

by electrocautery or an errantly placed retractor. The two most significant nerves which can be affected, are the spinal accessory nerve, which is very superficially located in the posterior triangle of the neck, coursing from the sternocleidomastoid to the trapezius muscle, and the marginal mandibular branch of the facial nerve, which courses along the angle of the mandible and can easily be injured when searching for a level II node, if the surgeon is not attentive to its location.

In general, while limiting the length of an incision is an attractive cosmetic option for sentinel node biopsy, and is consistent with the goals of the procedure, it should not be done at the cost of surgical exposure and concomitant risk to vital structures. The operating surgeon should determine the optimal incision length for each case while considering the patient's body habitus, anatomic location of the nodes and the distance between the nodes, if more than one SLN is identified.

Anatomic Basis of Complications

- The most common complication following the resection of a cutaneous lesion is a wound infection. The spectrum of infections can range from simple cellulitis to a florid abscess requiring an opening of the surgical site.
- A second common problem, and likely the most common complication after SLN biopsy is seroma. This is the result of persistent leak from microscopic lymphatic channels and increases the risk of subsequent wound infection and breakdown.
- Hematoma in the postoperative setting is also a concern, which can either be immediate (in the recovery room), necessitating a return to the operating room, or delayed, which, after 48 h usually does not mandate evacuation but complicates wound care and increases the potential for infection and wound breakdown.
- While numbness in the surgical field is not a true complication, it is critical to inform the patient about the field of distribution for expected sensory loss as this can be disconcerting to the patient who is otherwise unprepared for this, postoperatively. Most sensory deficits are compensated for by the body after a variable time, depending on the age of the patient and other comorbidities.
- Flap or graft failure is a rare, but significant complication which can lead to the need to depend on secondary intention for wound healing. The cosmetic results can be markedly compromised and these failures usually are the result of a compromise in blood supply, or an infection of the site.
- Lymphedema can occur after SLN biopsy. Since it is a rare event in the absence of a major lymphadenectomy, it is of less concern in the setting of treatment of primary cutaneous malignancy.

Summary

Skin cancers are a biologically heterogeneous group of entities. While this alone makes their management complicated, this issue is compounded by the fact that these cancers can develop anywhere on the body. As such, the surgeon treating these lesions must have a broad knowledge of the anatomy of all areas, and more importantly must consider cosmesis, function, and optimal oncologic outcome, at all times. It is not uncommon, to require more than a simple linear closure to adequately repair the defect from a resection of a melanoma or a MCC and, for the general or oncologic surgeon to need the assistance of a reconstructive specialist. Additionally, treatment of the regional nodal basin and the knowledge of the anatomy of these areas is vital to the success of SLN biopsy and completion lymphadenectomy and therefore, these procedures need to be in the surgeon's repertoire as well.

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One of the landmark randomized trials which helped to define the margins of excision currently used to treat primary melanomas. Like the French cooperative trial referenced below, this was a comparison between 2 and 5 cm margins in lesions less than 2 mm. Neither this trial, nor the Swedish trial demonstrated a survival or recurrence advantage to the greater margin of excision. From these two studies, 5 cm margins were all but abandoned.

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A broad, but detailed review of this rare entity. Poulsen covers pathogenesis, risk and treatment paradigms.

Thomas JM, Newton-Bishop J, A'Hern R, et al Excision margins in high-risk malignant melanoma. *N Engl J Med.* 2004;350(8):757–66

One of the landmark randomized trials which helped to define the margins of excision currently used to treat primary melanomas. Neither SLN biopsy nor elective lymphadenectomy were used in this study

which showed a higher locoregional recurrence rate in patients having a 1-cm margin in contrast to 3 cm, with lesions greater than 2 mm thick. The limitation was that many of these recurrences would have been eliminated if the lymph node basin had been treated with current protocols.

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