The Federal Democratic Republic of Ethiopia

Ministry of Health

Oxygen Therapy in Children and Adults

Participant's Manual

November, 2017

Contents

Foreword

The ability to detect and treat hypoxemia is critical for patient care and quality of services, especially for children and neonates. As a lifesaving medicine, oxygen should be available in all hospitals and health centers (HCs). Oxygen is vital to combat pneumonia related under-five children mortality and morbidity and for the treatment of many emergencies, including cardiac arrest, acute blood loss, shock, dyspnea (breathlessness), pulmonary edema, unconsciousness, convulsions (eclampsia), and fetal distress during labor.

Recognizing this, the Federal Ministry of Health (FMOH) has developed a *National Medical Oxygen and Pulse Oximetry Scale Up Road Map* to improve access to oxygen, including clinical care and systems. This road map has been developed as part of realizing the ambitious targets of the *Health Sector Transformation Plan (HSTP)* and related program strategic plans including child survival strategies and safe surgery initiatives which are aimed at improving equitable access to quality of health services.

Since the majority of health facilities in Ethiopia have limited availability of oxygen devices and pulse oximeters (POx), and many professionals lack basic knowledge and skills of oxygen therapy, the road map has identified improving availability and functionality of oxygen devices and POx, as well as building capacity of healthcare workers as key areas of intervention.

Therefore, this training material is designed to provide skills training for healthcare professionals that prescribe oxygen, administer and monitor patients on oxygen therapy, and improve their basic clinical knowledge and skills of hypoxemia management. We believe this training will improve patient care related to oxygen therapy and significantly contribute in reducing mortalities and morbidities nationally.

While this document is primarily intended as a training material for clinicians, it is hoped that health professionals across all level of health facilities will also use this as a reference document.

At this venture, we would like to take this opportunity to express our profound appreciation to all partners that have participated in the development of this important training material.

Clinical Services Directorate

Federal Ministry of Health

APPROVAL STATEMENT OF THE MINISTRY

The Federal Ministry of health of Ethiopia has been working towards standardization and institutionalization of In-Service Trainings (IST) at national level. As part of this initiative the ministry developed a national in-service training directive and implementation guide to implement trainings in a well standardized manner. The directive requires all in-service training materials fulfill the standards set in the implementation Guide to ensure the quality of in-service training materials. Accordingly, the ministry reviews and approves existing training materials based on the IST standardization checklist annexed on the IST implementation guide. As per the national IST quality control process, this oxygen therapy in children and adults training package has been reviewed using a standard review checklist and approved by the ministry in Feb, 2018.

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Acronyms

AC	Alternating Current
ALRI	Acute Lower Respiratory Infection
ARDS	Acute Respiratory Distress Syndrome
ARF	Acute Respiratory Failure
Bi PAP	Bi Phasic Airway Pressure
BME	Biomedical Engineer
BVM	Bag Valve and Mask
BW	Birth Wight
CHF	Congestive Heart Failure
COPD	Chronic Obstructive Pulmonary Disease
CPAP	Continuous Positive Airway Pressure
ECG	Electrocardiograph
ED	Emergency Department
EPAP	Expiratory Positive Airway Pressure
FRC	Functional Residual Capacity
GA	Gestational Age
HMIS	Health Management Information Systems
ICU	Intensive Care Unit
IPAP	Inspiratory Positive Airway Pressure
ISO	International Organization for Standardization
MDSR	Maternal Death Surveillance and Response
MV	Maximum Ventilation
NICU	Neonatal Intensive Care Unit
NIV	Non-invasive Ventilation
NRB	Non-rebreathable
OR	Operation Theater
PACU	Post Anesthesia Care Unit
PaO2	The arterial Oxygen Tension or Partial Oxygen Pressure
PEEP	Positive End-Expiratory Pressure
PPE	Personal Protective Equipment
RR	Respiratory Rate
SaO2	Arterial Oxygen Saturation As Measured By Gas Analysis
SpO2	Arterial Oxygen Pulsed Saturation
TB	Tuberculosis
WHO	World Health Organization

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Introduction about the Manual

Every year, approximately 5.9 million children die globally mostly from preventable or treatable diseases, and more than 95% of these deaths occur in developing countries. Pneumonia is the leading cause of death in children under 5 years of age, and is responsible for an estimated 18% of all deaths in this age category in Ethiopia.

- Hypoxemia (insufficient oxygen in the blood) is a major fatal complication of pneumonia, and the risk of death increases with increasing severity of hypoxemia.
- A systematic review estimated that, globally, hypoxemia affects about 13% of children admitted to hospital with pneumonia, about 20% of sick neonates and 10–15% of children admitted with conditions such as malaria, meningitis or convulsions.

Taking the limited information about oxygen therapy in the Ethiopian context, the Clinton Health Access Initiative (CHAI), in collaboration with the FMOH and PFSA, has conducted an oxygen and pulse oximetry availability and functionality assessment in more than 300 health centers and 110 hospitals as a part of its project baseline assessment in December 2015. The key findings were the following:

- Oxygen availability varied widely across regions, and between facility types (hospitals vs. health centers).
- Only 62% of hospital had sufficiently equipped or filled oxygen devices in the pediatrics IPD, and fewer had pulse oximeters available (45%). Availability was almost none in health centers.
- Availability was generally higher at the hospital level.
- Concentrators appeared to be consistently more functional, although Amhara and Oromia health centers did not have concentrators.
- Knowledge and training on the proper management of oxygen was also found to be a critical gap at both the hospital and health center level.
- Only 3% of health centers and 26% of hospitals have regular practice of oxygen consumption and stock monitoring mechanism.
- Few private medical & non-medical oxygen suppliers are located in Addis Ababa, in which accessibility is one of the critical challenges so far observed; some health facilities are supposed to travel more than 800km for refilling.
- There are no biomedical technicians at the health center level that can perform maintenance on oxygen equipment currently, but relatively higher proportion (41%) at hospitals.

The Medical Oxygen and Pulse Oximetry Scale Up Road Map in Ethiopia (2016-2021) has been developed and launched to provide wider access to oxygen supply and pulse oximetry as well as ensure utilization. The interventions articulated in the roadmap synergize with other interventions to meet HSTP goal of mortality reduction in maternal, newborn and surgical care settings.

Training for health care providers across all services and biomedical engineers/technicians is also necessary for the implementation of an effective oxygen system.

The course follows adult learning approach to build on the existing knowledge and skills of healthcare provider on clinical practices of oxygen therapy.

The main topics in this training course are clinical signs of hypoxemia and its detection, oxygen therapy in neonate and children, oxygen therapy in adults, oxygen and pulse oximetry device management and oxygen therapy program monitoring and evaluation.

The emphasis in this course is on how to assessment patients using pulse oximetry and clinical parameters to identify their oxygen need, how to deliver oxygen in children and adults in different conditions, how to monitor patents o oxygen therapy using pulse oximetry, when to discontinue oxygen therapy, how to conduct basic care and manipulation of oxygen devices and how to use information for decision-making as part of program monitoring and evaluation.

Core Competencies

The following are core competencies expected by each participant. They will be able to:

- Understand the situation of oxygen therapy in Ethiopia, efforts and challenges;
- Demonstrate detection of hypoxemia in both children and adults;
- Competently administer oxygen in different conditions, and monitor patients on oxygen therapy in a healthcare setting;
- Forecast oxygen demand for all service outlets, so as to ensure uninterrupted supply;
- Monitor the oxygen equipment for optimum utilization at each service outlet; and
- Document, review and report the findings for process improvement and quality of care.

Course Syllabus

Course Description

This three-day oxygen therapy in children and adults course is designed to provide all levels of health care workers with the basic knowledge and skills needed to provide oxygen therapy to save the lives of children and adults in healthcare settings using the available resources.

Course Goal

To provide the participants with knowledge, skills, and attitude needed to provide oxygen therapy for children and adults.

Course Objectives

At the end of this course participants will be able to:

- Explain the situation of oxygen therapy in Ethiopia, efforts and challenges;
- Describe the clinical signs of hypoxemia and its detection using pulse oximetry;
- Prescribe, dose and deliver oxygen in neonates, children and adults;
- Describe methods of improving oxygenation;
- Demonstrate knowledge and skills to initiate, manage and discontinue oxygen therapy Describe the different oxygen delivery mechanisms and techniques;
- Manage oxygen devices and pulse oximetry;
- Demonstrate forecasting of oxygen demand in a service outlet; and
- Document, review and report the findings for process improvement and quality of care.

Training/Learning Methods

- Interactive Lectures
- Demonstration
- Brainstorming
- Small group discussions
- Individual and group exercise
- Videotapes and discussions
- Clinical practice or facility visits

Training Materials, Supplies and Equipment

- Oxygen Therapy in Children and Adults: Participant's Manual
- Oxygen Therapy in Children and Adults: Facilitator's Guide
- Case studies
- Power Point slides
- Training videotapes
- Classrooms should include a space for the lecture presentations and a room for skill stations
- Pulse oximeters, oxygen cylinders, and concentrators
- Clinical settings for practical sessions
- Laptop and LCD projectors for lecture presentations

Participant Selection Criteria

Participants for this course should be health professionals (physicians, nurses, health officers, midwives, etc.) working in healthcare settings

Methods of Evaluation

Participant

- Pre and post-test questionnaire
- Evaluation of participant's performance on simulated/real setting

Course

- Daily evaluation to be completed by participants
- End of course evaluation to be completed by participants

Course Duration

- Three days

Suggested Course Composition

- 20-24 participants
- Preferred trainer to participant ratio is 1:6

Facilitator Selection

- Facilitators should have basic training on oxygen therapy in children and adults, with demonstrated proficiency in providing care in the area, and having relevant experience in facilitating training events and/or qualified in standard Training of Trainers (ToTs).

Certification

Certificate of Participation (given that all are qualified in real practice) will be issued by the agency authorized to organize the training event.

Certification will be based the score on:

- **Knowledge**: A score of at least 75% on the post-test questionnaire.
- **Skills**: Demonstrate the essential procedures in simulated patient/situation and/or during real practice.

Training Schedule: Oxygen therapy in children and adults course

Date and time	Activity	Responsible/s	Moderator/s
Day One:			
08:30AM – 08:45AM	Participants registration		
08:45AM – 09:00AM	Introduction of participants/briefing of agenda		
09:00AM – 09:10Am	Opening speech-Highlight objectives of the workshop		
9:10AM – 9: 25 Am	Course Overview		
9:25AM -9:50AM	Pre-test		
9:50 AM – 10:30Am	Chapter 1: Introduction to oxygen therapy		
10:30Am – 10:45Am	Tea/coffee break	Organizers	
10:30Am – 12:30PM	Chapter 2: Clinical signs of hypoxemia and its detection		
12:30pm – 01:30pm	Lunch		
1:30pm – 3:30PM	Chapter 2: Clinical signs of hypoxemia and its detection		
03:30PM – 03:45PM	Tea/coffee break	Organizers	
03:45PM – 05:30PM	Chapter 3: Oxygen therapy in neonates and children		
Day two:			
08:30AM – 10:30AM	Chapter 3: Oxygen therapy in neonates and children		
10:30AM – 10:45AM	Tea/coffee break	**Organizers**	
10:45AM – 12:30AM	Chapter 3: Oxygen therapy in neonates and children		
12:30PM – 01:30PM	Lunch		
01:30PM – 3:30PM	Chapter 4: Oxygen therapy in adults		
3:30PM -3:45PM	Tea/coffee break	**Organizers**	
4:00 PM- 5:30PM	Chapter 4: Oxygen therapy in adults		
Day Three:			
08:30AM – 10:30AM	Chapter 4: Oxygen therapy in adults		
10:30AM – 10:45AM	**Tea/coffee break**	**Organizers**	
10:45AM – 11:45 AM	Chapter 5: Oxygen device and pulse oximeter supply chain management		
11:45 AM – 12:30 PM	Chapter 6: M & E		
12:30PM – 01:30PM	**Lunch**		
01:30PM – 3:30PM	Facility visit and clinical practices		
3:30PM -3:45PM	**Tea/coffee break**	**Organizers**	
3:45PM- 4:15 PM	Post test		
4:15PM- 5:30PM	Closing		

Chapter One: Introduction to Oxygen Therapy in Ethiopia

At the end of this session the participant will able to:

- Explain the cost effectiveness of oxygen therapy in children;
- Describe the importance of oxygen therapy in obstetrics, medical, and surgical care settings;
- Describe the situation of oxygen therapy in Ethiopia, efforts and challenges; and
- Identify the key elements of the new roadmap to ensure access/utilization of oxygen therapy in Ethiopia.

Chapter outline
• Back ground • Cost effectiveness of oxygen therapy in children; • Importance of oxygen therapy in obstetrics, medical, and surgical care settings; • The situation of oxygen therapy in Ethiopia,

Key Questions for Self-Review

1. Have you ever come across a child under-five who died of pneumonia in your facility? Have any of them received oxygen therapy adequately?
2. As you work in emergency settings have you always provided oxygen to obstetric, medical and surgical emergencies? If no, what were the challenges to routinely provide oxygen?

1. 1 Background

Every year, approximately 5.9 million children die globally mostly from preventable or treatable diseases, and more than 95% of these deaths occur in developing countries. Pneumonia is the leading cause of death in children under 5 years of age, and is responsible for an estimated 18% of all deaths in this age category in Ethiopia.

- Hypoxemia (insufficient oxygen in the blood) is a major fatal complication of pneumonia, and the risk of death increases with increasing severity of hypoxemia.
- A systematic review estimated that, globally, hypoxemia affects about 13% of children admitted to hospital with pneumonia, about 20% of sick neonates and 10–15% of children admitted with conditions such as malaria, meningitis or convulsions.

Hypoxemia is also a major cause of morbidity and mortality associated with conditions such as acute and chronic lung disease in adults and can lead to death irrespective of age, sex, etiology, geographic region or clinical presentation of a patient.

The predominant causes of hypoxemia in adults are:

- Chronic obstructive pulmonary diseases, acute asthma and pneumonia.

- Hypoxemia also occurs in clinical conditions like sepsis, shock, major trauma, anaphylaxis, acute heart failure, pulmonary embolism, pleural effusion, pneumothorax, lung fibrosis, carbon-monoxide poisoning, and surgical emergencies.
- From a surgical perspective, oxygen is very important in operating theaters and anesthesia procedures, as well as during recovery periods in intensive care units.

Major causes of maternal deaths include:

- Hemorrhage, eclampsia, pre-eclampsia and abortion.
    - As a component of management of shock in such conditions, administration of oxygen is mandatory.
- Other causes of shock other than hypovolemic shock need the use of oxygen as well.

Studies show that an average of 13% of children classified as severe and very severe diseases using the World Health Organization (WHO) criteria suffer from hypoxemia. The number is even as high as 50% in hospitals, as most severe cases are referred there. In Ethiopia an estimated 196,000 children are dying each year. Over two-thirds of the childhood deaths are caused by a limited number of easily preventable conditions; mainly infections, neonatal conditions and malnutrition.

The major top five direct causes of under-five mortality are

- Pneumonia (18%),
- Diarrhea (9%),
- Prematurity (11%),
- Newborn infection (9%), and
- Asphyxia (14%).

The Ethiopian Maternal Death Surveillance and Response (MDSR) data (2014 G.C) also shows that 60% of reviewed maternal deaths were due to hemorrhage, while pre-eclampsia and eclampsia accounts for 12% of maternal deaths.

In averting such preventable deaths from hypoxemia, early detection and oxygen supplementation is very critical. Despite its importance in virtually all areas of acute severe illness, hypoxemia is often not well recognized or managed in settings where resources are limited.

Therefore, for a timely identification, prevention and management of hypoxemia; the presence of easier to use and reliable diagnostic modalities, like pulse oximeter, is highly important and contributes significantly to the quality of care.

Pulse oximetry can ensure the most effective and efficient use of oxygen therapy and monitor the response to treatment, which is especially important in resource limited countries like Ethiopia.

Oxygen is an essential medical drug that has been saving lives for over 100 years.

- It is included on the WHO *List of Essential Medicines*.
- In its guidelines, the WHO emphasizes the importance of oxygen within the necessary package of providing care for seriously ill children, and for obstetric, emergency, anesthesia, and surgical services.

Oxygen therapy is used not only for pneumonia and other primary lung diseases, but also many other conditions that result in hypoxemia, such as

- sepsis, severe malaria, status epilepticus, trauma;
- obstetric and neonatal conditions (respiratory distress, apnea, asphyxia, sepsis); and
- surgical care and anesthesia.

Given that hypoxemia is a major risk factor for death, oxygen therapy is important for improving patient outcomes.

Therefore, improving hypoxemia detection and oxygen treatment should be an undebatable priority to avert the morbidity and mortality related with hypoxemia. Oxygen therapy will be a core requirement in the management of medical illnesses, safe surgery, and anesthesia.

The benefits of a functioning oxygen system cut across several disciplines:

- internal medicine,
- pediatrics,
- obstetrics,
- anesthesia,
- surgery, and
- trauma and burns.

Implementing an effective oxygen delivery system requires strengthening of health systems, and building capacity and collaboration among clinicians, administrators and technicians.

Administration of oxygen at the point of care requires:

- a source, such as an oxygen concentrator or cylinder, and
- equipment for delivery, such as tubing, face mask or nasal prongs.

1.2 Situation of Ethiopia

Taking the limited information about oxygen therapy in the Ethiopian context, the Clinton Health Access Initiative (CHAI), in collaboration with the FMOH and PFSA, has conducted an oxygen and pulse oximetry availability and functionality assessment in more than 300 health centers and 110 hospitals as a part of its project baseline assessment in December 2015. The key findings were the following:

- Oxygen availability varied widely across regions, and between facility types (hospitals vs. health centers).

- Availability was generally higher at the hospital level.
- Concentrators appeared to be consistently more functional, although Amhara and Oromia health centers did not have concentrators.
- Knowledge and training on the proper management of oxygen was also found to be a critical gap at both the hospital and health center level.

As assessment findings,

- Although about 262 (83%) of health centers and 106 (96%) of hospitals are connected to the central electrical supply, over 90% of both HCs and hospitals report having power interruptions of at least two hours in the last week.
- 45% of HCs and 95% of hospitals have alternative sources of power.

At the health center level,

- A very small amount of health centers manages oxygen (11%).
- With even fewer (2%) maintaining a functional cylinder or concentrator.
- Staff members were generally untrained on providing oxygen therapy and health centers lacked SOPs/job aids for providing oxygen therapy.

At the hospital level,

- Most hospitals reported that they managed oxygen and had a functional cylinder or concentrator available.
- Only 62% had sufficiently equipped or filled oxygen devices in the pediatrics IPD, and fewer had pulse oximeters available (45%).
- Only 15 of the 109 hospitals had a staff member who had been trained on providing oxygen therapy or had SOPs/job aids available for providing the therapy.

Furthermore, having an appropriate supply monitoring practice and timely refilling system is critical at the facility level.

- Only 3% of health centers and 26% of hospitals have regular practice of oxygen consumption and stock monitoring mechanism.
- While 9% of health centers and 47% of hospitals think there are enough refilling sources for oxygen, which shows a need to expand supply base for oxygen supply both for health centers and hospitals.

Except one hospital already functioning, and a few others under construction,

- There is no public oxygen refilling center.
- The few private medical & non-medical oxygen suppliers are located in Addis Ababa, in which accessibility is one of the critical challenges so far observed; some health facilities are supposed to travel more than 800km for refilling.

While there are no biomedical technicians at the health center level that can perform maintenance on oxygen equipment currently, the relatively higher proportion (41%) at hospitals with this expertise could help if new graduates who could be assigned at zonal health department in consideration of the workload as in case of the Oromia region for quick experience of maintenance in remaining hospitals and health centers.

The Medical Oxygen and Pulse Oximetry Scale Up Road Map in Ethiopia (2016-2021) has been developed and launched to provide wider access to oxygen supply and pulse oximetry as well as ensure utilization. The interventions articulated in the roadmap synergize with other interventions to meet HSTP goal of mortality reduction in maternal, newborn and surgical care settings.

It contains six major areas for implementation:

1. Setting policy basis at higher level, coordination and decision support to health facilities to scale up oxygen supply;
2. Designing, setting up and rolling out supply chain systems and logistics to ensure sustainable oxygen supply;
3. Ensuring sustainable supplies for hypoxemia diagnostics and related consumables at service delivery points;
4. Establishing a mechanism for maintenance of oxygen equipment, and supply of spare parts;
5. Instituting a system for building capacity of health care workers in health facilities on supply chain management, utilization and basic maintenance skill of oxygen equipment; and
6. Ensuring sustainable financing to support oxygen supply system.

Chapter Two: Clinical Signs of Hypoxemia and Its Detection

Learning Objectives

At the end of this session, the participant will be able to

- Define hypoxemia,
- Identify the cause of hypoxia,
- Diagnose hypoxia,
- Describe the clinical signs of hypoxia,
- Develop skills in using a pulse oximeter and troubleshooting common problems, and
- Use a pulse oximeter in clinical practice.

Content outline
• Introduction to hypoxemia, • Cause of hypoxia, • Diagnosing hypoxia, • Clinical signs of hypoxia, • Use of pulse oximeter in clinical practice.

Key Questions for Self-Review

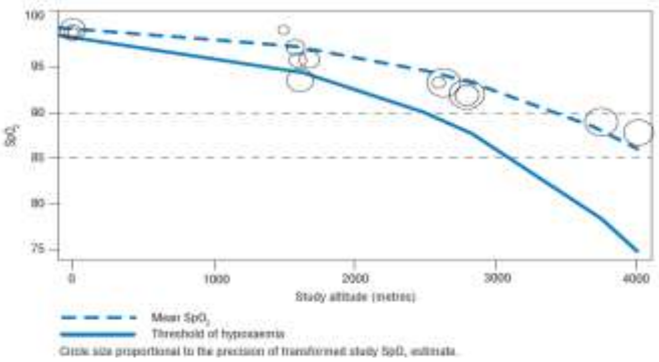
1. What is the normal range for arterial oxygen saturation at sea level? What is the lower limit (cut off) at sea level where oxygen is required?
2. What are the three methods where hypoxemia can be diagnosed?
3. What are the key clinical signs of hypoxemia in neonate, children, and adults that you commonly use to diagnose it?
4. What are the common causes of hypoxemia in neonate, children, and adults?
5. If you have ever used pulse oximetry in clinical care, what are the factors that affect the reading of pulse oximetry?

2.1 Definition of Hypoxemia

Hypoxemia refers to **low levels of oxygen in the blood** (decreased arterial concentration of oxygen). Arterial oxygen saturation can be measured by:

- Gas analysis (SaO_2), or
- Pulse oximetry (SpO_2), which is an easier method.
    - The normal range for arterial oxygen pulsed saturation (SpO_2) is 97-100% at sea level (with lower limit 94%).
    - It can be lower at higher altitudes because of lower partial pressure (PaO_2) of oxygen in arterial blood.

Figure 1: Threshold of Hypoxemia at Different Altitudes[1]



Most of the oxygen in the blood is chemically bound to hemoglobin in red blood cells (98%), while a very small percentage is physically dissolved in plasma (2%). The oxygen content of hemoglobin is expressed as oxygen saturation (SO2), i.e. the ratio between hemoglobin carrying oxygen (oxyhemoglobin) and total hemoglobin. The arterial oxygen tension or partial oxygen pressure (PaO2) is measured in mm Hg or kPa to determine how much oxygen is dissolved in plasma.

Baseline SpO2 levels will also depend on an individual's adaptation to **physiological** or **pathological** stresses.

- People residing in high altitudes adapt to lower baseline oxygen saturation due to the lower partial pressure of oxygen at higher altitude. Therefore, the normal range of SpO2 is progressively lower in populations living in mountainous regions.
- Similarly, patients with cyanotic congenital heart disease adapt to chronic hypoxia.

Note: It is important to know that soon after birth, ***normally newborns have lower normal oxygen level*** and it could take an hour or more for them to reach levels above 90%. Therefore, the normal level for a newborn in the first hours of life is typically 88%.

Hypoxia is:

- Inadequate level of oxygen in tissues for normal cell and organ function due to hypoxemia, and
- Lack of oxygen resulting in dysfunction of organ systems and death.

Hypoxemia is***:***

- A life threatening condition that requires early detection and treatment**.**
  - Oxygen is usually required when SpO2 <90%.
  - However, it can also be given if SpO2 is <94% in case of severe anemia, severe heart failure, severe sepsis or brain injury or in critically ill children with emergency signs.

[1] WHO, 2016. Oxygen Therapy for Children

2.2 Causes of Hypoxemia

2.2.1 Causes of Hypoxemia in Neonates

As mentioned above, the oxygen level is lower in the first few hours in neonates. Hypoxemia in newborns can be caused by:

- Respiratory distress syndrome,
- Birth asphyxia,
- Pneumonia,
- Sepsis,
- Congenital heart disease,
- Meconium aspiration syndrome, and/or
- Apnea.

Neonates can have apnea (which is cessation of breathing for 20 seconds or any duration associated with cyanosis and bradycardia) if they are premature, have sepsis, seizures, or hypoglycemia.

- Apnea or hypoventilation can also occur in neonates with very low birth weight (<1.5Kg or Gestational age of <32 weeks) as the respiratory drive has not matured yet.
- Apnea can also cause hypoxemia and slow the heart rate, further reducing oxygen delivery to tissues.

2.2.2 Causes of Hypoxemia in Children

The most common causes of hypoxemia in children are **acute lower respiratory infections (ALRI), such as pneumonia and bronchiolitis**.

- It is estimated globally that 1.5 to 2.7 million cases of pneumonia with hypoxemia come to health facilities annually and there are many more that are not even seeking care.

In addition, hypoxemia is also more common at higher altitude, in younger ages and seems to be more common in certain geographical regions.

Hypoxemia is a strong risk factor for pneumonia patients, and early detection and treatment needs to be given due attention.

Less frequent causes of hypoxemia in children include

- Acute asthma,
- Meningitis and sepsis,
- Heart failure or cardiac arrest,
- Anemia,
- Carbon-monoxide poisoning,
- Trauma,
- Perioperative emergencies, and
- Hospitalized cases of malaria (about 3-5 % of the cases have hypoxemia).

2.2.3 Causes of Hypoxemia in Adults

The major causes of hypoxemia in adults are **chronic obstructive pulmonary disease, acute asthma and pneumonia**. Other causes include:

- Sepsis
- Shock
- Major trauma
- Acute heart failure
- Pulmonary embolism
- Pleural effusion
- Pneumothorax
- Carbon-monoxide poisoning
- Obstetric and
- Surgical emergencies
- Women who suffer sepsis or acute complications of pregnancy such as hemorrhage, pre-eclampsia, eclampsia, abortion and cesarean section for different indications are prone to hypoxemia.

2.3 Diagnosing Hypoxemia

Hypoxemia can be detected by **clinical signs**, **pulse oximetry**, or **blood gas analysis**.

2.3.1 Clinical Signs

Detecting hypoxemia using only clinical signs is very difficult. Clinical signs are not reliable predictors of hypoxemia and can frequently result in misdiagnosis of children with normal oxygen saturation as hypoxic (false positive) or missing children who actually have hypoxemia (false negative).

- Clinical signs are not specific, especially in neonates and young infants, and this can result in delay in recognition of hypoxia and lead to progression to a more serious condition before oxygen therapy is initiated.
- Clinical signs alone should not be used for initiating oxygen therapy.

Yet, it is important to know clinical signs as other methods of detecting hypoxemia such as pulse oximetry which may not be available or functional.

2.3.1.2 Clinical Signs in Children

Central cyanosis is:

- Blue/purple discoloration of the skin and mucous membranes since deoxygenated hemoglobin is blue as opposed to oxygenated hemoglobin that is red.
- Can be identified by checking the tongue or gums (to a lesser extent lips) under sunlight or incandescent light.
- Central cyanosis may become visible when the SpO_2 is <80%.
- However, cyanosis may be difficult to detect in children with severe anemia and those with heavily pigmented mucous membranes appearing at severe levels of hypoxemia.

All children with central cyanosis should be started on oxygen therapy as this is a highly specific sign, but not sensitive, as less than 50% of children with hypoxemia develop this sign. Blue/purple discoloration of the extremities (peripheral cyanosis) is mainly due to restricted blood flow due to intense vasoconstriction because of hypothermia, exposure to low environmental temperature or circulatory shock and may occur without hypoxemia.

Other signs, that could be indicative of hypoxemia, include:

- Inability to drink;
- Fast breathing;
- Coma, severe lethargy, prolonged convulsions;
- Severe lower chest in-drawing;
- Head nodding, grunting or nasal flaring; and/or
- Crepitation or crackles.

Most of these signs are not specific and can also be due to other causes.

2.3.1.3 Clinical Signs in Adults

Acute breathlessness is a common indicator of hypoxemia in adults that warrants attention. Other signs that can be found in adults with hypoxemia include:

- Dyspnea or difficult breathing on minimal exertion,
- Inability to talk in sentences,
- Fast respiratory rate,
- Prominent use of accessory muscles to breathe,
- Central cyanosis,
- Chest crackles,
- Tachycardia,
- Restlessness, and/or
- Drowsiness or confusion.

2.4 Pulse Oximetry

What is a pulse oximeter and how is it used?

- A pulse oximeter is a device that measures accurately and non-invasively the oxygen saturation in the blood.
- A pulse oximeter transmits a light beam through tissue such as a finger, a toe, or in small children the whole hand or foot.
- A pulse oximeter is used to measure the percentage of oxygenated hemoglobin in arterial blood (SpO2). The saturation is measured in the small arteries, and is therefore referred to as the arterial oxygen saturation (SaO2).

- Pulse oximetry is the standard method for assessing patients for hypoxemia, and particularly in children.
- Pulse oximetry can correctly identify 20-30% more children with hypoxemia than relying solely on clinical signs.)
- Pulse oximetry can be used to monitor hypoxemia and make more efficient use of oxygen supplies and improve patient monitoring.
- Pulse oximetry is also cost-effective.

The normal oxygen saturation at sea level in children and in adults is 95–100 but it can drop as oxygen uptake in the lung is impeded. Therefore:

- Oxygen is usually given with a saturation <90% measured at room air and the response to oxygen therapy can be measured with the **pulse oximeter** as well, as the SaO2 should increase if the patient has lung disease but with cyanotic heart disease, SaO2 may not change when oxygen is given.
  The oxygen flow can be titrated in response to the **pulse oximeter** readings to obtain a stable SaO2 >90% without wasting too much oxygen.

Various pulse oximeters are available in the market:

- Bench-top (AC-powered),
- Fingertip pulse oximeters, or
- Hand-held pulse oximeters can be used, depending on the financial, electrical and staff resources available.

Hand-held oximeters are cheaper than their larger counterparts, but many hand-held oximeters have batteries that require replacement, which could be very easily lost, stolen or unavailable. A pulse oximeter consists of:

- A computerized unit, and
- A sensor probe, which is attached to the patient's finger, toe or earlobe. You should ensure that you are using the appropriate probe for the device.

The oximeter displays:

- The SpO2 with an audible signal for each pulse beat;
- A pulse rate; and
- In many models, a graphical display of the blood flow past the probe (pulse wave).

2.4.1 Clinical Use of Pulse Oximetry

Even the best combinations of clinical signs commonly lead to misdiagnosis of hypoxemia in some patients with normal oxygen saturation, or fail to detect some hypoxemic patients. When used correctly, pulse oximetry allows reliable monitoring with little or no distress to the patient and is an accepted standard for detecting hypoxemia.

Pulse oximetry should therefore be performed:

- on all patients admitted to an inpatient ward with respiratory illness,
- on cases with emergency signs or any sign of hypoxemia.

Oximetry should be done during triage for all patients with clinical signs of hypoxemia, *including* adults, children and neonates with any emergency sign, who should be screened by pulse oximetry to ensure identification of patients most likely to be hypoxemic.

2.4.1.1 Screening for Hypoxemia

Pulse oximetry may be done for:

- Selected patients during triage (in outpatient or emergency departments), and
- All patients who are admitted to the inpatient ward with respiratory illness.

One way to select patients at the time of triage is to screen them by pulse oximetry, particularly those patients with any Emergency or Priority signs (Annexed 4). This will identify patients for whom hypoxemia is most likely.

Pulse oximetry should also be standard practice in developing countries to ensure patient safety during and following anesthesia as perioperative monitoring of patients to improve the detection and management of hypoxemia.

2.4.1.2 Pulse Oximetry in Neonatal Care

Prolonged severe hypoxemia, especially if combined with low cardiac output, can acutely lead to:

- Hypoxic brain injury,
- Renal failure,
- Pulmonary hypertension, and
- Predispose to necrotizing enterocolitis and long-term cognitive and intellectual impairment.

On the other hand, hyperoxia in premature neonates causes

- Retinopathy of prematurity, and
- Increases the risk of bronchopulmonary dysplasia and brain injury.

The implementation of a package of measures, including intermittent monitoring with pulse oximetry, and apnea monitoring, to improve the quality of neonatal care in a health facility can significantly reduce neonatal mortality from very low birth weight, pneumonia and sepsis.

2.4.1.3 Monitoring the Progress of Inpatients

Monitoring can be done in several ways. In most resource limited hospitals, the most appropriate form of monitoring will be one off (“spot”) checks on patients who are:

- likely to need oxygen,
- are already on oxygen, have developed respiratory distress, or
- those who show other clinical signs of deterioration.

Pulse oximetry should also be used to determine how long patients require to be treated with oxygen. At least twice a day, patients who are receiving oxygen should be monitored clinically and with pulse oximetry. Also, a trial off supplemental oxygen for patients in a stable condition should be done once a day to determine if they still require oxygen.

Pulse oximeters provide no information on carbon dioxide concentration in blood and thus no direct information on ventilation sufficiency. Therefore, for patients receiving oxygen

- clinical observation of respiratory effort,
- respiratory rate, and
- level of consciousness can indicate CO_2 retention.

These are a better guide to the adequacy of ventilation.

2.4.2. Features of a Pulse Oximeter

2.4.2.1 Alarm

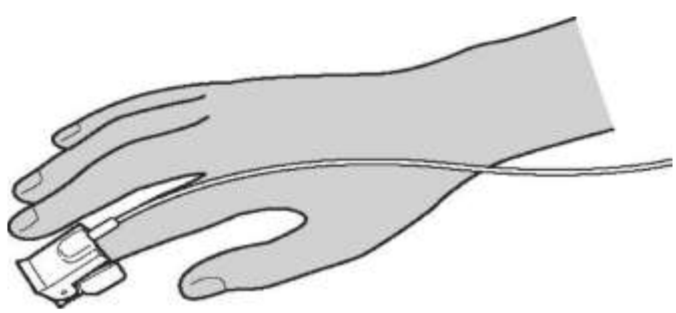
Alarm triggering events:

- Low saturation (hypoxia) i.e. SpO2 drops below 90%,
- No pulse detected, and/or
- Low or high pulse rate.

2.4.2.2 Sensors

A wide range of probes is available in different sizes. It is important to choose a sensor probe that is appropriate to the size of the patient and is intended for use with the model of pulse oximeter being deployed. Some are disposable; they can be reused for several patients, but they are difficult to clean, and the adhesive wears off after a few uses. There are several types of longer-life digital probes, which are more expensive but durable. For adults, there are hard plastic finger clips (**Figure 2**); these will not attach well to infants or children. There are also other types of sensors like soft rubber sensor, medical adhesive, etc.

Figure 2: Finger Clips



Learning point: In order to get a satisfactory reading the probe must be emitting a red light and must be correctly positioned to detect pulsatile blood flow.

Display

The pulse oximeter displays:

- the SpO2 together with an audible signal for each pulse beat,
- a pulse rate, and
- in most models a graphical display of the blood flow past the probe (pulse wave).

Examples of pulse oximeter displays showing normal and abnormal readings are given below (see Figures 3, 4 and 5).

Figure 3 shows a pulse oximeter with a normal reading in a child (pulse rate = 102 beats/min; SpO2 = 97%) and a pulse wave indicating a good arterial trace and a valid reading.

Figure 3: Pulse Oximeter Showing a Normal Reading

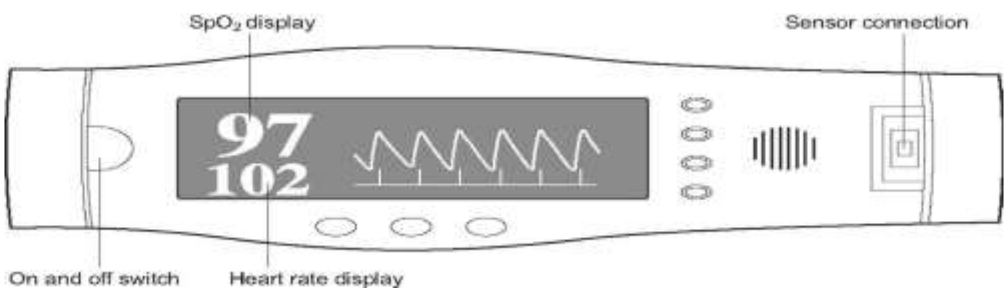
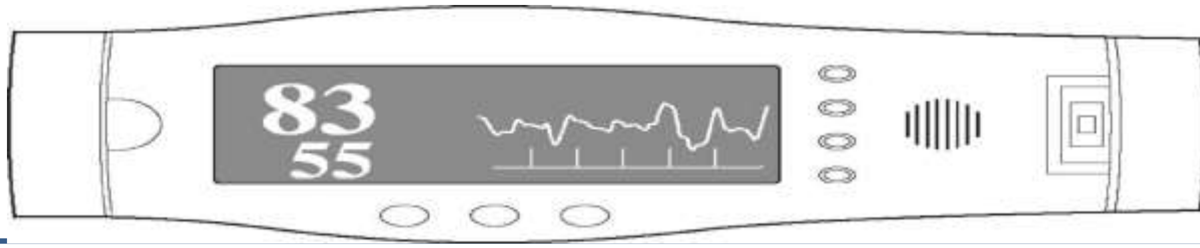


Figure 4 shows an abnormal reading (pulse rate = 55 beats/min; SpO2 = 83%). In this case, the pulse wave is uneven, indicating a poor arterial trace. The accuracy of the heart rate reading should be checked by comparing the number on the pulse oximeter display with auscultation of the heart and counting the true beats.

A poor pulse wave form on the pulse oximeter, as in this case, is usually due to

- inadequate attachment of the sensor probe to the skin, especially on an active patient, or
- due to poor peripheral perfusion. This SpO2 reading is not valid, and the probe should be repositioned.

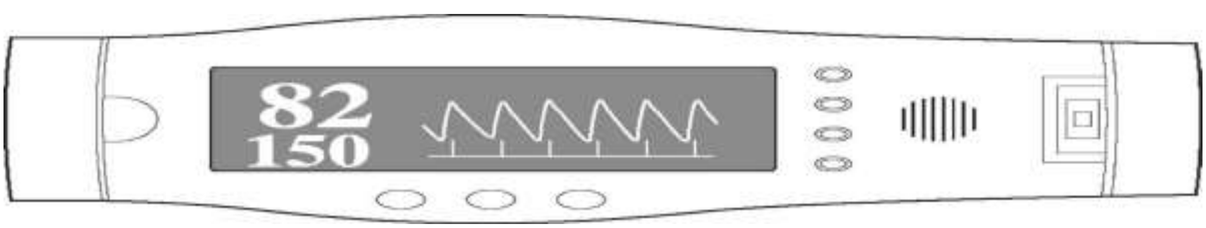
Figure 4: Pulse Oximeter Showing a Poor Pulse Wave



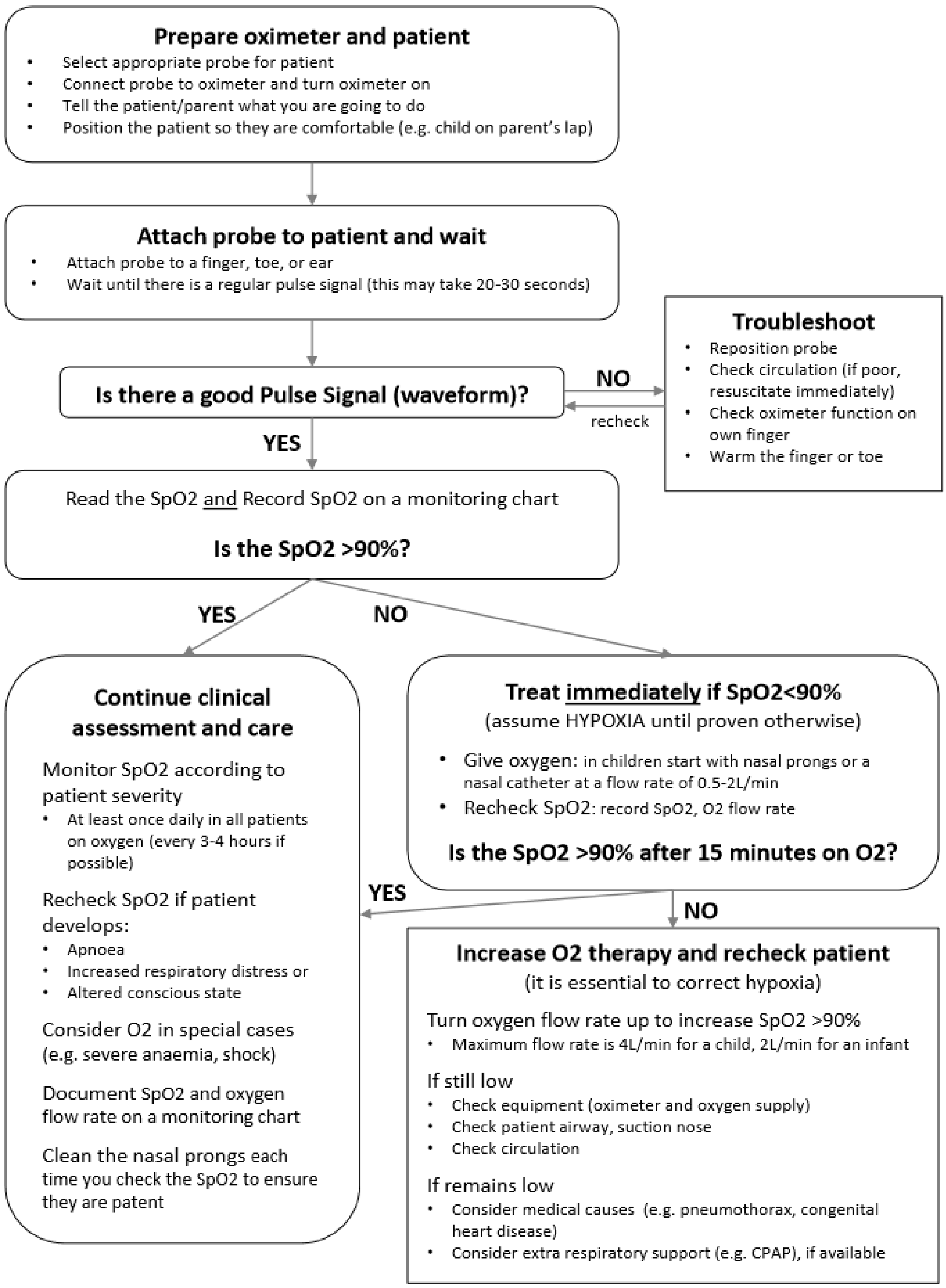
In **Figure 5** (Pulse rate = 150 beats/min; SpO2 = 82%), the pulse oximeter has a good pulse wave, indicating a valid arterial trace. Therefore, the SpO2 reading, which is

- abnormally low (82%).
- is accurate and indicates that the patient is hypoxemic.
- Oxygen should be given. Note the increased heart rate, which is common in seriously ill patients.

Figure 5: Pulse Oximeter Showing a Good Pulse Wave and Low Oxygen Saturation



USING AN OXIMETER



What Factors Can Interfere With Pulse Oximetry Reading?

Several factors can interfere with function of a pulse oximeter including:

- **Bright light**: shield the probe from direct light (operating theater light or sun light).
- **Shivering**: movement may make it difficult for the probe to pick up a signal.
- **Pulse volume**: the oximeter only detects pulsatile flow. When the blood pressure is low due to hypovolemic shock or the cardiac output is low or the patient has an arrhythmia the pulse may be weak and the pulse oximeter may not be able to detect a signal.
- **Vasoconstriction**: reduced blood flow to the periphery. The oximeter may fail to detect a signal if the patient is very cold and peripherally vasoconstricted.
- **Carbon-monoxide poisoning:** may give a falsely high saturation reading. Carbon-monoxide binds very well to hemoglobin and displaces oxygen to form a bright read compound called carboxy-hemoglobin. This is only an issue in patients following smoke inhalation from a fire.
- **Nail Polish:** Remove any nail polish/varnish as it may interfere readings of pulse oximeters.

2.5.3 Blood Gas Analysis

Blood gas analysis is another very accurate method for detecting hypoxemia. It is used to measure:

- The partial pressure of oxygen (PaO2),
- Carbon dioxide in arterial (or venous or capillary) blood,
- Blood pH, and
- The concentrations of the main electrolytes which is often abnormal in seriously ill patients.

Metabolic acidosis (low blood pH) is commonly seen when there is major disturbance of the circulation, as in severe dehydration, severe sepsis and severe malaria. Thus, blood gas analysis provides information on oxygenation, ventilation and circulation. Electrolyte concentrations (particularly sodium and potassium) are also measured using the same blood sample and analyzer. The method has several drawbacks:

- Blood gas analyzers are very expensive, and the chemical reagents represent a high recurrent cost, which may be unaffordable for hospitals with limited resources.
- Inaccurate measurements can easily result from factors such as a poorly taken sample (especially from a struggling or uncooperative child), delay in transfer of the sample to a laboratory, inadequate storage conditions before analysis and inadequate maintenance or quality control in the laboratory.

- Blood gas monitoring involves taking arterial blood, and is invasive, painful and distressing to patients, especially to children and infants.
- In addition, blood gas analysis provides information at only a single point in time.

Figure 6: Blood Gas Analysis vs. Pulse Oximetry

FACTOR TO BE CONSIDERED	PULSE OXIMETRY	ARTERIAL BLOOD GAS
Pain and distress to patient	Minor discomfort from being held.	Major discomfort from blood sampling
Risk to staff	Nil	Potential for needle stick injury
Suitability for monitoring	Continuous or regular spot checks.	Information for only a single time
Cost	Low to moderately expensive, plus moderate recurrent costs (sensor probes).	Very expensive plus high recurrent costs for reagents and maintenance
Skill required	Use and interpretation can be taught to nurses and non-specialist health workers.	High level of laboratory expertise and skill in clinical interpretation
Indication of ventilation adequacy	Useful information on ventilation only for patients breathing room air; gives no indication of ventilation for patients on supplemental oxygen.	Yes
Indication of acid-base state or electrolytes	No	Yes
Major sources of error	• Poor skin perfusion • Movement artifact • Greater margin of machine error at lower SpO2	• Uncooperative child • Clotted specimen • Air in syringe • Laboratory handling

KEY MESSAGES

- Hypoxemia is a low level of oxygen in the blood.
- The clinical manifestation of hypoxemia may not be specific but may include, respiratory distress, cyanosis, apnea, lethargy or convulsion.
- Pulse oximetry is more accurate in detecting hypoxemia in critically sick patients.
- It's essential to develop skills on hypoxemia detection (clinical signs and application of pulse oximetry).

Chapter Three: Oxygen Therapy in Neonates and Children

Learning Objectives

By the end of this chapter, participants will be able to:

- Identify neonates and children who need oxygen therapy;
- Explain different oxygen delivery techniques;
- Improve skills in starting, monitoring, and stopping oxygen therapy;
- Develop skills in using bubble CPAP;
- Recognize the need for humidification; and
- Recognize manifestations of oxygen toxicity.

Content outline
• neonates and children who need oxygen therapy; • oxygen delivery techniques; • skills in starting, monitoring, and stopping oxygen therapy; • skills in using bubble CPAP; • the need for humidification; and • Recognize manifestations of oxygen toxicity

Key Questions for Self-Review

1. What are the common causes of hypoxemia in neonates and children?
2. When do you give oxygen for neonates? What is the adverse effect of oxygen therapy in premature neonates?
3. What are the three methods where hypoxemia can be diagnosed?
4. What are the key clinical signs of hypoxemia in neonates and children that you commonly use to diagnose it?
5. Mention different oxygen delivery techniques that you use to administer oxygen in different clinical conditions.
6. What are the conditions that you need to humidify oxygen during administration?
7. When do you stop oxygen therapy while monitoring with pulse oximetry?
8. If you have ever used pulse oximetry in clinical care, what are the factors that affect the reading of pulse oximetry?

3.1 Indications for Oxygen Therapy in Neonates and Children

3.1.1 Indications for Oxygen Therapy in Neonates

Oxygen therapy in newborn infants, particularly when they are born preterm, should reflect the fact that in the first hours of life they have lower normal oxygen saturation than older newborns. **See the Table below.** Pulse oximetry should be used to monitor SpO_2, which should be maintained ≥ 88%, but in pre -term babies no higher than 95% to prevent eye damage.

Table 1: Normal Oxygen Saturation in Newborns

Age	Normal oxygen saturation
1min	60 to 65
2min	65 to 70
3 min	70 to 75
4 min	75 to 80
5min	80 to 85
10min	85 to 95

A number of conditions that may lead to hypoxemia occur more frequently in neonates, notably

- Birth asphyxia,
- Respiratory distress syndrome,
- Transient tachypnea of the neonate, and
- Pneumonia is also common.

Neonates who are very unwell for reasons such as prematurity, sepsis, seizures or hypoglycemia are also prone to apnea. Apnea and hypoventilation also occur in otherwise well infants of very low birth weight (< 1.5 kg or gestational age < 32 weeks) because of immature respiratory drive (apnea of prematurity). Apnea can lead to hypoxemia and slowing of the heart rate (bradycardia), further reducing oxygen delivery to tissues.

Recommended indication for oxygen in newborns also include;

- Bradycardia,
- Cyanosis,
- Floppy infant,
- Increased respiratory effort, and
- On post resuscitation care.

3.1.2 Indications for Oxygen Therapy in Children

Indications for oxygen therapy in children include:

- All children SpO2 <90% as measured by pulse oximetry.
- Children with emergency signs (obstructed or absent breathing, severe respiratory distress, central cyanosis, signs of shock, coma (or seriously reduced level of consciousness), seizures or severe dehydration) and SpO2<94%.
- Children with very severe anemia, severe heart failure and SpO2<94%.

Where there is no pulse oximetry, clinical signs may be used to guide use of oxygen. Children with any of the following signs are likely to have hypoxemia:

- Central cyanosis;
- Nasal flaring;
- Inability to drink or feed (when this is due to respiratory distress);
- Grunting with every breath; and
- Depressed mental state (i.e. drowsy, lethargic).

In some situations, and depending on their overall clinical condition, children with the following less specific respiratory signs may also have hypoxemia:

- Severe lower chest wall in-drawing;
- Respiratory rate of $\geq$ 70/min; and/or
- Head nodding (i.e. a nodding movement of the head, synchronous with the respiration and indicating severe respiratory distress).

When the oxygen supply is very limited, give oxygen to children aged > 2 months according to the order of priority suggested in the below table. Infants aged < 2 months with signs of severe respiratory distress (tachypnea, severe chest in-drawing, head nodding or grunting) should always be given oxygen, because hypoxemia increases their risks for apnea and death.

Other clinical conditions, such as:

- prolonged convulsions,
- acute coma, and/or
- acute neurological problems, may also be associated with hypoxemia due to an obstructed airway or impaired ventilatory effort.

Table 2: Clinical Indications for Oxygen Therapy

CLINICAL PRESENTATION OF SEVERE PNEUMONIA WITH	PRIORITY FOR OXYGEN
Central cyanosis	Very high
Decreased consciousness, unresponsiveness or responsive to painful stimuli only	Very high
Grunting with every breath	Very high
Nasal flaring	Very high
Severe palmar or conjunctival pallor (severe anemia) with severe lower chest wall in-drawing or fast breathing	Very high; high priority should also be given to correcting the underlying abnormality (i.e. blood transfusion and/or antimalarial agents).
Acute coma or convulsions lasting > 15 min	Very high until respiratory effort has returned to normal; also, protect airway and ensure adequate ventilation.
Inability to drink or feed	High
Severe chest in-drawing	Priority
Respiratory rate ≥ 70/min	Priority
Head nodding	Priority

KEY MESSAGES

- Children with hypoxemia should receive appropriate oxygen therapy.
- Administration of oxygen therapy should be guided by pulse oximetry, when available.
- Where there is no pulse oximetry, clinical signs may be used to guide use of oxygen.
- Children with respiratory disease living at ≤ 2500 m above sea level should receive oxygen therapy if their oxygen saturation is ≤ 90%, as measured by pulse oximetry.
- Children with emergency signs (obstructed or absent breathing, severe respiratory distress, central cyanosis, signs of shock, coma or convulsions) should receive oxygen therapy during the resuscitation phase if their SpO2 is < 94%.

Note: It is strongly recommended that children with oxygen saturation < 90% be given oxygen therapy. In areas at high altitudes and with limited resource, oxygen may be given at a lower SpO_2, by consensus.

3.2 Methods of Oxygen Delivery

The methods used to deliver oxygen should be safe, simple, effective, and inexpensive. The methods are non-invasive (through a face mask, head box, incubator or tent or holding tubing close to an infant's face) or semi-invasive (insertion of prongs or catheters into the upper airway). Semi-invasive delivery methods require a low oxygen flow and are cheaper than non-invasive methods, which require high oxygen flow. Nasal catheters have a beneficial effect on lung function.

Recommendations for oxygen delivery methods:

- Nasal prongs are the preferred method of delivering oxygen to infants and children <5 years of age with hypoxemia who require oxygen therapy.
- Where nasal prongs are not available, nasal or nasopharyngeal catheters can be used as alternative delivery methods.
- A face mask can also be used as an alternative method in emergency setting when high-flow (5-10L/min) oxygen is needed if target saturation is not achieved by above methods.
- Standard flow rates for oxygen through nasal prongs or nasal catheters are 0.5–1 L/min for neonates, 1–2 L/min for infants, 1–4 L/min for older children.

3.2.1 Recommended Methods of Oxygen Delivery for Neonates, Infants, and Children

The recommended methods for neonates, infants, and children are nasal prongs, nasal catheters, and nasopharyngeal catheters. The most common problem with all delivery devices is obstruction from airway secretions. Therefore, nurses should regularly check the delivery devices and clean or change them as necessary.

Table 3: Comparison of Different Methods for Oxygen Delivery

Method	Oxygen concentration achievable with 1 l/min in a 5 kg child	Danger of CO_2 accumulation	Equipment required
Nasopharyngeal catheter	45-60%	No	Nasogastric tubes, humidifier
Nasal catheter	35-40%	No	Nasogastric tubes
Nasal prongs	30-35%, up to 60%in neonates	No	Nasal prongs
Oropharyngeal catheter	45-60%	No	Nasogastric tube and humidifier
Simple Face mask	29%	Yes	Face mask
Head box	Variable	Yes	Head box

Table 4: Summary of Relative Safety, Tolerability and Complications Associated with Low Flow Oxygen Delivery Methods

	Nasopharyngeal catheter	Nasal catheter	Nasal prongs
Efficiency	+ + +	+ +	+
Tolerability by patient	+ +	+ +	+ +
Nursing demand	+ + +	+ +	+
Mucous production and risk of airways obstruction by mucus	+ + +	+ + +	+
Safety	+	+ +	+ + +
Reported major complications	Perforation of airways; Gastric distension	Nasal bleeding	Tube breakage

Giving Oxygen

Oxygen is usually given through a nasal catheter or nasal prongs.

Nasal prongs

- Appropriate sized nasal prongs should be placed just inside the nostrils and secured in place with tape, as shown in **Figure 7.**
- Check the patency and damage before using the prongs. Set a flow rate of 0.5–1 L/min for neonates, 1–2 L/min for infants and older children and up to a maximum of 4 L/min for older children.
- There is no risk of gastric distension at standard flow rates, as they cannot be inserted too far into the nasal passage.
- Humidification is not required with nasal prongs as long as these flow rates are used.

Oxygen prongs are more expensive than oxygen catheters, but they can be reused if they are carefully soaked in clean, warm soapy water, followed by dilute bleach, rinsing in water and careful drying.

The prongs should be checked at least every 3 hours, when there is a drop in saturation or worsening of respiratory distress.

Figure 7: Nasal Prongs, Correctly Positioned and Secured

Practical Considerations

The distal prong should fit well into the nostril (premature infants: 1 mm, infants weighing up to 10 kg: 2 mm). The prongs should be secured with a piece of tape on the cheeks near the nose, as shown in Fig. 7. Care should be taken to keep the nostrils clear of mucus to avoid blockage. The maximum flow rate without humidification is 1 L/min in neonates, 2 L/min in infants, 4 L/min in older children. Higher flow rates without effective humidification may cause drying of nasal mucosa, with associated bleeding and airway obstruction.

Nasal catheter

- A 6-F or 8-F catheter is passed for a distance equal to the distance from the side of the nostril to the inner margin of the eyebrow (see **Figure 8**). This usually reaches the back of the nasal cavity.
- Set a flow rate of 0.5 L/min for neonates or 1–2 L/min for infants and older children.
- Humidification is not required with a nasal catheter if these low flow rates are used. If an oxygen catheter is not available, a nasogastric tube with the end cut off is sufficient (and cheaper).

Catheters should be removed and cleaned at least twice a day, when there is a drop in saturation or worsening of respiratory distress as they can become blocked with mucus in between.

Figure 8: Nasal Catheter in Place

Practical Considerations

In neonates and infants, 8-French (F) size catheters should be used. A catheter passed for a distance equal to the distance from the side of the nostril to the inner margin of the eyebrow usually reaches the posterior part of the nasal cavity. In infants, this is about 2.5 cm. The tip of the catheter should not be visible below the uvula. A catheter is easily secured with tape above the upper lip. The maximum flow rate should be set at 0.5–1 L/min for neonates and 1–2 L/min for infants and older children. A nasogastric tube should be in place at the same time, in the same nostril so as not to obstruct both nostrils. Higher flow rates without effective humidification may cause drying of the nasal mucosa, with associated bleeding and airway obstruction, as well as coughing.

Exercise 3.1

Case Scenario 1

Alemitu brought her child to the emergency after she developed fast breathing and grunting of one day duration. On examination, she is tachypneic with chest in-drawing. Her oxygen saturation is 89%.

A. Does she need oxygen?

B. What if this she had central cyanosis and oxygen saturation is 92%?

C. What if this child had grunting but you don't have pulse oximetry to measure the saturation?

D. How would you administer oxygen? Demonstrate the different technique of administration.

3.3 Causes of Lack of Response to Oxygen Therapy

Once oxygen therapy has been initiated, the child must be checked within 15– 30 min to observe whether the treatment is working. In severely hypoxemic children, correction of oxygen may not be complete and clinical signs may remain, or the SpO_2 may still be low; this does not mean that oxygen therapy has failed, and it should not be abandoned. Other children will deteriorate rapidly or slowly despite receiving oxygen. There are a number of possible causes for lack of response:

1. Oxygen delivery is inadequate. Check that:
   - Oxygen is flowing (put the end of the tube under water in a beaker and watch for bubbles, or hold the end close to your hand to feel the air flow);
   - The oxygen tubing is not leaking;
   - The nasal prongs or nasal catheter are fitted correctly and not blocked; and

2. Look for other possible causes such as:
   - Pleural effusion: listen with a stethoscope for breathing sounds on both sides of the chest; do a chest X-ray;
   - Pneumothorax: listen with a stethoscope for breathing sounds on both sides of the chest; do a chest X-ray;
   - Upper airway obstruction (e.g. from croup or a foreign body): listen for stridor;
   - Bronchospasm (e.g. severe asthma): listen with a stethoscope for wheeze;
   - Cyanotic heart disease or congestive heart failure;
   - Ventilatory failure: the child's respiratory effort is inadequate, or the child has slow or shallow breathing and is lethargic.

3. If nasal prongs and catheters are used at maximum flow (4L/min) and the child is still hypoxemic:
   - Use face mask as an alternative method which requires higher flow rate (> 4 L/min) to reach a peripheral capillary oxygen saturation ≥ 94% or
   - Begin CPAP if the equipment is available.
   - If the child is not breathing you need to support the breathing artificially by ventilating the child with bag valve mask ventilation.
   - Consider mechanical ventilation if your hospital has an intensive care unit.

Exercise 3.2

Case Scenario 2

Alemitu's child saturation improved to > 95% after administration of oxygen but after two hours her saturation dropped to 88% and became lethargic.

A. What will be your next step?
B. How will adjust the oxygen delivery?
C. How frequently should we assess the patient?

3.4 Continuous Positive Airway Pressure (CPAP)

Continuous positive airway pressure (CPAP) consists of delivery of mild air pressure to keep the airways open. CPAP delivers PEEP[3] with a variable amount of oxygen to the airway of a spontaneously breathing patient to maintain lung volume during expiration. CPAP decreases

- Atelectasis (alveolar and lung segmental collapse) and respiratory fatigue,
- Improves oxygenation, and
- It is indicated for infants with severe respiratory distress, hypoxemia or apnea despite receiving oxygen.

CPAP requires a source of continuous airflow (often an air compressor) and usually requires an oxygen blender connected to an oxygen source. A CPAP system is available in some hospitals but should be used only:

- When it is reliable,
- When oxygen systems are in place,
- Where staff members are adequately trained and when close monitoring is assured.

3.4.1. Bubble CPAP

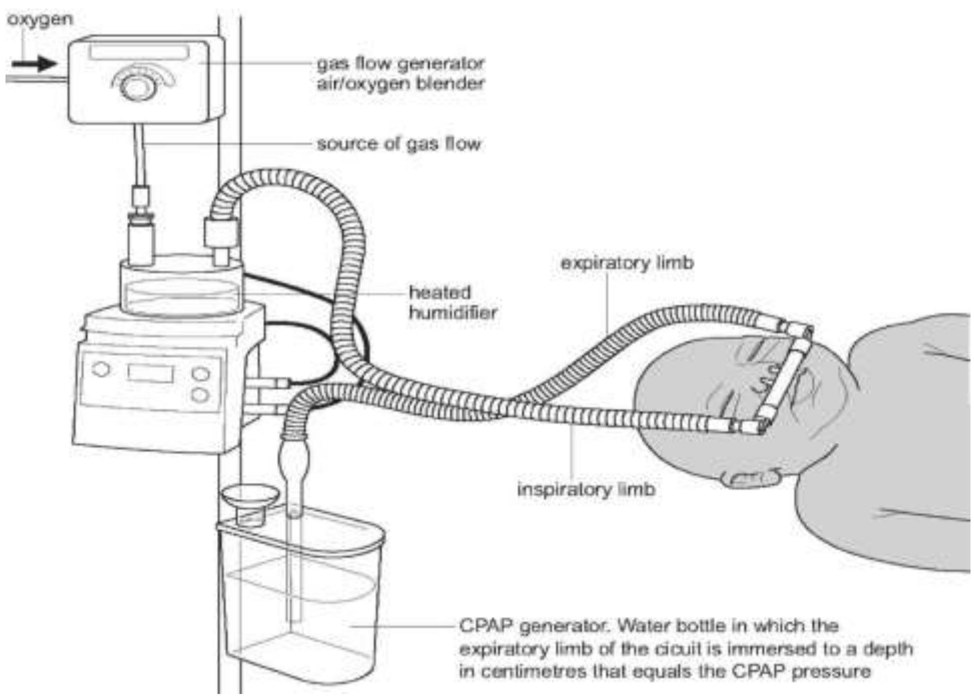
The bubble CPAP system has three components:

1. **Continuous gas flow into the circuit**: The gas flow rate required to generate CPAP is usually 5–10 L/min. This alone can generate CPAP, even without additional oxygen (FiO_2 = 0.21),[4] but many neonates require supplemental oxygen. Therefore, the system also usually requires an oxygen blender, which connects an oxygen source (cylinder or concentrator) to the continuous airflow to increase the FiO_2.
2. A **nasal interface connecting the infant's airway with the circuit** (**see Figure below**): short nasal prongs are generally used to deliver nasal CPAP. They must be carefully fitted to minimize leakage of air (otherwise, CPAP will not be achieved) and to reduce nasal trauma.
3. An **expiratory limb** with the distal end submerged in water to generate end-expiratory pressure: in bubble CPAP, the positive pressure is maintained by placing the far end of the expiratory tubing in water. The pressure is adjusted by altering the depth of the tube under the surface of the water.

[3] *Positive end-expiratory pressure (PEEP) is the pressure in the lungs (alveolar pressure) above atmospheric pressure (the pressure outside of the body) at the end of expiration.*

[4] *FiO_2 is the assumed fraction (or percentage) of oxygen concentration participating in gas exchange in the alveoli; natural air contains 20.9% oxygen, which is equivalent to FiO_2 of 0.21 or 21%. Patients given oxygen-enriched air breathe air with a higher-than-atmospheric FiO_2.*

Figure 9: A Bubble CPAP Circuit Connected to an Infant by close-fitting Nasal Prongs



An inexpensive form of bubble CPAP can be made with standard nasal prongs. The method is shown in **Figures 10 and 11**.

A gas (oxygen) flow rate of

- 5–10 L/min is required for older children with pneumonia,
- while 3–4 L/min may be sufficient to generate CPAP in small neonates.

In neonates born < 32 weeks' gestation, pure oxygen is not safe, as a high concentration can cause retinopathy of prematurity. Thus, another source of air flow, such as an air compressor or an oxygen blender, is required for premature infants. In older infants, who require a higher flow to generate CPAP, use of a 10-L/min oxygen concentrator is efficient.

Figure 10: An Inexpensive Bubble CPAP Setup with Modified Nasal Prongs

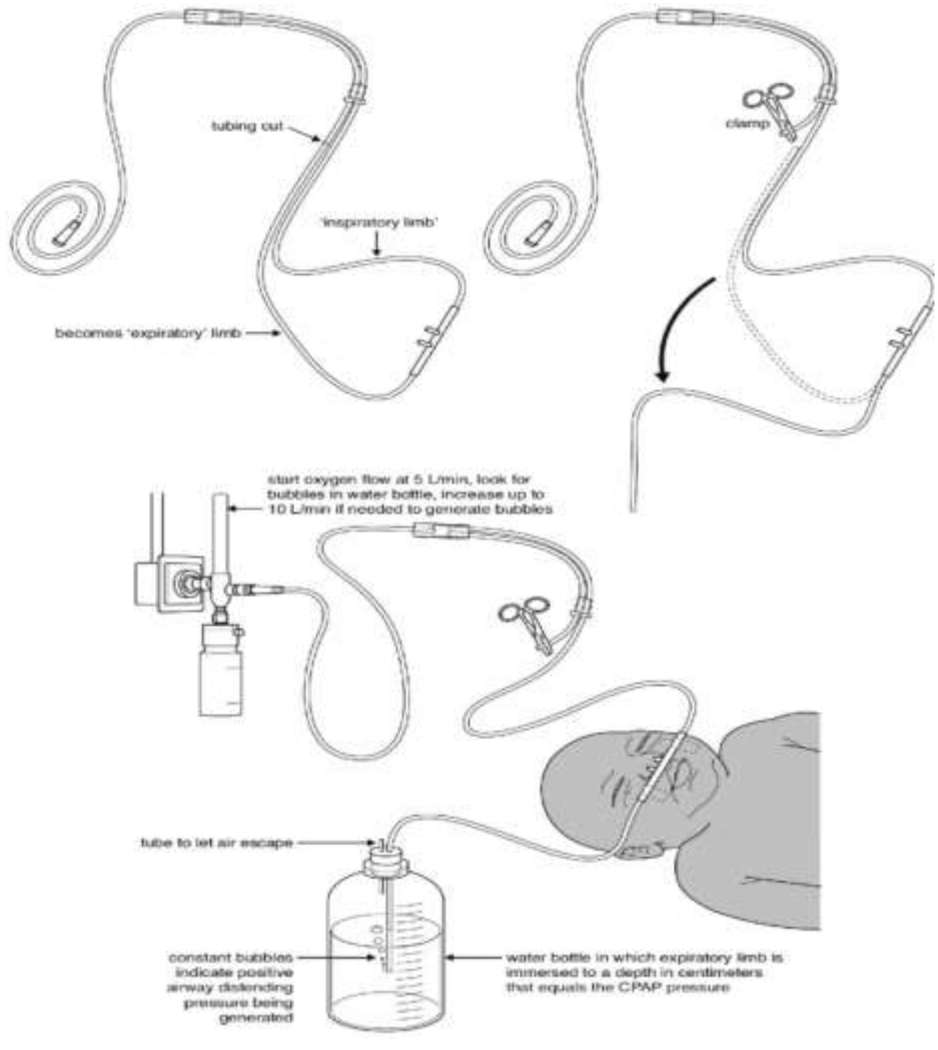
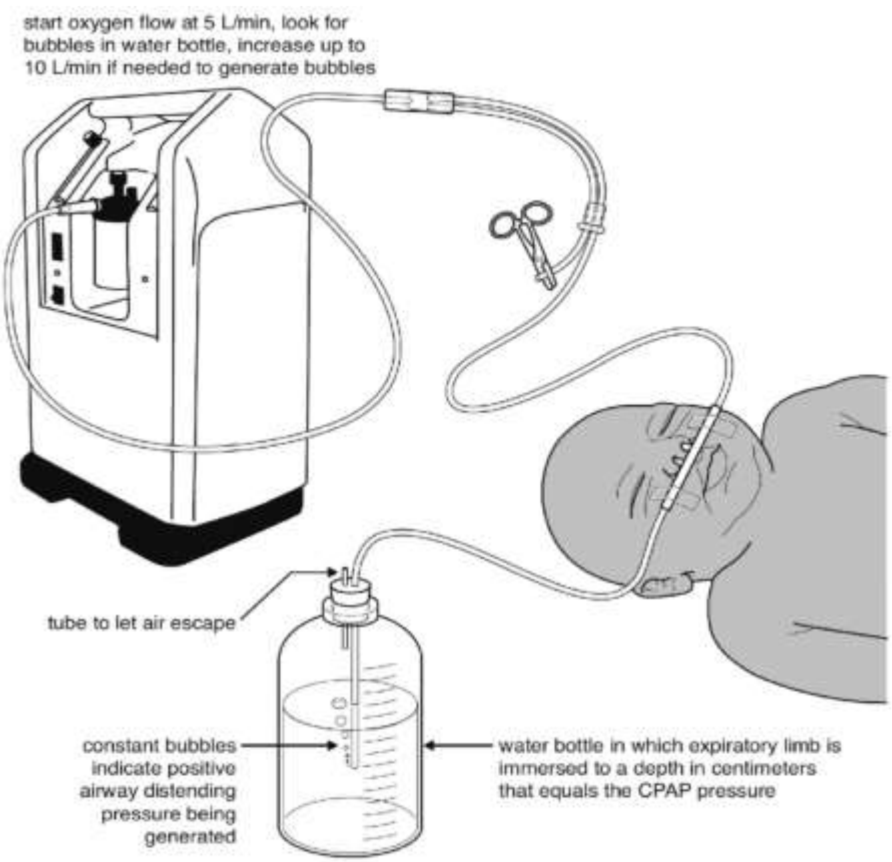


Figure 11: Bubble CPAP with Inexpensive Modified Nasal Prongs, can be run with an Oxygen Concentrator



3.5 Humidified High-flow through Nasal Prongs in Neonates and Infants

Experience with this simpler, less expensive method of delivering CPAP to neonates has been reported, with a high gas flow (up to 2 L/**kg** body weight per min) through normal nasal prongs. Higher flows through nasal prongs of an air–oxygen mix with humidification have been used for

- preterm neonates and infants with very severe pneumonia
- or bronchiolitis who are failing to respond to standard oxygen flow rates
- or when ventilation is inadequate.

High-flow CPAP may help to

- increase lung volume,
- reduce atelectasis (alveolar and lung segmental collapse), and
- stimulate breathing in infants with apnea.

Flow rates of up to 2 L/**kg** body weight per min through normal nasal prongs have been used as an alternative to CPAP with a mechanical ventilator or bubble CPAP circuit. This rate delivers 4–5 cm H_2 0 of PEEP. It requires special equipment – a source of gas flow, an oxygen blender and a humidifier.

High-flow CPAP

- Also requires an oxygen and air blender, so that the concentration of inspired oxygen can be controlled.
- It is often unnecessary and potentially dangerous to deliver a very high concentration of inspired oxygen to the lungs.
- With high-flow CPAP, there is also a risk for stomach distension and pneumothorax, which must be carefully monitored.

High-flow CPAP through nasal prongs is a promising low- cost method for providing additional respiratory support in hospitals that do not have mechanical ventilators or standard CPAP machines; however, there is limited experience with this method, and the risks described above must be taken into account and addressed.

The adequacy of ventilation must be monitored closely, as high-flow 100% oxygen can maintain SpO_2 in the normal range despite **dangerous hypercarbia** and near respiratory failure. CPAP requires humidification and careful monitoring.

KEY MESSAGES

- Any child with an SpO_2 < 90% should receive oxygen. This rule best applies to health facilities located between sea level and 2500 m above sea level and for altitudes higher than 2500 m where oxygen supplies are ample (such as in concentrators).
- Oxygen should always be given continuously and should not be administered for recurrent short periods (such as every hour or two).
- The child should be examined within 15–30 min of starting oxygen therapy to determine whether the treatment is working. In severely hypoxemic children, correction may not be complete and clinical signs may remain, or the SpO_2 may still be low. This does not mean that oxygen therapy has failed, and it should not be abandoned. Some children deteriorate rapidly or slowly despite receiving oxygen.

Exercise 3.3

Case scenario 3:

A newborn baby has fast and difficult breathing at 1 hour. His GA is 32 weeks and birth weight is 1800g, HR190, RR80, on the chest he has grunting, severe subcostal in-drawing, SpO2 85% then patient was started on oxygen at 2L/min, despite, this he had grunting and cyanosis and the oxygen saturation became 80%. How do you want to proceed?

Demonstrate the technique to assemble a bubble CPAP.

A. Equipment Required

B. The Procedure

3.6 Humidification

Some oxygen delivery methods require use of humidifiers for the patient's comfort. This section outlines when humidification is required and the types of humidifiers recommended.

3.6.1 Rationale

When oxygen is used at a low flow rate (< 4 L/min) through nasal prongs, humidification is not necessary. Humidification is needed when oxygen is given for all patients with an endotracheal tube or a tracheostomy.

Generally, because of the following reasons humidification is required:

1. Cold, dry air increases heat and fluid loss
2. Medical gases including air and oxygen have a drying effect and mucous membranes become dry resulting in airway damage.
3. Secretions can become thick & difficult to clear or cause airway obstruction
4. In some conditions e.g. asthma, the hyperventilation of dry gases can compound bronchoconstriction.

Recommendations on Humidification

STANDARD PRACTICES
When oxygen is delivered at a standard flow rate (0.5–1 L/min for a neonate, 1–2 L/min for an infant, 1–4 L/min for an older child) through a nasal catheter or nasal prongs, humidification is not necessary.
When oxygen is delivered at a higher-than-standard flow rate (> 4 L/min) through a nasal catheter or nasal prongs, humidification is necessary.

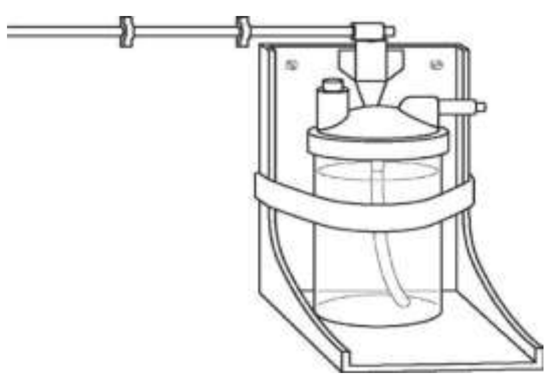
3.6.2 Unheated Bubble Humidifiers

An unheated bubble humidifier is a simple device that adds little to the cost of oxygen equipment. Unheated bubble humidifiers can be used when oxygen is delivered by cylinders through a nasal catheter, if a nasopharyngeal catheter is used to deliver oxygen or if a higher-than-standard flow is used.

Bubble humidifiers (see Fig. 12)

- Reduce the dryness of the oxygen supplied from a cylinder by bubbling the gas through water at room temperature.
- Is filled with clean water (distilled water or tap water that has been boiled and cooled), and then the humidifier is firmly attached to the oxygen outlet, taking care to avoid oxygen leaks and making sure that it is bubbling.
- The water level in it should be checked twice daily and topped up as necessary.
- It must be washed and disinfected regularly to prevent bacterial colonization.

Figure 12: An Unheated Bubble Humidifier Connected to a Wall Bracket



Maintenance of humidifiers is also important.

- The water should be changed daily;
- The humidifier, water jar and catheter should be washed in mild soapy water, rinsed with clean water and dried in air before reuse;
- Once a week (or whenever a patient ceases oxygen therapy), all the components of the humidifier should be soaked in a mild antiseptic solution for 15 min, rinsed with clean water and dried in air;
- Allow the humidifier to dry completely to discourage bacterial colonization; and
- A spare, clean humidifier filled with clean water should always be available, so that oxygen therapy is not interrupted while the humidifier is being cleaned.

Some bubble humidifiers have a high-pressure alarm in the lid, in the form of a whistle, that sounds if the tubing blocks or kinks between the humidifier and the patient. If the whistle sounds, inspect the tubing for blockage, and if there is no obvious block in the tubing, remove the oxygen delivery catheter and clean it

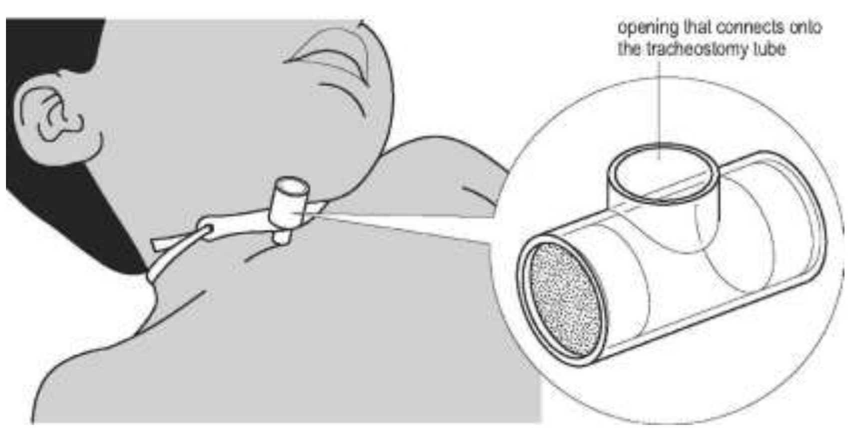
3.6.3 During Tracheostomy

Humidification is:

- Essential for patients with an endotracheal tube or a tracheostomy;
- The nose and mouth provide warmth, filtering and moisture for the air we breathe; however
- A tracheostomy tube (**Fig. 13**) bypasses these mechanisms, and humidification must be provided to keep secretions thin and to avoid mucous plugs.

Patients who have had a tracheostomy do best in an environment of ≥ 50% humidity. In patients who are not ventilated, secretions can be kept thin by applying a heat moisture exchanger (sometimes called a “Swedish nose”) to the tracheostomy tube (shown in **Fig. 13**). This humidifying filter fits onto the end of the tracheostomy tube; several shapes and sizes are available, but all styles fit over the standard tracheostomy tube opening.

Figure 13: Child with Tracheostomy Tube and Diagram of a Heat Moisture Exchanger connected to the Tracheostomy Tube



In patients with a tracheostomy or an endotracheal tube who are receiving supplemental oxygen or CPAP, heated humidifiers are preferred to unheated humidifiers.

> **KEY MESSAGES**
>
> - Humidification is necessary only when oxygen is delivered by methods that bypass the nose or high-flow rates are used. It is generally not necessary when oxygen is delivered through a nasal catheter or nasal prongs at standard flow rates.
> - Humidification is essential when cold oxygen is delivered from a cylinder through a nasopharyngeal catheter.
> - Humidifier reservoirs should be cleaned regularly to avoid bacterial contamination.
> - Humidification is essential for patients with an endotracheal tube or a tracheostomy. Endotracheal tube obstruction due to inadequate humidification is the cause of many unnecessary deaths in hospitals.

3.7 Monitoring the Progress of Children on Oxygen

3.7.1 Monitoring of the child on oxygen

The most appropriate way to monitor children is by regular pulse oximetry to determine whether they need oxygen and whether those who are already on oxygen have developed respiratory distress or show other clinical signs of deterioration.

Oxygen is a drug and has to be prescribed and the prescription has to indicate:

- The flow rate,
- Delivery system,
- Monitoring,
- What and how frequent to monitor,
- When to report,
- When to change the device and
- When and how to stop oxygen administration.

In severe pneumonia, hypoxemia can last from several hours to several weeks; the usual duration is 2–5 days.

- Hypoxemia may last longer at higher altitudes than at sea level for pneumonia of similar severity.
- For children in a stable condition and with $SpO_2 > 90\%$, oxygen should be interrupted once a day to determine whether they still require it.

As pulse oximeters provide no information on the carbon dioxide concentration in blood, they provide no direct information on ventilatory efficiency. It is unlikely that a child who has normal oxygen saturation while breathing room air has impaired ventilation; however, once oxygen is administered, SpO_2 can be maintained at normal levels despite severe hypercapnea.
As pulse oximetry cannot indicate the adequacy of ventilation in children receiving oxygen,

- Clinical monitoring of respiratory effort,
- Respiratory rate, and
- Consciousness level is a guide to the adequacy of ventilation. A child with inadequate ventilation will have slow or shallow breathing and be lethargic.

Any concern about the adequacy of ventilation should prompt efforts to ensure that the airway is

- Clear and protected;
- That the patient is positioned to facilitate chest expansion (e.g. sitting in a semi-recumbent position at 20–30°, head up to reduce diaphragmatic splinting if there is abdominal distension, passing a nasogastric tube to deflate the stomach); and
- Referral to intensive care unit (ICU) should be arranged if CPAP or mechanical support is available.

The main complications associated with oxygen delivery methods are hypercapnea (from head boxes and facemasks when inadequate flow is used), dislodgement (nasal prongs) and catheter or upper airway obstruction or nasal bleeding.

Oxygen administration by any method must be supervised by trained personnel to detect and manage complication appropriately

3.7.2 Monitoring of the Equipment

A trained personnel should check every 3 h that:

- ✓ The prongs or catheter are in the correct position and not blocked with mucus.
- ✓ All connections are secure, that the oxygen flow rate is correct.
- ✓ The airways are not obstructed by mucus.
- ✓ There is no gastric distension.

Prongs or catheters should be removed and cleaned at least twice a day. All severely ill children must be monitored regularly for vital signs and general condition. Many deaths in hospitals occur overnight, often when monitoring is infrequent or absent. As SpO_2 is the most vital clinical sign, pulse oximetry is an invaluable routine monitoring tool.

Monitoring of the Patient
SpO2
Vital signs
Air way obstruction
Ventilation
Sign of respiratory distress
Mental status
Gastric distension

Monitoring of Equipment and Oxygen Delivery
The prongs or catheter are in the correct position
The airway devises are not obstructed by mucus
All connections are secure (air leakage)
The oxygen flow rate is correct
Level of water in humidifier

3.7.3 When to Stop Oxygen

At least once each day, children who are clinically stable (have no emergency signs and $SpO_2 > 90\%$)

- should be disconnected from oxygen for 10–15 min,
- carefully examined for changes in clinical signs and SpO_2,
- assess whether supplemental oxygen is still required.

Supplemental oxygen is best interrupted first thing in the morning, when there are likely to be adequate staff to observe the child throughout the day. If supplemental oxygen is discontinued in the late afternoon, the presence of few overnight staff and the oxygen desaturation that sometimes occurs during sleep might increase the risk for unrecognized hypoxemia during the night.

The child who is ready for trial off of oxygen, and is surrounded by adequate staff to monitor, may be disconnected from the oxygen source and observed carefully to avoid any adverse complications of hypoxemia.

- If severe hypoxemia ($SpO_2 < 80\%$), apnoea or severe respiratory distress occurs, the child should be immediately restarted on oxygen.
- Some children will become hypoxemic very rapidly when they are taken off oxygen; this is a marker of very severe disease and a high risk for death.
- Parents and nursing staff should be advised to watch children to determine whether they develop cyanosis or severe respiratory distress.

Where oxygen supplies are ample,

- Children should receive supplemental oxygen until their SpO_2 on room air is $\geq 90\%$.

- If the SpO_2 is ≥ 90% after a trial on room air, they should remain off oxygen, and the SpO_2 should be rechecked after 1 h, as late desaturation can sometimes occur.
- If bed space allows, children should not be discharged until their SpO_2 has been stable at ≥ 90% while breathing room air for at least 24 h, until all danger signs have resolved and appropriate home treatment can be organized. This of course does not apply to children with cyanotic congenital heart disease who have chronic hypoxemia.

Children who have:

- An SpO_2 < 90% while still on oxygen, or
- Who are unstable or very unwell should not be given trials on room air. Before a trial of discontinuing oxygen, the SpO_2 should be checked to determine whether such a trial is safe (i.e. SpO_2 > 90%).

For all children who appear to deteriorate clinically,

- The SpO_2 should be checked to determine whether they need oxygen.
- For children with right-to-left intracardiac shunt (such as tetralogy of Fallot), oxygen will not be effective in relieving cyanosis or improving SpO_2.

The chest X-ray appearance is not a useful guide to the need for oxygen therapy or to when it is appropriate to stop oxygen.

3.8 Adverse Effects of Oxygen Therapy

See Chapter 4

In addition, neonates of very low-birth-weight may have eye damage, called retinopathy of prematurity, from exposure to excessive oxygen. Infants at highest risk are:

- Those born at < 32 weeks' gestation, or
- Weighing < 1250 g; the smaller the infant, the greater the risk.

If pulse oximetry is available, the SpO_2 should be maintained above 88% but no higher than 95%, to prevent eye damage.

Retinopathy of prematurity:

- Can develop even with meticulous monitoring in extremely premature infants who have multiple problems.
- Most cases resolve spontaneously.
- All infants born at < 32 weeks' gestation or weighing < 1250 g and larger preterm infants who received oxygen should be screened for retinopathy of prematurity at 4–6 weeks of age.

Bronchopulmonary dysplasia is one of the feared complications of oxygen delivery in premature patients on CPAP.

3.9 General Care of Children with Hypoxemia or Severe Respiratory Distress

Nursing care of children with hypoxemia is very important. The main considerations include minimal handling, positioning, fluids, and nutrition and close monitoring.

Handling can be upsetting to severely ill children, and any activity consumes more oxygen. **Handling should be gentle** and unnecessary stress or painful procedures should be avoided.

Give antipyretics if the child is febrile and address pain management. Transfuse the patient based on indication

Children will often find their own most comfortable position

- In bed or on their mother's lap;
- Sometimes their breathing may improve if they are nursed with their head raised about 30° with neck support, rather than lying flat; and/or
- Some hypoxic neonates and young infants may be more stable in the prone position, as long as their faces are not obstructed.

The following guidelines should be followed when providing fluids and nutrition to hypoxemic children:

✓ Withhold oral feeds while the child has severe chest in-drawing or severe respiratory distress to avoid the risk for aspiration.
✓ Use an intravenous drip or a nasogastric tube, depending on which is safest.

✓ **Do not give large volumes of intravenous fluids**, as they may make the lungs "wet" and worsen hypoxemia. The maximum rate of intravenous fluid administration required is usually 2–3 mL/kg body weight per hour and should be stopped once oral or nasogastric tube feeds are tolerated.
✓ If nasogastric tube feeds are given use small volumes, and ensure that the nasogastric tube is well in the stomach. Do not give large nasogastric feeds to children with severe respiratory distress, as they may vomit and aspirate.
✓ As soon as severe respiratory distress has resolved, make sure that the child receives good nutrition, preferably breast milk.

3.10 Overcoming Parents' Concerns about Oxygen Use

Parents must be educated about the need for oxygen in order to alleviate their fears. Many parents are afraid of oxygen and oxygen catheters, perhaps because they have seen other children receive oxygen just before they died and may fear that it was the oxygen that caused the death. It can be helpful to

- Show parents the pulse oximeter in operation;
- Explain to them why the child's oxygen level is low, and why supplemental oxygen would help; and
- Show them the clinical signs (such as chest in-drawing or cyanosis of the gums or tongue); when oxygen is given, the parents will see that the SpO_2 increases and the child's respiratory distress lessens.

The pulse oximetry checks were also considered a daily demonstration that special attention was being paid to the child, which the mothers appreciated. Even illiterate mothers could understand the significance of the number on the pulse oximeter and the threshold for safe discharge when this was explained to them.

KEY MESSAGES

- Children receiving oxygen should be monitored clinically at least twice a day by pulse oximetry.
- A nurse should check every 3 h that the prongs or catheter are in the correct position and not blocked with mucus, that all connections are secure, that the oxygen flow rate is correct, that the airways are not obstructed by mucus and that there is no gastric distension. Prongs or catheters should be removed and cleaned at least twice a day.
- SpO_2 is the most critical vital sign; therefore, pulse oximetry is an invaluable routine monitoring tool.
- In severe pneumonia, hypoxemia may last from several hours to several weeks; the usual duration is 2–5 days.
- At least once a day, children who are clinically stable (have no emergency signs and $SpO_2 > 90\%$) should be disconnected from oxygen for 10–15 min and carefully examined for changes in clinical signs and SpO_2, to determine whether supplemental oxygen is still required.
- Children should not be discharged until their SpO_2 has been stable at $\geq 90\%$ while breathing room air for at least 24 h, until all danger signs have resolved and until appropriate home treatment has been organized.

Chapter 4: Oxygen Therapy in Adults

Learning Objectives

By the end of this chapter, participants will be able to:

- To describe the indications of oxygen therapy,
- To develop skills on different oxygen delivery techniques and devices,
- To develop skills on monitoring oxygen therapy using pulse oximeters and clinical parameters,
- To develop skills on use of humidifiers and nebulizers,
- To identify oxygen therapy on specific conditions, and
- To describe adverse effects of oxygen therapy.

Content outline
• Indications of oxygen therapy, • Skills on different oxygen delivery techniques and devices, • Skills on monitoring oxygen therapy using pulse oximeters and clinical parameters, • Skills on use of humidifiers and nebulizers, • Oxygen therapy on specific conditions, and • Adverse effects of oxygen therapy

Key Questions for Self-Review

1. What are the indications for starting oxygen therapy in adults?
2. What are the common causes of hypoxemia in adults?
3. When do we administer oxygen via nasal prongs/catheter? when do we use facemask to give oxygen?
4. What are the two methods of non-invasive ventilation? What are the indications of each?
5. What are the indications we use non-invasive techniques to administer oxygen and when do we need to switch to invasive techniques?
6. Mention conditions that we need humidification during oxygen therapy?
7. What are the key clinical parameters that we need to monitor during oxygen therapy?
8. List three unwanted effects of oxygen administration?

4.1 Indications for Instituting Oxygen Therapy in Adults

- Cardio respiratory arrest
- Respiratory distress (respiratory rate >24/min) in adult
- Hypoxia with pulse oximeter measurement (saturation of oxygen <93%) except for COPD patients
- Hypotension (systolic blood pressure <90 mm Hg)
- Low cardiac output and metabolic acidosis (bicarbonate<18 mmol/l)

4.2 Methods to Improve Oxygenation

- Increase FiO_2- initiate supplemental administration of oxygen with nasal prong, different type of face mask and start to treat the causes
- Increase MV- assist breathing with BVM, non-invasive CPAP, invasive mechanical ventilation
- Increase Cardiac Output- treat causes of hypotension and shock
- Increase oxygen carrying capacity – blood transfusion when there is symptomatic anemia
- Optimize V/Q relationship – treat pulmonary edema, with drugs and when necessary with PEEP/CPAP
- Decrease oxygen consumption from- pain, shivering or fever – optimal use of analgesics

4.3 Oxygen Administration Devices and Techniques

85% of patients on oxygen therapy were inadequately supervised and oxygen was prescribed inappropriately. Oxygen is a drug and has to be prescribed and the prescription has to indicate:

1. Flow rate,
2. Delivery system,
3. Monitoring, what and how frequent to monitor
4. When to report
5. When to change the device
6. When and how to stop oxygen administration

4.3.1 Methods of Oxygen Administration

- Nasal cannula;
- Face mask – simple, partial rebreathing, non-rebreathing;
- Ambubag or Bag Valve Mask (BVM) – assist breathing; and
- None invasive CPAP/BiPAP (Bi Phasic Airway Pressure).

Nasal prongs or catheter

- Used for correction of mild hypoxia and when there is no marked tachypnea;

- Is suitable and better tolerated by patients;
- Oxygen administration via nasal prongs range from 1-litter -5litter/minute. To shorten the hypoxia time and patients sufferings oxygen administration has to be started from the highest possible L/m, in this case 5L/m, monitor the patient's response to this amount of oxygen flow rate, then if the saturation is above 93% you can titrate down ward gradually. If the saturation is not improving change to the next step which is facemask with high-flow rate;
- By administering 1-5litters/min oxygen, inspired oxygen concentration rises to 25-40% (each litter increases the delivered oxygen concentration by 4%);
- When the nasal prong is attached to a cylinder there must be attached pressure-regulating gage, flow meter measuring flow rate with a bottle and water for humidification; and
- When a flow rate greater than 5-6litre/min is used with this devise it results irritation, injury and bleeding to the nose. And doesn't increase the oxygen delivery to the patient rather it is wastage, therefore when a patient saturation is not improving with 5l/m with nasal prong it has to be changed to face mask without delay.

Figure 14: Patient on a Nasal Prong

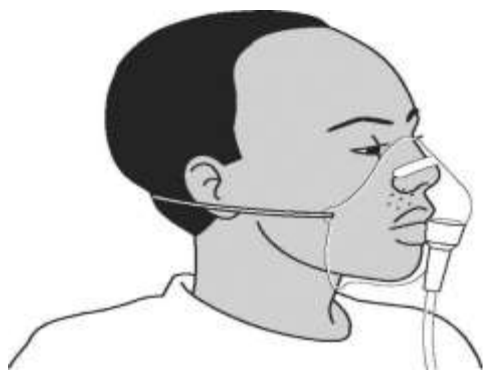
Face Mask

- There are different types of facemasks.
- They could be with reservoir or without, none rebreathing or simple.
- A flow rate of 6-15 liters/minute provides a rise in inspired oxygen concentration up to 60-70 percent, when the mask is simple or above 80% when face mask is with reservoir and none rebreathing.
- The flow rate shouldn't be less than 6 liters/minute to avoid rebreathing, i.e. breathing of their own exhaled gas which is reach on CO_2.
- If your assessment and decision is severe hypoxia start from the higher flow, which is 10-

15L/m, and titrate down ward according the patients response.

- If patients oxygenation and general conditions is not improving and signs of hypoxia or hypercarbia are persisting conceder the next technique of oxygen administration, which is non-invasive respiratory support (CPAP) if the patient has adequate breathing effort and conscious and cooperative or invasive (intubation and ventilation with mechanical ventilator) respiratory support.

Figure 15: Simple Facemask



Non-rebreather mask (NRB)

Non-rebreather facemask is a device used in clinical practice to assist in the delivery of oxygen. A NRB requires that the patient can breathe unassisted, but unlike low flow devices such as nasal cannula and simple facemask the NRB allows for the delivery of higher concentrations of oxygen. The NRB has

- an attached reservoir bag, typically contain 1 liter of oxygen as reserve,
- to be connected to an external oxygen tank.

Before a NRB is placed on the patient,

- The reservoir bag is inflated with oxygen to greater than two-thirds of its volume, at a rate of 15 liters per minute.
- It has to be connected continuously to the oxygen source with high-flow.
- Make sure the reservoir bag is always inflated with oxygen.

Exhaled air is directed through a one-way valve around the connection of the mask, which prevents the inhalation of room air and the re-inhalation of exhaled air. The valve, along with a sufficient seal of the mask around the patient's nose and mouth, allows for the administration of high concentrations of oxygen, approximately 60% - 80% oxygen.

Figure 16: Bag Valve Mask (BVM), Ambubag

Indications

- BVM is used for temporary assist breathing and oxygenation during respiratory arrest, bradypnea or low breathing rate<10b/m
- Severe respiratory failure till appropriate definitive airway management and ventilation is ready. This device is lifesaving and the techniques on how to use them has to be practiced by all professionals.

Bag Valve Mask (BVM) has three parts:

1. Bag with oxygen connector
2. Unidirectional valve between the face mask and the bag
3. Face mask

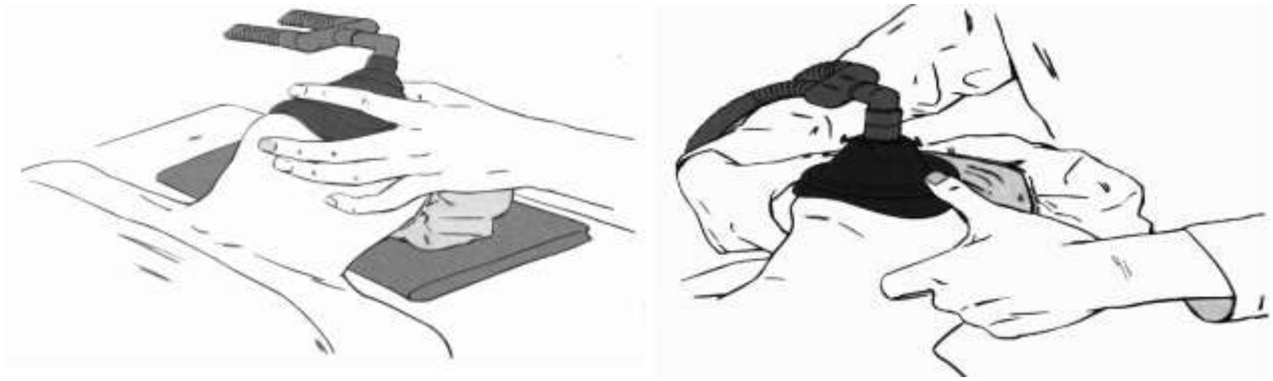
Figure 17: Bag Valve Mask (BVM)

BVM implementation technic

- Position the patient supine;
- Make head tilt and chine lift if patient is medical or non-trauma or jaw thrust for all trauma patients;
- Choose appropriate size of face mask that covers the patients nose and mouth only;
- Check the functionality of the BVM;
- Connect the BVM with the oxygen source with high-flow, 10-15L/M;
- Fix the facemask covering the nose and the mouth using C&E method(see picture below)
- Squeeze the bag just to raise or inflate the lungs. But remember do not over inflate, this creates injury to the lungs and decrease the venous return;
- Give a rate of 10-12breaths/minute. Do not hyperventilate, this creates oxygen washout and patients respiratory center will be depressed and patient will have delayed breathing initiation by himself/herself; and
- If the chest is not moving when you squeeze the bag reposition the head and neck and insert oro-pharyngeal airway.

One hand C&E technic and two hands technique using jaw thrust

Figure 18: Applying BVM



CPAP & BiPAP Non-invasive ventilation (NIV)

NIV is defined as a ventilation modality that supports breathing without the need for intubation or surgical airway. Non-invasive ventilation method is used on adult respiratory management in both the emergency department and the intensive care unit (ICU). The advantage of this technic is avoiding the adverse effects of invasive ventilation, and patient comfort.

Indications/Adults

Non-invasive ventilation (NIV) is indicated in adult patients with

- Obstructive sleep apnea syndrome
- Exacerbation of COPD, Asthma
- Severe Pneumonia
- Acute CHF with pulmonary edema with sign and symptoms of congestion
- Neuromuscular disorders
- Acute lung injury
- Weaning from ventilator (A 2009 meta-analysis indicated that non-invasive ventilation, as a method of weaning critically ill adults from invasive ventilation, was significantly associated with reduced mortality and ventilator-associated pneumonia). The net clinical benefits of this method have not yet been determined.

Contraindications

Absolute Contraindications

- Respiratory arrest or unstable cardiorespiratory status
- Uncooperative patients
- Inability to protect airway (impaired swallowing and cough reflexes)

- Trauma or burn involving the face
- Facial, esophageal, or gastric surgery
- Apnea (poor respiratory drive)
- Reduced consciousness

Relative Contraindications

Relative contraindications to non-invasive ventilation are as follows:

- Extreme anxiety
- Morbid obesity
- Copious secretions
- Need for continuous or nearly continuous ventilatory assistance
- Diseases with air trapping, such as asthma

Ventilator mode/how it works

- A continuous positive airway pressure (CPAP) ventilator delivers air at a constant pressure during inspiration and expiration.
- The patient must be able to breathe spontaneously.

Use

- CPAP is mainly used for hypoxemic respiratory failure, such as in acute pulmonary edema. It prevents alveolar collapse and facilitates oxygen delivery to pulmonary capillaries. CPAP increases the Functional Residual Capacity (FRC) and opens collapsed alveoli, which, in turn, enhances gas exchange and oxygenation.
- CPAP reduces left ventricular transmural pressure, therefore increasing cardiac output. Hence, it is very effective for treatment of acute pulmonary edema and is considered the modality of first choice in these patients. Pressures usually are limited to 5-15 cm of H_2O. Each patient's requirements must be reviewed in light of his or her disease process and disease pathophysiology. Caution is advised in patients with borderline low blood pressure; they may become hemodynamically unstable, as one of the disadvantages of CPAP is reduced venous return.
- In the ED and ICU, CPAP is generally administered using a facemask, creating a seal over the mouth and nose, as shown in the images below. However, a smaller mask can be used in some cases, covering just the nose.
  Continuous positive airway pressure (CPAP), administered on an adult patient.

Figure 19: CPAP

Bi Phasic Airway Pressure (BiPAP)

- BiPAP provides two levels of positive pressure: inspiratory positive airway pressure (IPAP) and expiratory positive airway pressure (EPAP). This is highly beneficial in patients with respiratory fatigue or failure. During exhalation, pressure is variably positive. Airflow in the circuit is sensed by a transducer and is augmented to a pre-set level of ventilation. Cycling between inspiratory and expiratory modes may be triggered by the patient's breaths or may be pre-set. BiPAP helps in improving patient comfort.
- BiPAP is a particularly effective respiratory modality when patients are not improving sufficiently on CPAP alone. Not only does it provide the benefit of CPAP by providing increased airway pressure during expiration, but it adds inspiratory assistance that may further reduce the work of breathing and assist with augmenting the ventilator in patients at risk for hypercapnea (eg, patients with COPD).
- A common practice is to use initial IPAP settings of 10-12 cm H_2O pressure and EPAP settings of 5-7 cm H_2O, and then adjust IPAP to 15-20 cm H_2O, depending upon the response over the next hour or so.
- In conditions such as lung collapse or pulmonary edema, the initial EPAP may have to be high. However, an EPAP that is too high can lead to reduce preload. Hence, a balance in adjusting the ventilatory settings is desirable. Back-up rates can be chosen according to the age of the patient. The fraction of inspired oxygen (FiO_2) is another useful variable in titrating the response to oxygenation.
- Invasive management of respiratory failure is considered when all other none invasive methods of oxygen administration technics were not effective or the condition of the patient doesn’t give time for trial of the above. It is accomplished with endotracheal intubation and mechanical ventilation.

4.4 Humidification

Some oxygen delivery methods require use of humidifiers for the patient’s comfort and to decrease dryness of the airways. This section outlines when humidification is required and the types of humidifiers recommended.

When oxygen is used at a low flow rate (< 4 L/min) through nasal prongs, humidification is not necessary. Humidification is needed when oxygen is given via a facemask and for all patients with an endotracheal tube or a tracheostomy.

Generally, because of the following reasons humidification is required:

1. Cold, dry air increases heat and fluid loss
2. Medical gases including air and oxygen have a drying effect and mucous membranes become dry resulting in airway damage.
3. Secretions can become thick & difficult to clear or cause airway obstruction
4. In some conditions e.g. asthma, the hyperventilation of dry gases can compound bronchoconstriction.
5. Humidifiers prevent cold, dry oxygen from drying respiratory secretions, which can blockage of the nose or throat. There are several types, but most commonly used in simple oxygen systems is a bubble humidifier, in which the oxygen is bubbled through water.

4.5 Giving Oxygen in Specific Conditions in Adults

Acute Respiratory Failure (ARF) or severe respiratory distress: ARF is a life threatening complication of respiratory system (air way, lung, neuromuscular junction disorders or neuropathies, or respiratory center dysfunction). It is characterized with features of respiratory distress, which is due to hypoxemia (low oxygen concentration in the blood): Tachypnea, (fast breathing) usage of accessory muscles, restlessness, palpitation, sweating, altered consciousness, headache, confusion and cyanosis.

Common conditions that lead to ARF are:

- Acute respiratory distress syndrome (ARDS),
- Severe asthma,
- Severe pneumonia,
- Severe sepsis,
- Tension pneumothorax,
- Pulmonary thromboembolism,
- Severe COPD.

Higher concentrations of oxygen are required initially during ARF and achieved by higher flow rates via different modalities of facemasks.

- It is important to reduce the severity of hypoxemia as fast as possible to prevent organ damage.
- Therapy is continuously monitored with at least pulse oximetry and all other vital signs.

- In case hypoxemia is not correctable, assisted ventilation may be required. It may also be stressed that correction of blood PaO2 is not the only objective of therapy. Therefore, all the factors responsible for tissue oxygen delivery should be taken in to consideration.

4.5.1 Trauma and Surgery

During trauma, **two phases** of tissue and organ damage occur.

- The initial traumatic impact or **primary insult** is due to direct impact of the event (like lung contusion, brain hemorrhage, rupture of spleen or liver, bone fracture or muscle crush injury).
- Following the primary insult, if on time medical care is not initiated **secondary injury** from hypoxia and hypovolaemia take over. This secondary injury can be prevented; by treating hypoxemia, hypotension, hyper or hypoglycemia, and hyperthermia.

The approach to minimizing tissue hypoxia in the traumatized patient is based on airway, breathing and circulation (ABCD) assessment. Oxygen therapy in major trauma should normally be started at a high-flow, using a facemask, preferably with an oxygen reservoir.

4.5.2 Obstetric Care

When considering the rational use of oxygen on a pregnant mother, consideration should be given to the well-being of both the mother and the unborn child. The gravid uterus reduces the Functional Residual Capacity (FRC the amount of air in the lungs at expiration) and impairs oxygenation. Oxygen partial pressure in placental blood is very low, but fetal hemoglobin binds avidly to oxygen at low partial pressure, enabling efficient oxygen delivery to the fetal tissues under normal conditions. Maternal hypoxia from any cause will compromise the mother and also significantly impair fetal oxygen delivery

Maternal causes:

- Maternal hemorrhage,
- Reduced consciousness level with pre-eclampsia or eclampsia,
- Amniotic fluid embolism,
- Shock , CHF, Cardiac diseases,
- Maternal sepsis,
- Laboring mother with pulmonary TB, Pneumonia, and/or
- The pregnant mother undergoing cesarean section under general anesthesia is at risk from hypoxia, especially during induction of anesthesia, which may be complicated by difficult intubation.

Fetal causes:

- Fetal distress, and/or
- Cord prolapse.

4.5.2.1 Oxygen Administration for Obstetric Case

- In any situation where the mother or fetus is compromised, tissue hypoxia is likely to occur and, as with trauma, high-flow oxygen should be delivered in the initial stages while the situation is managed.
- Maternal hemorrhage, reduced consciousness level with pre-eclampsia or eclampsia, or fetal distress, all benefit from oxygen therapy to prevent further deterioration in fetal oxygenation. Give high-flow of oxygen 6-10l/min with face mask and proper monitoring of the response is important
- Pre-oxygenate with 100% of oxygen for 4 minutes before induction of anesthesia. This will minimize the risk of hypoxemia during induction and intubation.
- At least 30% oxygen mixture of gas should be used during maintenance of anesthesia for elective cesarean section, with the precise level guided by pulse oximetry monitoring.
- The use of oxygen during cesarean section under spinal anesthesia depends on whether the procedure is elective or emergency, and whether the fetus or the mother may be hypoxemic.
- If the mother is undergoing emergency cesarean section under spinal anesthesia for fetal compromise, then administration of oxygen to the mother is indicated, even if the mother is not hypoxemic, as this may help the fetus.
- During spinal anesthesia for cesarean section, the mother's SpO_2 should be monitored with a pulse oximeter, and oxygen administered if the level falls below 95%. For this purpose at all times the oxygen source and oxygen delivering equipment has to be ready for use at all times.

Recommendations

- ✓ Women who suffer from major trauma, sepsis or acute illness during pregnancy should receive the same oxygen therapy as any other seriously ill patients, with a target oxygen saturation of 94–98%. The same target range should be applied to women with hypoxemia due to acute complications of pregnancy (eg, collapse related to amniotic fluid embolus, eclampsia or antepartum or postpartum hemorrhage).
- ✓ Women with underlying hypoxemic conditions (eg, heart failure) should be given supplemental oxygen during labor to achieve an oxygen saturation of 94–98%.
- ✓ All women with evidence of hypoxemia who are more than 20 weeks pregnant should be managed with left lateral tilt to improve cardiac output.
- ✓ The use of oxygen during labor is widespread but there is evidence that this may be harmful to the fetus. The use of oxygen during labor is therefore not currently

recommended in situations where the mother is not hypoxemic (except as part of a controlled trial).

4.5.3 Recovery from Surgery & Anesthesia

During recovery from anesthesia the patient remains under the effect of anesthetic agents and requires careful supervision and monitoring. The patient is at risk from hypoxia due to

- airway obstruction (including laryngospasm and poor consciousness state),
- retained secretions,
- atelectasis, or
- increased oxygen consumption due to shivering.

Therefore, monitoring of such patients has to be accomplished in Post Anesthesia Care Unit (PACU), by properly trained nurse and oxygen supplementation, when necessary

- suctioning of the airway,
- assessment for airway obstruction, and
- monitoring at least with pulse oximetry should be routine until consciousness returns.

Typically, this can be provided via facemask with 6 liters and above/minute of oxygen. Postoperative airway obstruction can be masked by high concentration oxygen, so after anesthesia patients need to be carefully observed for

- stridor,
- other signs of obstructed breathing, and
- their consciousness level.

Nasal prongs are best tolerated, and 2–3 litres/minutes is ideal. Monitoring SpO2 will guide therapy. Administration of oxygen in the perioperative period (up to 2 hours postoperatively) has been shown to be associated with a reduced incidence of wound infection, but a high concentration of inspired oxygen is not advisable for prolonged periods in the patient with normal oxygen saturation.

4.6 Monitoring of Oxygen Therapy

- Respiration quality: if the patient had fast breathing with adequate oxygen administration it gradually decreases and use of accessory muscle also decreases, so you have to monitor closely and document your findings;
- Vital Sign/V/S – hypoxia increases heart rate and to some extent the blood pressure, therefore monitoring of the heart rate and blood pressure also is very important (RR, Pulse, blood pressure;
- Mental status;

- Pain – pain increases body metabolism and oxygen consumption, therefore it aggravates the hypoxia by increasing the oxygen demand. Treat pain if it is there;
- Oxygenation- A blood-oxygen monitor or pulse oximetry displays the percentage of blood that is loaded with oxygen. More specifically, it measures what percentage of hemoglobin, is loaded with oxygen. An acceptable normal range for patients without pulmonary pathology breathing room air (21% Oxygen) at near sea level is from 93 to 99 percent. During oxygen therapy with pulse oximeter the reading has to reach above 93%;
- Ventilation- End Tidal CO_2, which is measured with capnometer. Itis also very important device to monitor oxygen therapy. It measures the amount of CO_2 in the patient's body. The normal amount is 40-50mmHg. This is also non-invasive method of monitoring of ventilation or removal of CO_2 from the body through the lungs. It can be attached on the oxygen delivery tubing. If the value of ETCO2 above the allowable number Consider invasive airway and ventilation management; and
- Document all monitoring findings properly, regularly and use it for management of the patient.

4.7 Unwanted Effects of Oxygen and Its Management

Oxygen toxicity can be considered when a patient is taking oxygen concentrations >60% for >24 -48hrs. In adults oxygen toxicity generally manifests as new onset of convulsions due to generalized cerebral vasoconstriction, damage to pulmonary epithelium due to oxygen radicals and worsening of the respiratory failure:

- *Pulmonary oxygen toxicity* - High concentrations of oxygen (>60%) may damage the alveolar membrane when inhaled for more than 48 hours resulting in pathological lung changes.
- *Retrolental fibroplasia* (also known as retinopathy of prematurity) An alteration of the normal retinal vascular development, mainly affecting premature neonates (<32 weeks gestation or 1250g birthweight), which can lead to visual impairment and blindness.
- *CO_2 Narcosis* - This occurs in patients who have chronic respiratory obstruction or respiratory insufficiency, which results in developing hypercapnea (i.e. raised $PaCO_2$). In these patients the respiratory center relies on hypoxemia to maintain adequate ventilation. If these patients are given oxygen this can reduce their respiratory drive, causing respiratory depression and a further rise in $PaCO_2$ resulting in increased, CO_2 levels in the blood and CO_2 narcosis.
- *Sub sternal pain*-due: characterized by difficulty in breathing and pain within the chest, occurring when breathing elevated pressures of oxygen for extended periods.

4.8 Summary

- Oxygen should be treated like a drug; it should be prescribed in writing, with the required flow rate and the method of delivery clearly specified;
- Failure to correct hypoxemia (PaO2>60mmHg or SpO2>93%) for fear of causing hypoventilation and carbon dioxide retention is unacceptable clinical practice;
- Careful monitoring of treatment is essential for continuation of the treatment with same device, to change to another device, and to titrate the flow rate; and
- Intermittent oxygen therapy is particularly dangerous since the increased alveolar CO_2 concentration which may then occur, results in an even lower oxygen concentration when the patient breathes atmospheric air (oxygen supply is discontinued), so titrate oxygen administration slowly before discontinuation. The amount can be adjusted and regulated according to the results of pulse oximetry and arterial blood gas analysis if available and according the general conditions of the patient.

Case scenario 1:

A 34years old young man came to the emergency department after surviving road traffic injury after 2hrs duration. On assessment at the triage area: he was conscious and alert, RR28/M, BP 85mmHg systolic, P120/min, Saturation 84-86% on room air and has injury to the chest and fracture on both lower extremities

a. Does this patient need Oxygen administration? Yes /No
b. If yes, what are the indications?
c. What additional treatment does this patient require?

Case scenario 2:

A 60 years old obese female patient came with C/C of cough, fever, and pain all over her body. During triage she is sick looking, vs: p100/min, RR 30/min, BP160/100mmHg, agitated, saturation 90%.

a. Does this patient need oxygen administration? Yes /No
b. How and with what type of devise you are going to administer Oxygen?
c. When do you consider changing the device or the flow rate?

Case scenario 3:

A 60 years old female patient came with c/c of cough, fever, and pain all over the body. During triage she is sick looking, vital sign: puls100/min, RR 30/min, BP160/100mmHg, agitated, saturation 90% and she was put on oxygen via nasal prong and kept for fallow up and treatment and you are assigned to follow her and give nursing care

a. How, and how frequent are you going to monitor?
b. What devices you need for monitoring?
c. What variables has to be documented?
d. When are you going to report on the patient's development?

Chapter 5: Oxygen & Pulse Oximeter Devices Management

Learning objectives

At the end of this session, participants will be able to:

- Explain the three modes of oxygen sources.
- Describe the function of oxygen device.
- Develop basic skills on preventive maintenance and troubleshooting on oxygen devices.

Content outline
• Modes of oxygen sources. • The function of oxygen device. • Basic skills on preventive maintenance and troubleshooting on oxygen devices.

Key Questions for Self-Review

1. What are the three modes of oxygen sources available in Ethiopia?
2. What are the drawbacks of using oxygen cylinder versus oxygen concentrator?
3. Have you ever worked out how to determine oxygen consumption for a health facility using a formula or did you use common sense? If so what was the formula, you used to determine the consumption?
4. What are the common problems you would face in using oxygen concentrator and how do you correct them?

5.1 Types of Oxygen Supply

Main types of oxygen supply are:

1. Oxygen cylinder: high pressure gas supplied via portable canisters delivered to facilities.
2. Oxygen concentrator: oxygen enriched gas is supplied by entraining air from the environment.
3. Oxygen plant distribution system: oxygen is provided via a large central source on-site.

Figure 20: Oxygen Supply Options

	Oxygen cylinders	Oxygen concentrators	Central oxygen source / Oxygen plant
			
Description	High pressure gas supplied via portable canisters delivered to facilities	Oxygen enriched gas is supplied by entraining air from the environment	Oxygen is provided via a large central source on-site
Current usage	Prevalent in many Hospitals, but transport only reliable to higher levels	Prevalent in many hospitals, but usage often affected by lack of power	Only plant at Hayer Hospital in Mekele and Adama (plant at Saint Paul and Jimma hospitals under construction)
Advantages / Draw-backs	+ No need for electricity – High cost of transport	+ Low running cost – **Max flow rate 5 L / min (not recommended for surgery)** – Requires access to uninterrupted power – Service and supply of spare parts needed	+ Most cost effective for larger facilities – High capital investment – Need for adequate infrastructure

Figure 21: Determining Oxygen Consumption for your Respective Health Facility

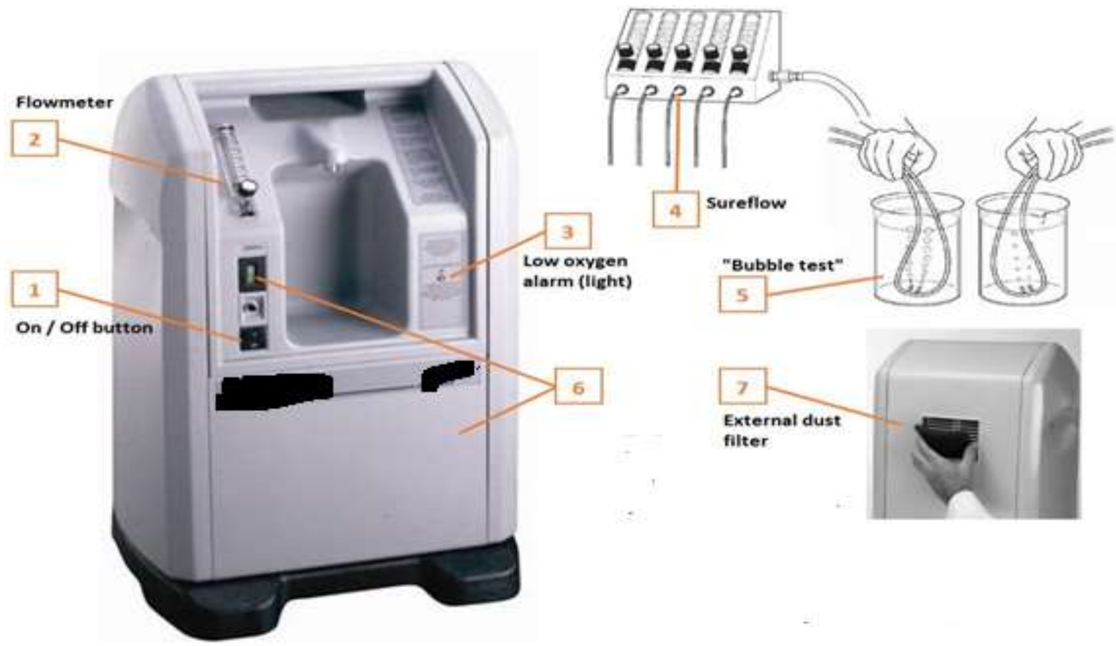
Exercise 5.1

Assume Adama hospital has the following number of beds, hypoxemia prevalence, bed turnover ratio, oxygen consumption per case:

- Number of beds per ward medical (50), Surgical (40), Gynobs (40), pediatrics and , NICU (40), OR and Recovery (4), ICU and Emergency (20);
- Prevalence of hypoxemia 20%;
- Bed turnover ratio 8 per quarter; and
- Oxygen consumption per case 4000 liters:
    - A. Calculate oxygen consumption for each ward.
    - B. Total oxygen consumption of the hospital.

5.2 Safe Usage of Oxygen & Pulse Oximeter

Figure 22: Oxygen Concentrator



Oxygen Concentrator

Concentrators:

- Draw in air from the environment, which usually contains 21% oxygen, 78% nitrogen and 1% other gases, and extract the nitrogen to leave almost pure oxygen.
- Supply oxygen at a concentration of 90–96%.
- Provide a safe, less expensive, reliable, cost-efficient source of oxygen, which is more convenient than oxygen cylinders, particularly for low resource settings.
- Can provide a continuous supply of oxygen for up to four patients at the same time when used with flow splitters or flow meters.

Concentrators nevertheless require regular maintenance to ensure proper functioning and a source of continuous power. Concentrators can be run on AC mains power, a power generator or solar power. Having a power independent oxygen source, such as a cylinder, as a back-up is important.

Patient Safety

Following these guidelines will help reduce potential risks. See the manufacturer website or user manual if you would like more information about your equipment.

- Post the *Oxygen in Use* sign that comes in your oxygen kit where visitors can see it.
- Do not use the oxygen concentrator with in the same room as an open flame or spark.
- Keep the concentrator in a well-ventilated area at least 6 inches from the wall, furniture, or draperies.
- Minimize static electricity around the concentrator. Try to avoid bedding or clothing fabrics that produce static electricity such as wool or synthetics like nylon.
- Do not place concentrators near swamp coolers, heat registers, space heaters, large windows, or any other source of heat.
- Do not use an extension cord or a wall outlet that powers other electrical equipment.
- Closely supervise children and rodents around the concentrator.
- Operate in a smoke-free and soot-free environment.
- Make sure aback-up system is available if you use a concentrator for 24-hour continuous therapy.

Using a Concentrator Operating Instructions

- Plug in the power cord directly to an electric outlet—do not use extension cords.
- Connect the humidifier (if used).
- Connect the oxygen tubing to the oxygen outlet (or humidifier bottle outlet fused)and fit the nasal cannula or mask to your face.
- Press the power switch to on and ensure the green indicator light comes on.
- Turn the flow meter knob to the setting prescribed by your physician—do not change the level of oxygen flow without your doctor's consent.
- To turn the unit off, press the power switch to off.

Oxygen Purity Indicator Lights

- A green light: indicates proper oxygen flow (> 85%).
- A yellow light: indicates below normal oxygen purity (50%-85%). Continue using the concentrator but be certain that back-up oxygen is nearby. Call BME/T Immediately.
- A red light: indicates unit shut down (<50%). Switch to back-up oxygen. Call BME/T immediately.

Maintenance and Cleaning[2,]

2Fact sheet for patient and families, Intermountain Homecare & Hospice

- Remove and clean each filter at least to once a week or more often in areas with high dust, smoking, or other air pollutants.
- Vacuum external filters or wash them in warm soapy water, rinse thoroughly, and dry fully.
- Wipe ether concentrator cabinet with a damp cloth.
- Change your cannula every 2 weeks. Change your oxygen tubing every 2 month

Table 5: Troubleshooting an Oxygen Concentrator

Problem	Probable Cause	Solution
Unit not operating (power failure alarm).	• Plug not firmly in wall • Concentrator circuit breaker tripped • No power at wall outlet • Electrical power outage	• Check plug outlet. • Press set button on concentrator. • Check outlet fuse or circuit breaker. • Verify the wall switch that controls outlet is on. • Try another outlet. • Use your back-up oxygen until power is restored.
Oxygen not flowing from cannula Place your oxygen cannula in a small glass of water and look for a steady flow of bubbles —if you see bubbles, the system is working.	• Oxygen tubing or nipple adaptor not connected tightly • Obstruction in tubing • Obstruction in cannula • Humidifier lid not secure	• Check that oxygen tubing is connected tightly to system. • Make sure nipple adaptor is attached tightly. • If flow is restored when tubing is disconnected, replace tubing. • If flows restored when cannula is disconnected from tubing, replace with new cannula. • Attach the humidifier lid securely to the jar; make sure it is not cross-threaded.
Unable to dial prescribed flowrate.	• Obstruction in tubing • Obstruction in cannula • Obstruction in humidifier bottle	• If flow is restored when tubing is disconnected, replace tubing • If flow is restored when cannula is disconnected from tubing, replace with new cannula. • If flow is restored when humidifier bottle is disconnected, clean or replace the humidifier bottle
Temperature light/	• Unit overheated	• Make sure unit is not blocked by

Alarm is on		something like drapes. • Make sure filters are clean. • Turn off concentrator for 30 minutes to allow cooling and then restart; Use your back-up system while the concentrator is cooling.
Oxygen tubing contains water (if using a humidifier).	• Overfill humidifier bottle • Tubing lying on a cold floor	• To dry the tubing, attach it directly to the concentrator (Without the humidifier bottle). • Use your back-up oxygen system while drying the tubing.

MEDICAL OXYGEN CYLINDER

Information Medical grade oxygen

Medical grade oxygen is an odorless, colorless and tasteless gas that is stored as a compressed gas in cylinders. These cylinders are identified according to ISO color codes. They will be white cylinders.

Changing a Cylinder

If a pressure system (such as a compressed gas cylinder) fails, it is likely to result in an uncontrolled release of energy causing serious injury to personnel and damage to property. The overall intention of the Pressure Systems Safety Regulations is to prevent the risk of injuries from such a failure.

A simple guide to changing a cylinder

- It is important that clinical staff can change cylinders safely, efficiently and competently.
- This guide to changing gas cylinders will help you fully meet your requirements.

The Basics

- Anyone who changes a gas cylinder must:
- Be fully trained for their own protection and to comply with the Manual Handling regulations;
- Use appropriate protective clothing (PPE) such as gloves, safety glasses and protective footwear; and
- Appreciate and understand the safety precautions required in handling oxygen cylinders.

Initial Safety Checks

- Before handling cylinders ensure your hands are clean
- If alcohol based gels or liquids have recently been used ensure it has totally evaporated before oxygen use.
- If moisturizers or sun cream have been used ensure hands are dry before oxygen use.
- When selecting a cylinder for use ensure it is clean and free from any damage, free from oil or grease.

Prepare Cylinder

- Ensure you have the correct medical oxygen gas and that it is within its' expiry date. (Found on batch label of the cylinder)
- Check the cylinder contents gauge on the cylinder valve to ensure that there is sufficient gas contents in the cylinder
- Remove the tamper evident seal and cover fitted over the valve outlets
- Ensure the flow selector is set to zero before using the (black) hand wheel to open the cylinder valve
- Open the cylinder valve slowly (turn anti clockwise until it stops) and check for any leak.
- Ensure the outlet (fir tree connector) is free of obstruction.
- If dirt or other obstruction is seen; briefly turn the flow dial to maximum to clear it
- Ensure that the correct equipment is selected for connection to the cylinder
- Connect tubing to the fir tree connector and select appropriate flow rate

Cylinder Leaks

- Check the connection for leaks using the following procedure:
- Should leaks occur this will usually be evident by a hissing noise
- Close valve, remove connection, check and refit
- Never use excessive force when connecting equipment to cylinders
- If leak persists, label cylinder and return to store.

Use of Cylinders

- When compressed medical oxygen cylinders are in use, ensure that they are:
- Only used for medicinal purposes
- Used only be personnel trained in their use and aware of the potential dangers
- Turned off, when not in use, using only moderate force to close the valve
- Only moved with the appropriate size of handling device
- Handled with care and not knocked violently or allowed to fall
- Firmly secured to a suitable cylinder support when in use
- Not allowed to have any markings, labels or batch labels obscured or removed
- Do not used in the vicinity of persons smoking or near flames.

- Always check service/expiry dates before use.

After Use

- If any contact with salt water has occurred cylinder should be rinsed in fresh water.
  - Do not use any cleaning materials that may contain chlorine or ammonium as they may cause damage to the cylinder package.
  - When the compressed medical oxygen cylinder is empty ensure that the:
  - Cylinder valve is closed using moderate force only and the pressure in the regulator or tailpipe released;
  - Valve outlet cap, where fitted, is replaced; and
  - Empty cylinders are immediately returned to the empty cylinder store (dry place/room).

Storage of Cylinders

1. Oxygen is a non-flammable gas, but strongly supports combustion.
2. Do not store or use cylinders near naked flames, sources of ignition or combustible materials.
3. Ensure the oxygen cylinders are stored in a safe and secure area where they cannot fall over and cause injury. Commonly this is within a secure cage or chained to the wall.
4. Clearly identify the storage areas with appropriate signage.
5. Ensure separation of full and empty cylinders.
6. Store medical gas cylinders separately from industrial and other non - medical cylinders, fuel, oil, grease, alcohol based hand cleaner etc. in a well-ventilated area that is clean and dry, preferably inside.
7. Medical gas cylinders should not be stored in the same area that is being used to dry equipment
8. Smoking should not be permitted in the vicinity where cylinders are used or stored.

Accidental Release Measures

If a large volume of medical oxygen is released, for example if the cylinder is damaged. It may begin moving at high speed in erratic directions. If safe to do so, you should:

1. Close the cylinder valve
2. Where possible, isolate all sources of ignition
3. If release continues, evacuate the area and ensure that the affected area is
4. Adequately ventilated before re-entry.

Transport of Cylinders

When medical oxygen cylinders are required to be transported, ensure that the cylinders are:

1. Located in a compartment separated from the driver
2. Adequately restrained
3. Check for leaking, and have their valves closed.

The vehicle must be adequately ventilated, and the load be secured. Signs should be carried on the outside to inform the public of what is being carried. Ensure the driver is aware of the potential hazards and that detail of this information sheet is carried and understood in the event of any emergency.

It is advisable to provide the driver with written instructions that detail the actions to be taken in the event of an accident or emergency. Cylinders should be removed from the vehicle as practicable as possible.

Exercises 5.2

1. List and describe three oxygen sources.

PULSE OXIMETRY

Pulse oximeters were introduced in the 1970's and have gone through a number of significant changes to reach the current generation. Advanced signal processing to reduce motion artifact and read low perfusion situations is characteristic of today's generation of machines. Also, individual sensor calibration is part of the newest generation. For pulse oximeters which are part of a monitoring system, there should be integration of functions such as ECG/pulse oximeter to improve measurement, alarms and system performance. Pulse oximeters have shrunk in size, so extreme portability is now available for applications requiring a small package.

Pulse oximeters are relatively safe devices with a few safety issues:

- Infection especially with reusable sensors
- Possible heating and minor burns to sensitive skin due to the red/infra-red LEDs
- Routine electrical safety concerns

Common Problems and Solutions

Pulse oximeter measurements problems and solutions may include:

Problem	Cause	Solution
Reading intermittent	• Skin pigmentation • Nail polish on finger measuring O2 sat • Ambient light interference • Electrical/electromagnetic interference	• Remove nail polish or choose a different site • If lower pigmentation site available, use it • Shield probe from interfering light source or remove light source • Remove interfering source
Reading intermittent with baseline wander	• Motion artefact • Wrong probe for application site used	• Reduce motion if possible (e.g. blanket over shivering patient); use a newer pulse oximeter with motion artifact reduction • Use correct probe
Reading intermittent; waveform low	• Poor perfusion	• Find a site with better perfusion or use a newer pulse oximeter with more sensitivity
Reading periodically goes away and device alarms	• Probe problem	• Contact BME/T
Unit on; No reading or waveform; red LED light on	• Defective cable or probe/cable unit • Defective pulse oximeter	• Contact BME/T
Unit on; No readings of waveforms; red LED light is off	• Defective probe • Defective cable or probe cable unit • Defective pulse oximeter	• Contact by BME/T

Chapter 6: Monitoring & Evaluation

Learning objectives

At the end of this session, participants will be able to:

- Explain terms used in monitoring & evaluation
- Record relevant information on the registers and formats
- Identify and explain key indicators
- Describe how indicators be used to monitor program performance
- Analyze the data and utilize the information for decision making
- Describe basic concept and implementation of supportive supervision and review meeting

Content outline
• Terms used in monitoring & evaluation • Recording information on the registers and formats • Indicators to monitor program performance • Data and utilize the information for decision making • Basic concept and implementation of supportive supervision and review meeting

Key Questions for Self-Review

1. What are the common types of indicators that we use to monitor a program?
2. List out the common input, output and outcome indicators you use to monitor oxygen therapy in a health facility.
3. What is the ultimate goal of data collection and analysis?

6.1 Definition of Terms

Monitoring and Evaluation (M&E) system refers to all the indicators, **tools** and processes that you will use to measure if a program has been implemented according to the plan (monitoring) and is having the desired result (evaluation)

Monitoring: is a continuous and periodic tracking of program implementation using input, process and outcome indicators data that are collected, collated and analyzed on a regular basis. Monitoring is also used to assess whether or not planned activities are carried out according to the plan. Such monitoring activities involve:

- Record activities regularly on appropriate register
- Keep records safely for easily retrieval.
- Update the health facilities' records regularly,
- Compile and analyze data based on the key indicators.

- Conduct Supervision and Review Meeting regularly.

Evaluation: It is an episodic in depth assessment of program implementation and achievement of objectives. Evaluation explains the relationship between the program and its effects. It helps to answer the 'why' and 'how' questions of program implementation.

Evaluation is very helpful to improve programmatic implementation and experience sharing among stakeholders. After an evaluation process a judgment should be made about the worth of the program

Recording: is the process of properly keeping data using standardized format for immediate or future use.

Reporting: is the process of disseminating information on activities performed.

Indicator: is a measurable variable expressed in number, proportion, percentage or rate that suggests the extent of achievement of a program, or the level of some condition in the population.

Generally, M & E is very essential for program management and is specifically used to:

- Systematically monitor patient progress and evaluate treatment outcome
- Monitor and evaluate the program performance
- Identify problem and measure its magnitude
- Evidence based planning (e.g. resource allocation for drug and laboratory supplies, designing interventions, etc.).

Therefore M & E process involves data collection, compilation, analysis and reporting. The health care workers should always ensure that records are at all times up-to-date, complete, accurate and reliable.

Exercise 6.1

Case 1.

Sr. Ayisha has compiled the monthly report of the health center on the oxygen consumption using the report form. After analyzing the report she has sent timely to the Woreda Health office.

What does this M&E process correspond to:

a) Evaluation
b) Monitoring
c) Recording
d) All

6.2 Indicators

It is a specific measure of program performance that is tracked over time by the monitoring system. The following indicators are used to monitor the performance. The indicators are compiled and analyzed at all levels to evaluate the progress of the program. Indicators are divided in to three that show the monitoring the process (Input/output), outcome and impact by which the latter two show the evaluation

6.2.1 Input indicators

- Number of oxygen cylinders in the health facility.
- Number of concentrators in the health facility.
- Number of pulse oximeter in the health facility.
- Amount of budget allocated for procurement/refilling of oxygen
- Amount of budget allocated for maintenance of oxygen supply machines (12.5% of original cost of the devices).

6.2.2 Output indicators

- Number of health care workers trained/oriented on oxygen use and currently working in the health facility.
- Number of technicians/engineers trained/Oriented on oxygen devices maintenance and repair and currently working in the health facility.
- Number of functional oxygen cylinders in the health facility.
- Number of functional concentrators in the health facility.
- Number of functional pulse oximeter in the health facility.
- Number of patients diagnosed with hypoxemia using pulse oximeter.
- Total number of patients diagnosed with different clinical conditions where oxygen therapy was prescribed.

6.2.3 Outcome indicators

- Proportion of patients with hypoxemia and diagnosed with different clinical condition who received oxygen therapy.

6.3 Analysis of Data and Utilization of the Information for Decision Making and Planning

Calculating proportions/percentages for specific indicator

Calculating proportion for specific indicator is not the end of the job, the figure has to be interpreted and used for appropriate decision making and planning purposes at all levels. For some indicators, analysis may involve comparing the actual proportion achieved to the expected standard or desired proportion and/or analysis may also involve comparing results achieved from the previous years/quarters to monitor the outcome.

To see the progress of the program overtime, it is advisable to keep a graphical display of achievements from quarter to quarter; the graph may be kept on the wall of the health facility and should be updated at quarterly bases.

For example, you can calculate the proportion of cases with hypoxemia treated with oxygen from the total cases needing oxygen therapy.

$$\frac{\textbf{Total cases treated with oxygen}}{\textbf{Number of cases identified with hypoxemia requiring O2}} \times 100 =$$

6.4 The Use of M&E to Solve Problems

KEY MESSAGES

- Indicators, analysis may involve comparing the actual proportion achieved to the expected standard or desired proportion and/or analysis
- Calculating proportion for specific indicator is not the end of the job, the figure has to be interpreted and used for appropriate decision making and planning purposes

The purpose of monitoring is to recognize success, gaps and solve problems timely.

The steps in problem solving are as follows:

- Identify the problem
- Investigate the causes of problems
- Determine solutions
- Implement solutions

Exercise 6.2

Case 1.

Chala is an officer working at zonal health department. He received a quarterly report on oxygen supply and use from two woredas which highlighted shortage of oxygen supply in their respective health facilities. What steps should he follow to solve the shortage problem?

Case 2.

Sr. Ayalnesh is a nurse in charge of pediatrics ward. During monthly report compiling from the record, there were 200 under-five children admitted to hospital, among which 20 cases had hypoxemia, with SpO2 < 90%, due to ***pneumonia*** and 30 cases due to other conditions. Because of shortage of oxygen in the hospital only 30 children were treated with oxygen. Among children treated with oxygen 25 children came out of hypoxemia.

A. What proportion of the admitted children in the hospital had hypoxemia?
B. What proportion of children with hypoxemia was due to pneumonia?
C. What proportion of children with hypoxemia was treated with oxygen? What problems do you see and how do you solve the problem?
D. What proportion of hypoxic children treated with oxygen came out of hypoxemia?

6.5 Recording, Reporting, Data Flow and Quality Assurance

Based on standardized recording and reporting tools, oxygen therapy data are recorded daily, compiled and reported on monthly basis. Facilities aggregate and review their data and report to their respective next level facility or administrative office monthly. Data aggregation methodology is maintained throughout the reporting chain so that it is possible to disaggregate data by facility type and ownership at all level. Data quality assurance should be done at all levels.

6.6 Supportive Supervision and Review Meetings

Supportive Supervision

Supportive supervision is aimed at improving performance and quality of care through provision of technical and administrative support at all levels. It enhances competence and staff satisfaction. It consists of observation, discussion, guidance, and should be planned and done regularly. Supervision can be done for oxygen program specific or integrated with other program and should be done using standard checklist.

Review Meetings

Review meetings are organized at various levels to create very good opportunity to review the status of program implementation which includes achievements, challenges and come up with agreed upon workable solutions for problems encountered. Furthermore, review meetings are forums for exchange of ideas and experiences among the health professionals and program coordinators. Therefore, as part of all programs M&E, FMOH/RHBs/Zonal health departments/Woredas should review oxygen therapy related issues regularly.

Annexes

Annex 1: Guidelines for the Use of Pulse Oximetry in Children’s Wards

A pulse oximeter can tell you vital information about a sick child. It is the best way to tell if a child needs oxygen, but it is vital to also look for clinical signs of hypoxemia and severe illness.

A.1 When to use a pulse oximeter

Pulse oximeters should be used to monitor:

- Every child or neonate at admission (not just those with pneumonia)
- All children at the time of admission to the ward
- The progress of children, during ward rounds and nursing observations
- Any child who deteriorates with respiratory distress, apnea or decreased consciousness state.

A.2 Using a pulse oximeter

To use a pulse oximeter:

1. Turn the pulse oximeter on.
2. Have the child sitting comfortably in the parent’s lap.
3. Attach the oximeter probe to the finger or toe of the child.
4. Wait until there is a consistent pulse signal (this may take 20–30 seconds).
5. Record the SpO2 on a monitoring chart.
6. If the SpO2 is <90% the child should receive oxygen.

– through nasal prongs or a nasal catheter

– at a flow rate of 0.5–2 litres/minute continuously.

7. Recheck the SpO2.
8. Record the SpO2 on a monitoring chart 15 minutes after giving oxygen.

A.3 Daily monitoring using pulse oximetry

At least once a day, all children who are receiving oxygen should be tested using pulse oximetry:

1. Take the child off oxygen (unless they have severe respiratory distress).
2. Monitor the SpO2.
3. If the SpO2 >90% 10–15 minutes after coming off oxygen, leave off oxygen.
4. Check the SpO2 again in one hour. 5. If the SpO2 is <90%, resume oxygen.
6. Each day, record the SpO2 on the patient’s monitoring chart, and beside it record if there are sufficient supplies of oxygen.
7. Oximetry should be used regularly to monitor any child who develops worsening respiratory distress, apnea, any deterioration in consciousness or any other clinical sign of deterioration.

A.4 Discharge planning

Pulse oximetry can be used to determine when it is safe to send a child home. In most circumstances it is not safe to send a child home when their SpO2 is <90%.

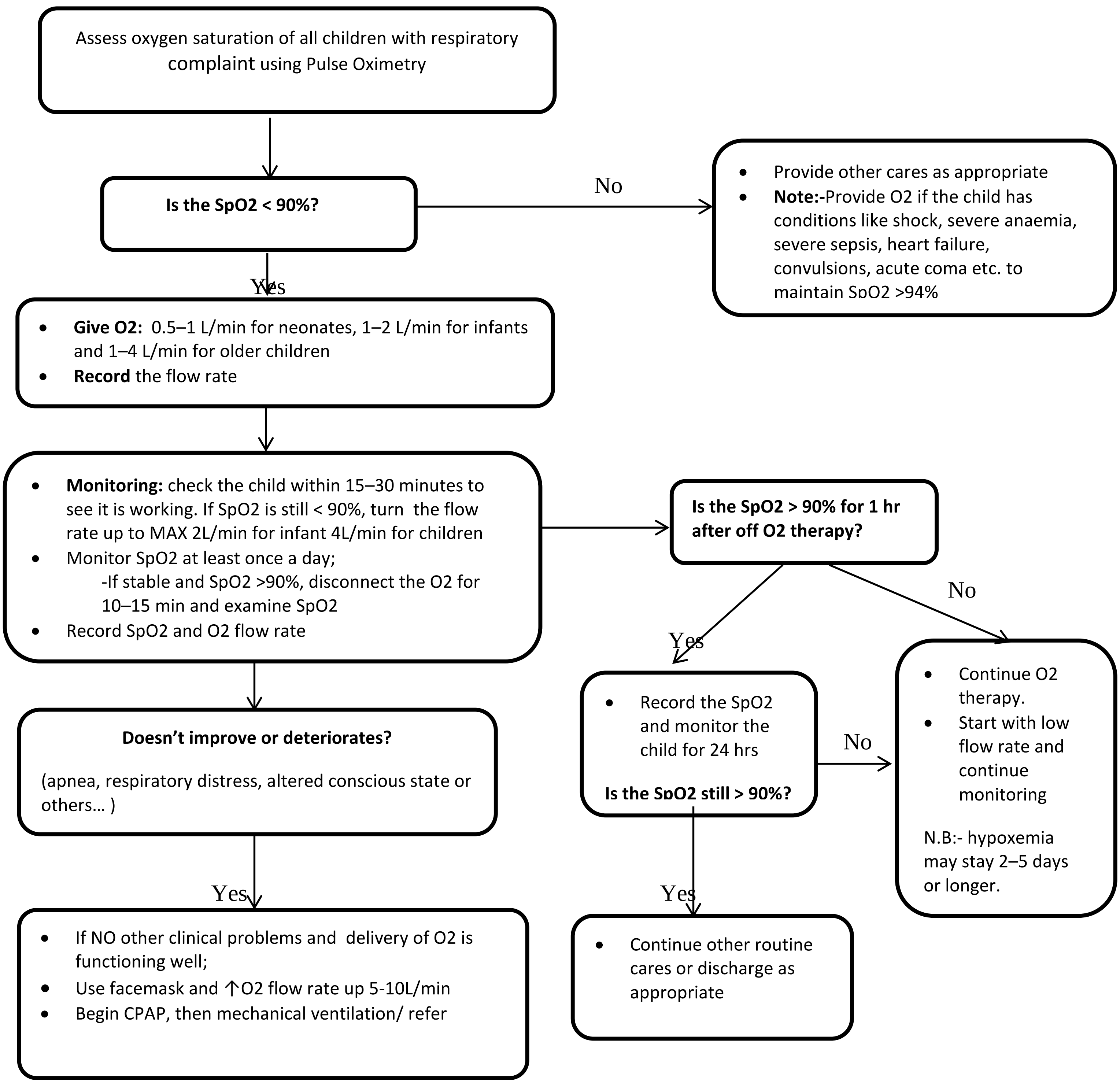
A.5 Care of a pulse oximeter

The pulse oximeter finger probes and leads are fragile, so it is important to look after them carefully. They should not be put on the floor or where they could be stepped on.

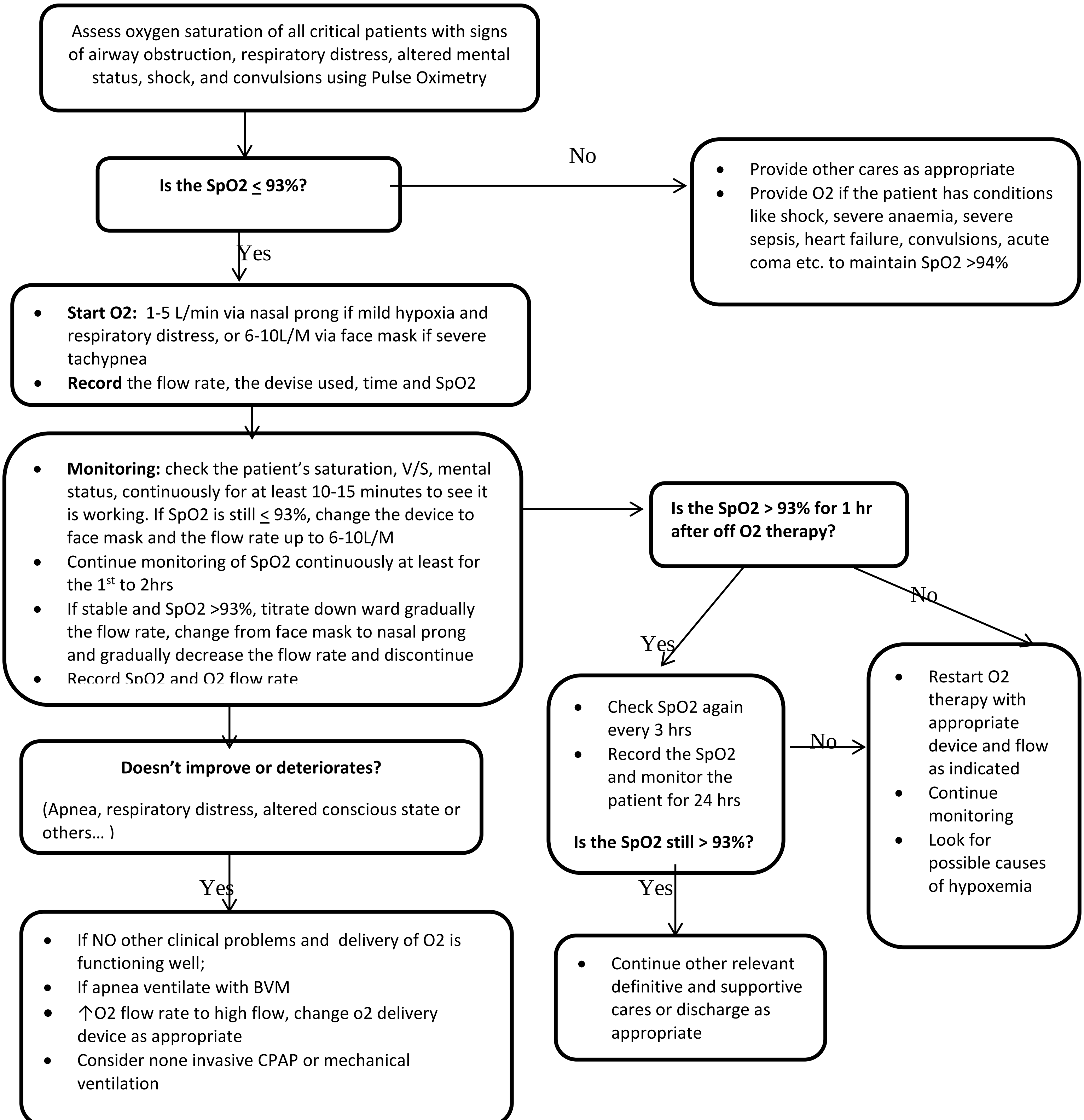
It is important to keep pulse oximeter probes clean so that they do not spread infection from one patient to another. They should be wiped with an alcohol swab between patients, and health workers must always wash their hands before and after monitoring each patient.

Always remember to plug the oximeter into the mains power at regular intervals to recharge the internal battery.

Annex 2: Flowchart for Oxygen Therapy in Children



Annex 3: Flowchart for Oxygen Therapy in Adults



Annex 4: Emergency, Priority and Hypoxemia Signs

EMERGENCY SIGN	PRIORITY SIGN	SIGN OF HYPOXEMIA
Emergency signs include: • obstructed or absent breathing • severe respiratory distress • central cyanosis • signs of shock: cold hands, capillary refill time > 3 s, high heart rate with weak pulse, and low or unmeasurable blood pressure • coma or seriously reduced level of consciousness • convulsions • signs of severe dehydration in a child with diarrhea: lethargy, sunken eyes, very slow return of the skin after pinching or any two of these	Priority signs that must also be recognized are: • **T**iny infant: any sick infant aged < 2 months • **T**emperature: patient is very hot • **T**rauma or other urgent surgical condition • **P**allor (severe) • **P**oisoning (history of) • **P**ain (severe) • **R**espiratory distress • **R**estless, continuously irritable or lethargic • **R**eferral (urgent) • **M**alnutrition: visible severe wasting • **Oedema** of both feet • **B**urns (major) These signs can be remembered from the mnemonic **3TPR MOB.**	Oxygen should be given to children with any of the following signs: • SpO2 < 90% • central cyanosis • nasal flaring • inability to drink or feed (when due to respiratory distress) • grunting with every breath • depressed mental state (i.e. drowsy, lethargic) In some situations, and depending on the overall clinical condition, children with the following less specific signs may also require oxygen: • severe lower chest wall in-drawing • respiratory rate ≥ 70/min • head nodding, i.e. a nodding movement of the head, synchronous with respiration and indicating severe respiratory distress

Annex 5: Oxygen Prong Cleaning & Disinfecting

1. Prepare equipment and put on PPE

- Equipment: detergent (soap) solution; brush (e.g. toothbrush); syringe; Bucket/sink; clean storage container; clean water.
- Put on the PPE (personal protective equipment)

↓

2. Clean prongs with soap and water until visibly clean

- Use standard soap or detergent. Use a small brush (e.g. toothbrush) to brush the prongs under the water. Use a syringe to flush the tubing.
- Cleaning should remove all visible particles. Check they are clean before commencing disinfection. Discard the prongs if they have blood on them.

↓

3. Rinse in clean water to remove all bubbles

- Syringe – use a 10ml syringe to flush the tubing

↓

4. Disinfect using 'Boiling water' OR 'Bleach / Hypochlorite' method

'Boiling water' method

a. Prepare a container of boiling water
b. When the water is visibly boiling, place the entire nasal prongs into the water
c. Leave in the boiling water for 10 minutes

'Bleach / Hypochlorite' method

a. Prepare the equipment: bleach, water, 10L bucket, brush, syringe
b. Prepare the 0.5% hypochlorite solution
c. Use a syringe to flush the tubing with hypochlorite solution, then put the entire nasal prongs into the solution
d. Leave in the solution for 30 minutes
e. Rinse in clean water (use a syringe to flush the tubing)

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5. Dry prongs using oxygen from the concentrator

Wash hands before touching the prongs
Attach the prongs to the oxygen tubing (as you would for a patient)
Leave for 15 minutes, or until there is no moisture remaining in the tubing

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6. Store prongs in a clean container

- Wash hands before touching the prongs
- Store in a clean container (wash the container regularly)

Annex 6: How to Prepare Soapy Water

Annex 7: Monitoring & Evaluation Tools

Hypoxic Patient Registry

Region ____________________Zone __________________Woreda________________Name of Health Facility ________________

Name of Ward/ Department/Unit_________________________________ Month and year ______________

Registration number	Patient Name	Kebele/ Village	Sex	Age	Wt	Date of admission	Patient diagnosed to have hypoxia by: 1. Clinical 2. Pulse oximeter	PaO_2 at admission	Patient received oxygen therapy: 1.Yes 2 .NO	Treatment outcome (1. Cured 2. Improved/on follow up 3. Discharged against medical advice 4. Died)	PaO_2 at discharge	Date of discharge

Monthly Health Facility Summary of Data for Oxygen Therapy

Region ________________Zone______________________ Woreda ___________________ Name of health facility _______________

Name of Ward/Department/unit	Total no of patients seen in the Ward/Department/unit	Sex (total for male and female)		Age range of patients				Diagnosis approach of hypoxia		Total no of patient received oxygen therapy	Treatment outcome for underlying causes (total for each outcome) 1. Cured 2. Improved/on follow up 3. Discharged against medical advice 4. Died (total number)			
		M	F	≤28 days	28 days -1 yr	1 ≤ 5yr	>5yr	Total number with Clinical dx	Total number diagnosed with pulse oximeter		1	2	3	4

Monthly Woreda/Zone/Region Summary of Data for Oxygen Therapy

Region __________________________Zone_____________________ Woreda __________________ Reporting month and Year ____________

Name of facility	Total no of patients seen in the facility	Sex (total for male and female)		Age range of patients				Diagnosis approach of hypoxia		Total no of patient received oxygen therapy	Treatment outcome for underlying causes (total for each outcome) 1. Cured 2. Improved/on follow up 3. Discharged against medical advice 4. Died (total number)			
		M	F	≤28 days	28 days -1 yr	1 ≤ 5yr	>5yr	Total number with Clinical dx	Total number diagnosed with pulse oximeter		1	2	3	4

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