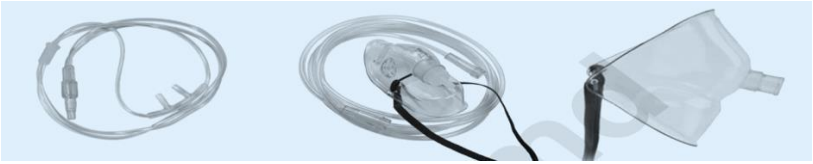
United Republic of Tanzania

Ministry of Health

National Guideline on Oxygen Therapy

2022



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FOREWORD

Oxygen therapy is defined as the administration of oxygen at concentrations greater than that found in the air we breathe. Oxygen therapy is indicated in the management of hypoxemia defined as below normal level of oxygen in the blood. Hypoxaemia is a life-threatening condition that requires early detection and management. Both WHO and the Tanzania National list of essential medicines have identified Oxygen as an essential drug. This guideline reiterates the importance of oxygen therapy, and it should be available from the dispensarylevel to the national hospital and at all relevant points within the health facility.

This guideline aims to standardize the management of oxygen therapy from detection to management of patients with oxygen needs. It also clearly outlines the steps needed in the management of hypoxemia based on the capacity at the facility level and disease severity. While the basic principles of conventional oxygen therapy are almost the same for all patients, some patients with special needs have different indications and thresholds for oxygen therapy, as well as desired targets while on treatment. This guideline has identified these groups and outlined their approach which will enable proper management which will ultimately minimize the rate of complications or deaths emanating from hypoxemia.

In addition, patients who require oxygen therapy are severely or critically ill. They have a life-threatening condition, and often require other care beyond oxygen therapy. The first line, most basic care is known as essential emergency and critical care andshould be provided to all critically ill patients in all healthfacilities in Tanzania. To ensure effective care of patients receiving oxygen therapy, this guideline also aims to standardize the provision of essential emergency and critical care.

Development of this guideline used the participatory approachwhere experts in the emergency and critical care were involved in the development of draft document, review and validation. The experts were gathered from Ministry of Health, National, Specialized and Zonal hospitals, and other partners. Also, biomedical engineers provided valuable contributions in the aspect of maintenance and repair of equipment.

This guideline is expected to be utilized by all health providers involved in patients' management and I urge them to make useof this guideline for early detection and timely effective management of hypoxia. This guideline will be reviewed regularly based on the new research findings on oxygen therapyand feedback from users.

Prof. Abel N. Makubi
Permanent Secretary,
Ministry of Health

ACKNOWLEDGEMENT

The Ministry of Health acknowledges all the contributions from the various stakeholders in the development of this Oxygen Therapy Guidelines. The importance of having this guideline was realized following COVID-19 which exponentially increased demand of oxygen. The surge exposed gaps in oxygen production, distribution, and proper use of oxygen as well as provision of the other aspects of essential emergency and critical care. Health care providers have varying knowledge and skills in oxygen use, the detection and management of hypoxemia was not standardized across the facilities. This guideline will equip health providers with key skills in detection and management of hypoxemia and other physiological derangements.

The ministry appreciates the coordination role played by Dr. Elias M. Kwesi and all staff of the Emergency Preparedness and Response Section. Their efforts in organizing the workshops, developing, and reviewing the manual are highly appreciated.

We also appreciate the technical and financial support from UNICEF during development and finalization of this guideline. Technical contribution by key experts who participated in the technical workshops to develop the guideline is highly acknowledged. These experts hailed from Bugando Medical Center, Benjamin Mkapa Hospital, JKCI, Muhimbili Orthopaedic Institute (MOI), Mbeya Zonal Referral Hospital, Kibong'oto Infectious Disease Hospital, Muhimbili University of Health and Allied Sciences (MUHAS), and Ministry of Health Emergency Preparedness and Response Section.

Prof. Tumaini J. Nagu

Chief Medical Officer.

ABBREVIATIONS

ADPIE	Assessment, Diagnosis, Planning, Intervention and Evaluation.
AVPU	Alert, Verbally responsive, Pain responsive, Unresponsive.
BVM	Bag Valve Mask
COPD	Chronic Obstructive Pulmonary Diseases
CPAP	Continuous Positive Airway Pressure
EECC	Essential Emergency and Critical Care
EMD	Emergency Medicine Department
FiO2	Fraction of Inspired Oxygen
HBOT	Hyperbaric Oxygen Therapy
ICU	Intensive Care Unit
LRS	Low Resource Setting
MoH	Ministry of Health
PORALG	President's Office, Regional Administration and Local Government
PPM	Planned Preventive Maintenance

PSA	Pressure Swing Adsorption
PSI	Pressure per Square Inch
SOP	Standard Operating Procedure
SaO2	Arterial Oxygen Saturation usually measured by blood gas analysis
SpO2	Oxygen saturation measured by pulse oximeters
UNICEF	United National International Children's Emergency Fund
WHO	World Health Organization

DEFINITION OF TERMS

Hypoxia is a condition in which the human body tissues are not oxygenated sufficiently to maintain adequate homeostasis, resulting from inadequate oxygen delivery to the tissues due to either low blood supply or low oxygen content in the blood.

Hypoxemia is a reduction in the partial pressure of oxygen in the blood below 10kPa/75 mmHg, (94%)

There is variation in the range of normal oxygen levels across different settings, thus for the purpose of this guideline the depicted values above should be utilized when describing hypoxemia.

Anoxia is a state of total oxygen deprivation within tissues or organs. It is an extreme form of hypoxia.

Hyperoxia is defined as excess levels of oxygen in body tissue.

Hyperoxemia refers to an excess of oxygen in the blood

Oxygen therapy is defined as the administration of supplemental oxygen at concentrations greater than that found in the air we breathe.

Essential Emergency and Critical Care (EECC) is the first line, most basic care that should be provided to all critically ill patients in all hospitals, including oxygen therapy and other care needed by oxygen-requiring patients.

1. INTRODUCTION

1.1 BACKGROUND

Oxygen is an essential gas that is vital to human life. Oxygen is a life-saving medical gas for treating respiratory illnesses and for managing various health system needs, like emergency obstetric care, surgery, and anesthesia. Hypoxemia, an abnormally low level of oxygen in the blood, can be fatal. It results from complications of common illnesses or surgery and requires oxygen therapy for treatment

The use of supplemental oxygen is required where prescribed and hence no patient should be deprived of it when indicated. This requires understanding of the body's physiology with regard to oxygen uptake and use, the oxygen delivery devices and correct use of various gadgets available in oxygen therapy administration and monitoring. Arterial oxygen saturation is referred to as SaO2 when measured by gas analysis and as SpO2 when measured by pulse oximeter. The normal range of SpO2 at sea level is 97–99%, with a lower limit of 94%.

Patients who require oxygen are severely or critically ill. Critical illness is any acute, life-threatening illness and can occur in anyone irrespective of age, gender, or social status. It has the potential for reversibility if timely care is provided. Critical illness can begin in the community or in health facilities and does not respect traditional divisions into medical specialties. Patients with conditions such as sepsis, pneumonia, eclampsia, hemorrhage, trauma, peritonitis, asthma, and stroke can all develop critical illness. Critical illness is common throughout the world and has high mortality. An estimated 45 million adults become critically ill each year, resulting in several million deaths. All critically ill patients should be provided with oxygen therapy and the other first-line, basic care required to stabilize their vital organ functions and prevent death. This care is known as essential emergency and critical care (EECC). Effective provision of oxygen therapy and EECC has the potential to save many lives.

1.2 INTENDED USERS OF THE GUIDELINE

This guideline is mainly intended for use by all healthcare professionals who may be involved in providing oxygen and EECC. This will include ambulance staff, first responders, paramedics, doctors, nurses, midwives, and all other healthcare professionals who may deal with critically ill or dyspneic patients.

2. OXYGEN SOURCES AND DELIVERY DEVICES

2.1 Oxygen Sources

At facility level, supplemental oxygen can be given to the patients in need through various sources. In limited resources settings (LRS), the three most common sources of medical oxygen in healthcare facilities are: compressed gas cylinders, oxygen concentrators and oxygen plants. A fourth oxygen source, though less common in LRS, is bulk-stored liquid oxygen.

The appropriate choice of oxygen source is multifactorial; it is important to take into consideration the amount of oxygen needed at the health facility, available infrastructure, cost, capacity, and supply chain for local production (and delivery) of medicinal gases, reliability of electricity, access to maintenance services and spare parts.

Table 1. Details of various oxygen sources[1]

Device name	Description	Advantage	Disadvantage	Handling/Safety precautions
Oxygen cylinders:	Oxygen cylinders differ according to the material they are made of, and the amount of oxygen filled. Oxygen gas is compressed and stored in cylinders of	Cylinders provide reliable oxygen at a given pressure and concentration (Not compared to Oxygen concentrators). They do not require electricity, although they	The use of cylinders typically involves transport to and from the bulk supply depot for regular refilling, which could have logistical challenges and	Handle cylinders and their accessories gently and avoid dropping or knocking them over.

[1] WHO-UNICEF Technical Specifications and Guidance for Oxygen Therapy Devices. Geneva.2019

	various sizes (from 1 litre to 50 litres capacity) Can be connected to manifold systems (groups of cylinders linked in parallel) that are piped to areas of the health facility; or cylinders can be used directly within patient areas.	do require several accessories and fittings to deliver oxygen, such as pressure gauges, regulators, flowmeters, and, in some cases, humidifiers.	ongoing cost implications, often leading to unreliable supply in many settings.	Use only designated regulators and gauges specific for oxygen delivery. Do not attempt to repair or alter damaged cylinder or regulators, report the damage to the manufacturer or

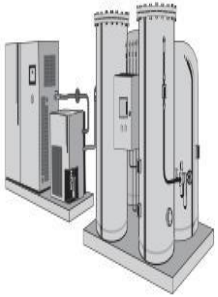
	These cylinders when depleted can be refilled at a certified gas manufacturing plant.			biomedical engineers. Store cylinders in designated location, specific for cylinders (no other items allowed). Storage rooms should be dry and free from excessive high

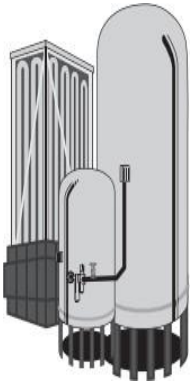
				temperatures, highly flammable substances like gasoline, kerosene, sparks or flames. All cylinders should be labeled and marked with appropriate

				color code and collar. Should have specified pressure in Pressure per inch square (PSI)
Oxygen concentrators	An oxygen concentrator is a self-contained, electrically powered medical device designed to concentrate oxygen from ambient air. Utilizing	Concentrators can provide a safe and cost-efficient source of oxygen, but they do require a source of continuous and reliable power and regular	They cannot operate when power supply is cut off that is why concentrators should also have a reliable power	Always use stable supply of electricity and preferably designated Voltage

	PSA technology, an oxygen concentrator draws in air from the environment, extracts the nitrogen, and can produce a continuous source of 95.5% concentrated oxygen. Oxygen concentrators are portable and can be moved between clinical areas, but they are also often set up to be	preventive maintenance to ensure proper functioning.	supply 24/7 or back-up power. It is best practice to also have cylinders as a backup supply. Cannot provide high flow and high-pressure oxygen, and for this they are not ideal for use in Mechanical ventilators	stabilizers to avoid damage to the device Ensure cleaning and avoid spillage of blood or secretions as they may reduce air filtration and hence reduce efficiency of

	stationary fixtures in patient areas.		(Convectional concentrators can deliver maximum flow rates between 5 and 10 L/min).	Oxygen production.
Oxygen plant (central oxygen supply system):	An oxygen plant is a large, onsite, central source of oxygen that is piped directly to terminal units within patient areas or sub-central manifold	Reliable, large-scale production of Oxygen for use even in high oxygen demand periods. Best source of oxygen supply at high pressure to equipment such as	Note that oxygen plants require a reliable source of power. They can easily fail if power supply is erratic. It is best practice to also	SOPs for preventive maintenance should be considered

	systems built at the health facility. Plants can also be set up to refill cylinders for oxygen distribution or backup oxygen supply.	anaesthetic machines and ventilators. A key advantage of pipeline systems is that they obviate the need for handling and transporting heavy cylinders between hospital wards	have cylinders as a backup supply. Expensive to install and they need regular maintenance from certified Engineers and designated service parts.	Personnel dedicated to run the oxygen plant should have appropriate training.
Liquid oxygen	Facilities can be equipped with large bulk liquid	Self-vaporization, meaning that a power supply is not required.	Expensive and requires high technical	Avoid extreme

	oxygen tanks that are refilled Periodically by a truck from a supplier. The liquid oxygen tank supplies a centrally piped system throughout the health facility.		Knowledge and large well-ventilated spaces.	Temperature and humidity. It is best practice to also have cylinders as a backup supply

Recommendations regarding sources of oxygen

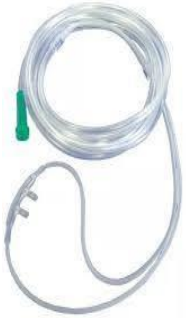
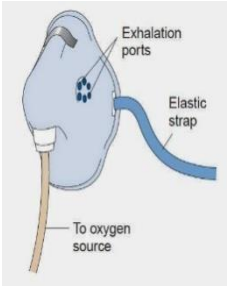
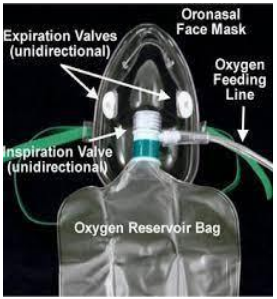
- Fire extinguishers should be easily available and accessible.
- To every source of oxygen, there should be an alternative supply in case of breakdown.
- All devices/accessories for oxygen sources of different sizes should be available.
- Oxygen concentrator should be available at all health facility levels as backup supply of oxygen.
- Biomedical engineers should be available at all regional hospitals and budget allocation should be done to enable them to serve even the lower health facilities.
- All health facilities with mechanical ventilators and anaesthetic machine should have oxygen plant or manifold starting from district hospital level to the higher health facilities.

2.2 OXYGEN DELIVERY DEVICES

These are devices that are used to deliver oxygen to the patient at variable percentage and flow. These delivery methods can be

used in correlation with the source of oxygen used (cylinder, concentrator or piped system). Devices for oxygen delivery differ in cost, efficiency on use, and ability to provide there quired fraction of inspired oxygen (FiO2). Fraction of inspired oxygen is the percentage of oxygen that a patient inhales. The choice of appropriate delivery device will thus depend on clinical needs and device capabilities.

Table 2. Oxygen Delivery Devices[1]

Nasal Cannula/Prongs	Simple Face Mask	Non-Rebreather mask with Reservoir	Venturi Masks	High flow nasal cannula
				

• Can deliver 1-6L/min at approximately 24-44% FIO2. • It is best for mild hypoxemia. • The FIO2 depends on oxygen flow and patient's minute volume and inspiratory flow	• Delivers flows from 5-10L/min at approximately 40% - 60% FiO2. • Flow must be at least 5 L/min to avoid build-up of CO2 and resistance to breathing.	• Delivers oxygen at concentrations between 60% and 90% when used at a flow rate of 15 L/min • The delivered oxygen concentration is variable and will depend on the mask fit and the patient's breathing pattern	• Effective and efficient in quantifying fraction of inspired oxygen to match patient's need • Different types and colors, each one correlating in different FiO2	It delivers adequately heated and humidified medical gas at up to 60 L/min of flow and is considered to have a number of physiological effects: reduction of anatomical dead space, PEEP effect, constant fraction of

and pattern of breathing. • Comfortable and easily tolerated. • No re-breathing. • Low-cost product. • Higher flow rates > 4l/min may lead to dryness and nasal irritation.		• These masks are most suitable for emergency use in patients in whom carbon dioxide retention is unlikely	• Especially useful in COPD or other underlying lung pathology where amount of delivered oxygen needs to be precise • In general Venturi masks require higher	inspired oxygen, and good humidification.

			flows to deliver desired FiO2 compared to other delivery devices.	
Recommendation: • It should be available at all levels of health facilities.	**Recommendation:** • It is strongly recommended that these	**Recommendation:** • It should be available at the level of District	**Recommendation:** • It should be available at the level of	**Recommendation:** To be used for respiratory support only for critically ill patients and when

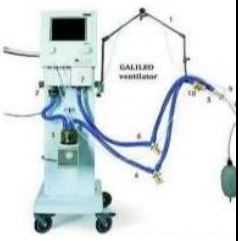
• When maximum flow rates are attained, change to a higher capacity device.	masks are used at specified flow rates to prevent the risks for hypercapnia (CO2 build up). • It can be fatal in patients at risk of hypercapnic	hospital and above.	District hospital and above. • When maximum flow rates are attained, change to a higher capacity device.	there are very high flows and large reserves of oxygen available.

	respiratory failure.			

All above devices come in different sizes for every age and body type. Please ensure that appropriate sizes are available and used for your patients.

Note that, there are devices that are used for Assisted Ventilation in conjunction with oxygenation in circumstances where the patient can not initiate breathing particularly in respiratory failure. These include bag valve masks, CPAP and mechanical ventilators.

Table 3. Oxygen Delivery devices in Assisted Ventilation

Bag valve masks (BVM)	CPAP	Mechanical ventilator
		

2.3 DEVICES FOR OXYGEN REGULATION AND CONDITIONING

Devices covered in this section include flowmeters, flow-splitting devices and humidifiers. These devices play different roles in the regulation and conditioning of oxygen gas for the delivery to the patients.

2.3.1 Flowmeters

Flowmeters measure and control the rate of oxygen flow to a patient, either from a concentrator, a high-pressure cylinder, or a terminal unit of a piped system. Concentrators have built-in flowmeters so there is no need to purchase them separately. Three types of gas flowmeters are described in this section: Thorpe tube, Bourdon gauge and Dial/click. All three types come in various flow ranges and the choice of appropriate flowmeter will depend on clinical needs and device capabilities.

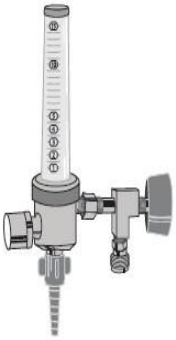
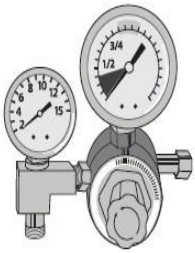
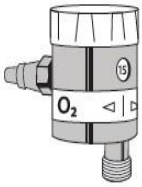
	Thorpe tube (rotameter)	Bourdon gauge (single and multiple stage)	Dial/click (flow restrictor)
General characteristics			
Illustration/image			
Description	A variable orifice flowmeter consisting of an upright clear tube containing a float, which rises and falls in relation to gas flow. There are two types: uncompensated and compensated for back pressure. Requires a separate pressure-reducing valve.	A fixed-orifice flowmeter, whereby gas enters a chamber and as the pressure is increased, a coiled copper tube straightens out and the needle valve turns to read a higher unit. This device integrates a pressure-reducing valve.	A fixed-orifice flowmeter calibrated to deliver flow in specific increments, adjusted with a click dial. This device integrates a pressure-reducing valve.
Clinical application and/or use case	• For all inpatient clinical areas in health care facilities where oxygen therapy is provided. • Recommended for use with terminal units (wall outlets) of piped distribution systems or for large stand-alone cylinders.[a]	• Ideal for ambulance transportation. • Recommended for use with smaller portable cylinders common for emergency and ambulance transportation.[a]	• For all inpatient clinical areas in health care facilities where oxygen therapy is provided (terminal units – either wall outlets or ceiling mount drops of piped oxygen distribution systems in hospitals). Also common with portable cylinders for intrafacility, interfacility or air transport.

Figure 1. Description and Comparison of flowmeters[1]

Recommendation for flowmeters

- it is recommended to use Thorpe tube as it is user friendly, simple to apply and durable

2.3.2 Flow Splitting Devices

A flow-splitting device provides an effective and efficient means of economically administering medical oxygen to multiple patients from a single source, when supply permits. Flow-splitting devices may be used with concentrators, cylinders, and centralized systems for both pediatric and adult patients. The two main devices for splitting oxygen flow discussed here are the *flowmeter stand* and the *dual flowmeter.*

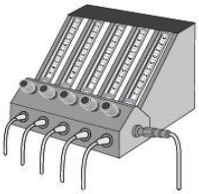
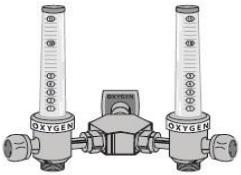
	Flowmeter stand	Dual flowmeter
General characteristics		
Illustration/image		
Description	A device that distributes medical oxygen by splitting output flow from a single oxygen source across multiple outlets through independently regulated flowmeters, to meet individual patient needs.	A device that distributes medical oxygen by splitting output flow from a terminal unit (wall outlet) oxygen source through two independently regulated flowmeters, to meet individual patient needs.
Clinical application and/or use case	Splitting oxygen flow for inpatient oxygen therapy, particularly paediatric or neonatal wards where lower flow rates are used. One inlet can be divided into several independently regulated outlets for up to five patients. Set flow rates cannot exceed output flow rate of the concentrator.	Splitting oxygen flow for inpatient oxygen therapy. One inlet can be divided into two independently regulated outlets for up to two patients.
Appropriate level of health system (and relevant medical units)	Primary, secondary, tertiary (anywhere oxygen therapy is provided; health centre, general hospital, district hospital, provincial hospital, regional hospital, specialized hospital).	Secondary, tertiary (requires piped terminal unit).

Figure 2. Flow-splitting devices[1]

2.3.3 Oxygen Humidifiers

These are medical devices that can be integrated into oxygen delivery systems to humidify supplemental oxygen. Humidification is generally not necessary when oxygen is delivered at relatively low flow rates through nasal prongs or nasal catheters. When oxygen is delivered at higher-than-standard flow rates, or when methods of oxygen delivery bypass the nose, such as when nasopharyngeal catheters are used, humidification is needed. Generally, two kinds of humidifiers are available.

Non-heated humidifiers: non-heated bubble humidifiers are simple, low-cost devices that add water to oxygen gas by bubbling the gas through water at room temperature. These humidifiers function by allowing pressurized oxygen gas to flow down a tube into the bottom of a water container. The gas escapes from the distal end of the tube forming bubbles that gain water vapor as they rise to the surface.

Figure 3. Non-Heated Oxygen Humidifier

Heated humidifiers:

Heated humidifiers consist of a heat source and a humidification chamber (a refillable transparent container). The built-in heater warms the water in the chamber to add moisture to the airstream as it passes over the water surface. The heat is adjustable for moisture level. Heated humidification is needed for CPAP and for high-flow nasal cannula (HFNC) oxygen therapy.

Heated humidifiers are more effective at humidifying gas than non-heated ones. However, heated humidifiers are moderately

expensive compared with non-heated humidifiers and require a continuous power supply.

Figure 4. Heated Humidifier

Recommendation

- It is strongly recommended that every health facility with mechanical ventilation services should use heated humidifiers.

3. BASIC CARE AND MAINTENANCE OF OXYGEN EQUIPMENT

With an increasing scale up of the oxygen production and distribution to all level of the healthcare system, number of oxygen producing equipment and delivery devices has enormously increased. Proper care and maintenance of these devices is crucial to maximize usage and longevity. This chapter will cover basic care and troubleshooting of oxygen production and delivery devices.

3.1 Oxygen Concentrators

An Oxygen Concentrator is a medical equipment which has the mechanism of capturing oxygen from within the surrounding atmosphere to provide patients with reliable oxygen supplementation. Two techniques of oxygen enrichment by the oxygen concentrators are in common use namely Pressure Swing Adsorption (PSA) technique and membrane gas separation technique. The former, PSA, utilizes molecular sieve in zeolite to trap atmospheric nitrogen leaving oxygen to pass

through. The PSA technology is economically reliable for small scale oxygen generation and is the one in common use.

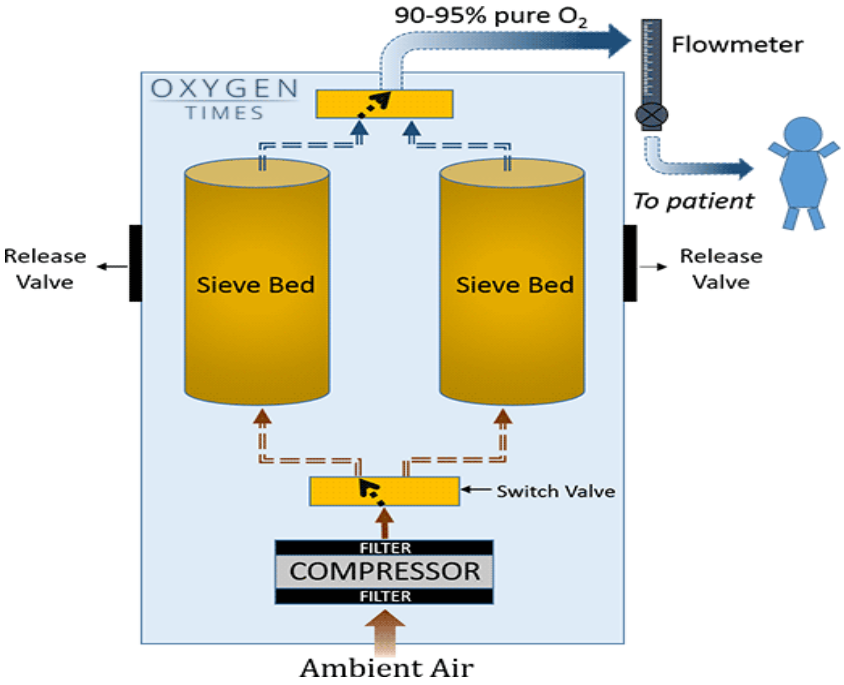


Figure 5. Mechanism of oxygen concentrators

Factors affecting oxygen flow

The oxygen concentrator should deliver oxygen concentration at between 82 – 96%. However, several factors might impair this expected delivery of oxygen. These include:

- Clogged filters due to lack of regular maintenance
- Dust contamination of Zeolite making the absorb moisture.
- Defective tubing and leaks or blocked flow
- High relative humidity

Indicators and alarms

The oxygen concentrator shall sound alarm under the following conditions:

- Low oxygen concentration, below 82%
- No flow
- High/low pressure
- Low battery
- Power supply failure
- High temperature

Key user maintenance

To keep the oxygen concentrator in good condition, the user must do regular checks and cleaning. The cleaning procedures should be integrated in the daily or weekly routines of the respective hospital departments.

Table 4. Oxygen Concentrators User Maintenance

Daily	Weekly
Change water of the humidifier daily and rinse the humidifier. (Use distilled water only, Fill humidifier up to the mark with distilled water) Clean outside of machine by using disinfectant (alcohol-based solution) with a soft, dry cloths. Disinfect humidifier part by immersing them in disinfectant solution between patients.	Wash the intake air filter and dry it (do not use hot water) Let the concentrator run for half an hour every week if it is not in regular use. Check humidifier sill is in good condition

Table 5. Planned Preventive Maintenance for Oxygen Concentrators

No	PPM Procedures	Action to betaken
1	Check air Inlet Filter	Gentle clean with clean water and allow it to dry. If damage replace with the new one.
2	Check the motor and the pump for proper operation	Clean the outer part of the motor and cooling fan with the soft brush and compressed air
3	Measure the percentage of oxygen purity by using oxygen gas analyser	If the purity is below 85% replace the zeolite canisters with respect to final product filter.
4	Check the connectors and tubing system for any leakage	Tighten the connectors and the tubing system or replace if damaged
5	Check the bacterial filter	Replace when the recommended operating hours has been attained
6	Check final product filter	If it restricts the flow of oxygen replace it

7	Check the flow meter and the adjustment knobs	Clean and tighten in case of any loose
8	Check the Power supply cord and plug	Insulate or replace the damaged power cord and plug
9	Check floating ball up and down movement	Tighten tubing system or replace if damaged. Replace valves if broken. Replace control card
10	Check humidifier bottle and tube	Wash in warm soapy water, rinse thoroughly, and replace.
11	Check alarm system battery	An audible alarm should sound when machine is turned on or off. Replace 9V battery if damage
12	Check machine physical appearance (housing, casters, knobs etc.)	If damage fix them
NOTE: Never attempt to open zeolite canisters		

3.2 OXYGEN CYLINDERS

Oxygen cylinder is medical equipment used for storing pressurized oxygen to be used by patients who need it. Oxygen cylinders are cylindrically shaped metal containers used to store oxygen compressed at very high pressures. Cylinders usually come in different sizes with different storage capacity. Oxygen cylinders for medical use are usually black colored with a white top; in some cases, small cylinders may be colored entirely black. The black color helps to differentiate it from other substances that are stored in similar containers. Cylinders are fitted with customized valves (either bullnose or pin-index type) with valve guards, which are opened with valve keys.

A flowmeter measures the flow rate of a liquid or a gas. In healthcare facilities, gas flowmeters are used to deliver oxygen at a controlled rate either directly to patients or through medical devices. Oxygen flowmeters are used on oxygen tanks and oxygen concentrators to measure the amount of oxygen reaching the patient or user.

Table 6. Oxygen Cylinder User Maintenance

Daily care	Routine care
After use close flow meter regulator and cylinder valve. Remove facial mask/nasal catheter from the patient. Disconnect, discard/decontaminate the nasal catheter. Then open the flow meter regulator to release out any excess oxygen held in the system when the hissing sound stops close the flow meter regulator	Check whether the Oxygen cylinder set is in good working condition. Daily dump dusting using soapy water and leave it dry. Check humidifier bottle if it has distilled water (2/3) between maximum and minimum or required level. Distilled water to be changed weekly, then tap water changed daily. Check tubing for cracks and deterioration. Ensure the right key and spanner is available. If empty, label and take to the store for refill. Use secluded designated areas to refill medically treated cylinders according to acceptable

	health and service standards.

Always keep oxygen cylinders in a cool, dry place. Never allow them to be exposed to extreme temperatures. Always keep cylinders in an upright position and secured.

Table 7. Troubleshooting Oxygen Cylinders and Flowmeters

Faulty	Possible cause	Solution
No oxygen is flowing	Empty cylinder Flow meter knob or cylinder valve is closed. Faulty regulator	Replace cylinder Open valves, then check flow meter registers flow Close all valves and replace regulator
Leakage from cylinder or flowmeter	Cylinder is not connected to pressure regulator properly Faulty or missing washer between regulator and cylinder Flowmeter seal damaged or loose Cylinder faulty	Tighten all fittings Replace washer Tighten flowmeter Label Faulty and return to manufacturer
Leakage cannot be located	Leakage too small to be heard	Apply detergent solution (NOT oily soap) to joints. Bubbles will show at leak point.

		Clean/replace washer and tighten at that joint.
Flowmeter ball not moving, yet oxygen is flowing	Faulty flow meter	Close all valves, disconnect flowmeter, and clean inside. Reconnect and test. If problem persists, replace flowmeter
Pressure gauge does not show pressure, yet oxygen is flowing	Faulty pressure gauge.	Replace pressure gauge.

3.3 FLOWMETERS

Flowmeters are needed to measure and control the rate of oxygen flow to a patient, either from a concentrator, a high-pressure cylinder, or a terminal unit of a piped system. Concentrators have built-in flowmeters so there is no need to purchase them separately.

Table 8. Troubleshooting for Flowmeters

Problem or fault	Possible cause	Solution
No oxygen is flowing	Flowmeter knob or cylinder flow valve is closed.	Open valves, and then check meter registers flow.
Leakage from cylinder or flowmeter	Flowmeter seal damaged or loose.	• Check for leaks at the connection between the flowmeter and the oxygen source, at the connection between the oxygen flowmeter and the oxygen delivery device, and along the oxygen delivery device to the patient. • If leak occurs at the regulator, try tightening the connection. • If leak occurs at the terminal unit, try another flowmeter. If a different flowmeter still leaks, the leak is

		probably at the terminal unit.
Leakage cannot be located	Leakage too small to be heard.	• Apply detergent solution (NOT oily soap) to joints. Bubbles will show at leak point. • Clean/replace washer and tighten at that joint.
Flowmeter ball not moving, yet oxygen is flowing	Faulty flowmeter.	• Close all valves, disconnect flowmeter and clean inside. Reconnect and test. • If problem persists, replace flowmeter.
Flowmeter fails to deliver expected flow or behaves erratically	Faulty flowmeter.	• Check the output with a calibrated flow analyser. • If necessary, send it for repair to a biomedical engineering unit or replace the flowmeter.
Patient is on oxygen and the patient's	Patient is not getting oxygen flow.	• Check that oxygen is flowing from the delivery device.

oxygen saturation is declining		• Check that the oxygen tubing is connected to the flowmeter. • Check that the correct oxygen flow is set.

3.4 OXYGEN DELIVERY DEVICES

Nasal canula/prongs, catheters, and facemasks

These are single-use products and should be disposed after use by a patient.

3.5 PULSE OXIMETRY

Pulse oximetry is a simple and non-invasive method to indirectly measure the oxygen saturation of Haemoglobin in arterial blood (SpO2). Pulse oximeters are the accepted global standard for detecting and monitoring hypoxaemia.[1] The basic maintenance and troubleshooting of the fingertip, hand-held and tabletop oximeters is given below.

Care and preventive maintenance of fingertip oximeter

- Run functionality tests before applying to the patient e.g. displays and probe lights are

illuminated.

- Clean and disinfect the fingertip oximeter after each patient tested, according to the manufacturer's instructions and IPC protocol specific to the setting.

- When it is not used, store in appropriate place (well ventilated and secured in readily accessible storage case).
- Do not use expired or short life span batteries. Otherwise:
    - Frequent battery replacements will be required, increasing running costs.
    - Performance will be reduced when the battery is low.
    - Changing batteries will be a routine activity for the operator/nurses leading to delayed patient care, when low battery indicator is displayed.

Refer to user and service manuals for more guidance.

Table 9. Troubleshooting and repair of fingertip pulse oximeters.

Problem or fault	Possible cause	Solution
Display suddenly turns off	• The oximeter is automatically powered off when no signal is detected (time to shut off may differ by model; consult user manual).	• Relocate the probe on another finger or restart the oximeter and be sure the signal strength is strong enough for stable display.
	• The power of the battery is too low.	• Replace the battery.
Display lockup	• Display does not appear to change (you should see a change to the pleth wave or pulse indicator if the device is on the finger).	• Reposition finger or relocate on another finger. Remove and replace battery. If the problem persists, contact technical service of the provider.

SpO2 or pulse rate does not display	• Oximeter is not placed correctly on the finger.	• Reposition the device.
	• Patient's SpO2 value is too low to be measured.	• Shield the probe from excessive ambient light. • Try device on another patient for comparison to ensure it is not a faulty device.
Unstable SpO2 or pulse rate	• Finger might not be placed deep enough into the clamp probe.	• Retry by inserting the finger to the end.
	• Excessive movement.	• Prevent movement of the finger, hand or body.
No readings	• Low pulse quality (no reading).	• Reposition finger. • Warm finger by rubbing. • Select another finger.

The oximeter will not turn on or blank display	• No battery or low power of battery.	• Replace battery.
	• Battery installed incorrectly.	• Reinstall the battery or check the polarity/direction of the battery.
	• The display might be damaged.	• Replace with new device.
	• Dirty/corroded contact.	• Decontaminate the contact.
	• Finger positioned incorrectly.	• Shift finger to activate the device.
	• Device may be too cold.	• Allow device to sit at room temperature for at least 30 minutes

Table 10. User care and preventive maintenance of handheld and tabletop pulse oximeters.

Schedule period	Activities	Check
Daily	Cleaning	Clean and disinfect exterior surfaces of the pulse oximeter according to the manufacturer's instructions and IPC protocol specific to the setting. Clean and disinfect the probe after each patient tested, according to the manufacturer's instructions and IPC protocol specific to the setting. Discard single-use probes after each use.
	Visual checks	Check all parts are present and connected.

		Ensure that probes which are not in use are not left hanging or lying about where they can be damaged. Check cables are not twisted and remove from service if any damage is visible.
	Function	Check operation on healthy subject if in doubt of function.
Weekly	Cleaning	Unplug, remove equipment cover (if applicable), clean and disinfect exterior surfaces of the pulse oximeter according to the manufacturer's instructions and IPC protocol specific to the setting. Replace cover.

	Visual checks	Tighten any loose screws and check parts are fitted tightly. If plug, cable or socket are damaged, replace.
	Function	Check operation of all lights, indicators and visual displays. Check probe disconnection alarm.
Every 6 months		Biomedical engineering unit preventive maintenance check required (refer to service manual)

4. MEDICAL OXYGEN THERAPY

4.1 INDICATIONS FOR OXYGEN THERAPY

During both medical and surgical clinical care oxygen therapy is indicated in patients with **Hypoxia/Hypoxemia**. Hypoxia/hypoxemia occurs frequently in diseases such as lower acute respiratory tract infections, upper airway obstruction, and chronic obstructive pulmonary diseases (COPD). Hypoxemia can also occur in conditions like birth asphyxia, respiratory distress syndrome, sepsis, heart failure, cardiac arrest, trauma, carbon monoxide poisoning, obstetric conditions and during surgery.

Majority of patients with hypoxia end up with **Hypoxemic respiratory failure** following delay in treatment or poor/no response to oxygen therapy. This can be recognized by presence of the following signs of severe respiratory distress such as:

- Hypoxaemia (SpO2 < 90%) despite escalating oxygen therapy

- SpO2/FiO2 < 300 while on at least 10L/min oxygen therapy, where heart failure is not the primary cause

Lack of oxygen leads rapidly to dysfunction of the organ systems and if not timely corrected may lead irreversible damage and death. Therefore, hypoxemia is a life-threatening condition that requires early detection and treatment.

4.1.1 Initial Assessment

Health care providers should assess all acutely ill patients by measuring the vital signs which include respiratory rate, pulse rate, blood pressure, conscious level and temperature and assessing circulating blood volume and anaemia. Vital signs should be checked on-arrival to a health facility, at regular intervals on the wards for all in-patients, and more frequently for any patient who is critically ill or at risk of deteriorating. Best practices in routine and emergency care of patients are based on the need to prioritize patients care through triaging using **ABCDE approach**. The ABCDE approach provides a framework for the systematic and organized evaluation of acutely ill

patients to rapidly identify and intervene for life-threatening conditions:

A – Airway: check for and correct any obstruction to movement of air into the lungs

B – Breathing: ensure adequate movement of air into the lungs

C – Circulation: evaluate whether there is adequate perfusion to deliver oxygen to the tissues;

check for signs of life-threatening bleeding

D – Disability: assess and protect brain and spine functions

E – Exposure: identify all injuries and any environmental threats and avoid

The ABCDE approach can be used for the initial assessment and treatment of patients in acute medical and surgical emergencies both prehospital and in –hospital settings. When performing the initial primary survey/ABCDE approach providers should pay special attention to patients presenting

with emergency signs that may call for oxygen therapy, these include:

- Obstructed or absent breathing.
- Severe respiratory distress, Altered pattern of respiration (e.g., labored breathing, agonal breathing
- Nasal flaring
- Use of accessory muscles of respiration, intercostal recession, chest indrawing
- Auscultation-added sounds and or limited air entry
- Central Cyanosis
- Carbon monoxide poisoning.
- Severe anemia
- During anesthesia- short term therapy e.g. post anaesthetic or surgical procedure
- Increased metabolic demand for example severe trauma, burn, shock, myocardial infarction.

- Signs of shock, defined as cold extremities (hands and/or feet) with capillary refill time >2 sec and weak and fast pulse.
- Coma (or seriously reduced level of consciousness).
- Seizures.
- Severe anemia

A substantial number of patients may present with Evidence of hypoxemia i.e., **SPO2< 94% or PaO2 <75mmHg** with or without majority of the above signs and symptoms.

Generally, for patients who present with above conditions and meet diagnostic criteria for hypoxia immediate and timely initiation of oxygen therapy should be undertaken. If the measured SPO_2 falls to below 94% consistently in a patient at all levels of health care a trained provider should initiate oxygen therapy while the patient is undergoing urgent resuscitation, awaiting medical review and definitive care.

The **SAMPLE** approach is a standard way of gathering the key history related to an illness or injury. Sources of information

include: the ill/injured person, family members, friends, bystanders, or prior providers. SAMPLE stands for:

S: Signs and symptoms

The patient/family's report of signs and symptoms is essential to assessment and management.

A: Allergies

It is important to be aware of medication allergies so that treatments do not cause harm.

Allergies may also suggest anaphylaxis as the cause of acute symptoms.

M: Medications

Obtain a full list of medications that the person currently takes and ask about recent medication or dose changes. These may affect treatment decisions and are important to understanding the person's chronic conditions.

P: Past medical history

Knowing prior medical conditions may help in understanding the current illness and may

change management choices.

L: Last oral intake

Record the time of last oral intake and whether solid or liquid. A full stomach increases the risk of vomiting and subsequent choking, especially with sedation or intubation that might be

required for surgical procedures.

E: Events surrounding the injury or illness

Knowing the circumstances around the injury or illness may clarify the cause, progression and severity.

4.1.2 Initiation of oxygen therapy

The basic principles of oxygen therapy are the same for almost all patients with regards to the indications and thresholds for initiation of oxygen therapy. However, the desired targets while on treatment may differ for different patient groups.

Regardless of different patient groups, the following are general steps to be followed when initiating oxygen therapy.

Communicating with Patients and Relatives on Oxygen Therapy

Oxygen therapy like any other medical intervention is based on client centered care approach. The patient and relatives have the right to information regarding treatment options, advantages, and the disadvantages in order to obtain an informed consent for preferred treatment options.[2]

Before initiation of oxygen therapy, health care providers are advised properly communicate with the patient and their relative with regards to the following key issues:

- Give reassurance.
- Clearly explain the problem
- Explain the goal/target intended to solve the impending problem

[2] Girardis M, Busani S, Damiani E, Donati A, Rinaldi L, Marudi A, Morelli A, Antonelli M, Singer M. Effect of Conservative vs Conventional Oxygen Therapy on Mortality Among Patients in an Intensive Care Unit: The Oxygen-ICU Randomized Clinical Trial. JAMA. 2016

- Give instructions on the proper use of oxygen devices used
- Instruct patient/relative on position that will promote quick recovery e.g., prone position
- Allow room for patient/Relative to ask question and explain his/her feeling to relieve anxiety.
- Instruct about precautions to take including eye protection especially if there is leakage of oxygen.
- Give counseling about common side effects about oxygen delivery devices and how to attend to them.

Preparations

Selection of oxygen source to use, oxygen delivery method and appropriate oxygen delivery devices depending on patient assessment findings and set target of care.

See table 2 and 3 for guidance on choices of the delivery devices and their flow rate capacity

Generally, the Oxygen delivery method (Low flow or High flow) and devices for use are selected depends on:

- age of the patient
- oxygen requirements/therapeutic goals
- patient tolerance to selected interface
- humidification needs

Low flow delivery method

Low-flow systems include:

- Simple face mask.
- Non re-breather face mask (mask with oxygen reservoir bag and one-way valves which aims to prevent/reduce room air entrainment).
- Nasal prongs (low flow).
- Tracheostomy mask.
- Tracheostomy Heat Moisture Exchanger (HME) connector.
- Isolette - neonates (usually for use in the Neonatal Intensive Care Unit only).

High flow delivery method

High flow systems include:

- Ventilators.
- CPAP/BiPaP.
- Face mask or tracheostomy mask used in conjunction with an Airvo2 Humidifier.
- High Flow Nasal Prong (HFNP).

Note: Oxygen therapy should not be delayed in the treatment of life-threatening hypoxia. Commence therapy while making the necessary preparations.

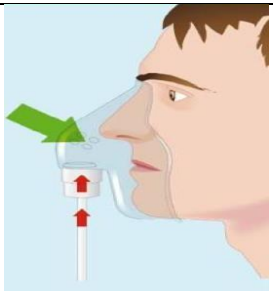
Provider of oxygen therapy and institute monitoring for decision on effectiveness of the intervention and need for escalation ofcare or weaning from oxygen therapy.

Titrate oxygen therapy by using appropriate or recommended devices to match the degree or severity of hypoxia.

Table 11. Choice of oxygen delivery devices by SPO_2.

Range	SPO_2	Delivery Choice
Normal	95%-100%	none
Mild hypoxia	91%-94%	Nasal cannula/Simple face mask (SFM)
Moderate hypoxia	86%-90%	SFM/Non-rebreather mask or Bag Mask Valve (BVM)
Severe hypoxia	<85%SPo	Non-rebreather mask or BMV

Table 12. Oxygen flow rate and choice of devices.

		
O_2 dose 1–5 L/min	**O_2 dose 6–10 L/min**	**O_2 dose 10–15 L/min**
FiO_2 estimate 0.25–0.40	**FiO_2 estimate 0.40–0.60**	**FiO_2 estimate 0.60–0.95**
Nasal cannula	**Simple face mask**	**Face mask with reservoir bag**

4.1.3 Monitoring of oxygen therapy

All patients on oxygen therapy should be monitored for improvement or deterioration to allow for de-escalation or escalation of care. Combined use of both clinical monitoring of changes in patient's signs and symptoms and use of monitoring devices is recommended. In addition to routine patient

monitoring, oxygen saturation measurement and/or blood gas analysis are recommended to guide oxygen therapy escalation or de-escalation. This allows for objective decisions regarding change of therapy in case of deterioration or improvement of patient condition.

Three most common devices for monitoring a patient on oxygen therapy are:

- Pulse oximeters
- Patient monitors
- Blood gas analyzer

NB: See detailed account of the devices and their use in table 6

Monitored Normal Values and SpO2 Targets in oxygen therapy

- Partial pressure of arterial oxygen (PaO_2) 75 -100 mmHg (SpO_2 >94%), - children/adults, PaO_2 (50 - 80 mmHg)/SPO_2 (85% - 95%) neonates.
- Partial pressure of arterial CO_2 ($PaCO_2$) 35 - 45 mmHg children/adults.
- pH = 7.35 -7.45

4.2 MONITORING DEVICES USED DURING OXYGEN THERAPY

4.2.1 Pulse oximeters:

The use of pulse oximeter is a rapid, easy, and noninvasive way of measuring SpO_2. Pulse oximeters extract and display SpO_2 and heart rate from the photoplethysmographic waveform. One side of the pulse oximeter probe contains 2 light-emitting diodes that transmit 2 wavelengths of light, and the other side contains a photodetector. This allows the device to record percentage of Haemoglobin saturated with oxygen therefore estimating amount of oxygen in tissues.

The probe of pulse oximeter can be clamped on a finger, earlobe, or toe to obtain readings. SpO_2 may be measured using tabletop pulse oximeter, portable handheld pulse oximeter, self-contained fingertip pulse oximeter and bedside patient monitor.

How to use pulse Oximeters

i. Place clip like device (probe) on a finger, earlobe or toe

ii. Obtain the reading from the device; ensure the good quality of waveform on the device display prior obtaining results.

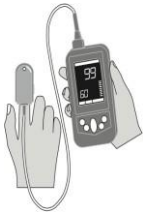
iii. Document results

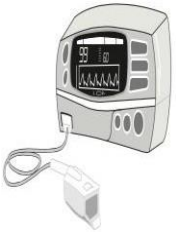
iv. Leave the probe in place if the patient needs continuous close monitoring.

v. If no need for continuous monitoring, remove the probe and keep the oximeter in a safe place.

vi. Be aware that multiple factors can affect the accuracy of a pulse oximeter reading, such as poor perfusion, skin pigmentation, skin thickness, skin temperature, current tobacco use, and use of fingernail polish.

Table 13. Description and Types of Pulse Oximeters

Type of pulse Oximeter	Advantages	Disadvantages	Recommendation
Self-contained finger grip 	• Portable • No cables • Relatively cheap	Poor grip in neonates Easy to wear, get lost/misplaced. Less accurate	Be available across all health care facilities
Portable handheld 	Portable but more operational capacity	For reusable probe can wear easily	May be best option when long hours of monitoring needed. Be available at all levels

Tabletop 	Most accurate and uses electricity	Not portable, expensive	Best for units (emergency, labor ward, HDUs) Recommended to be available at all levels in designated units

Accuracy of pulse oximeter readings can be reduced by poor circulation (hypotension), colored nails, skin pigmentation, cold peripheral skin, ambient light as well as low battery. Anemia and carbon monoxide poisoning might also give you false readings. For reliable SpO_2 readings you must see good quality of waveform and high perfusion index.

4.2.2 Bedside patient monitor

This device measures SpO_2 and pulse rate. It also has cardiac parameters monitoring (blood pressure, heart rate, ECG) as

well as respiratory rate. It can be a simple bedside monitor or advanced depending on the need. It displays numbers as well as waveforms.

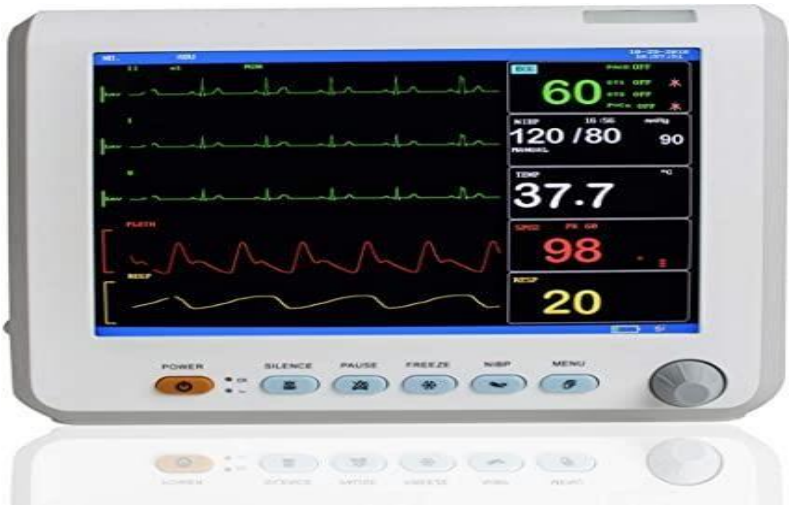


Figure 6. Bedside patient monitor

Recommendations and safety.

Bedside patient monitors are best used for continuous monitoring of patients. They allow multiple parameters to be measured at once, so it is much detailed and easy way to monitor patients. They are recommended to be available from health center level and above.

Bedside monitors can be a source of electrical hazards if the cables are worn and not replaced properly. Also, readings can be interfered if diathermy is used concurrently.

4.2.3 Arterial blood gas (ABG) monitoring

Arterial blood gases monitoring can be done using a blood gas analysis machine. It analyzes and provide standard patient's partial pressure of oxygen (PaO_2), carbon dioxide ($PaCO_2$) and levels of pH in acid-base content. PaO_2 provides information on the oxygenation status, and $PaCO_2$ offers information on the ventilation status (chronic or acute respiratory failure).

The ABG analysis is performed using blood from any point of circulatory system i.e., artery, vein, or capillary. Arterial blood gas tests refer to an ABG analyses of blood taken from an artery.

Figure 7. Blood gas analyzer machines

Recommendation and safety:

- It needs proper training on how to use and interpret results. Recommended to be available from district hospital level and above, where biomedical technical support is available.

4.3 MAINTENANCE, SCALE-UP AND WEANING OF OXYGEN THERAPY

4.3.1 Maintenance Oxygen Therapy

After the initial resuscitation phase, and in the absence of any emergency signs, supplemental oxygen therapy should continue aiming for SpO2 >92%. If emergency signs persist, a target of SpO2>94% should be set. Continuous or intermittently SpO2 check is mandatory to evaluate the patient if the desired target is achieved.

The flowcharts in Annexes 9.2, 9.3 and 9.4 provide a stepwise guide on how to initiate oxygen therapy, the type of device to be used and how to adjust according to your patient's needs.

Note that;

i. Clinical signs are not reliable indicators of hypoxemia.
ii. After every change, monitor the patient for 3-5 minutes.
iii. Continue to assess response through regular measurements of SpO2.
iv. Patients on flow rates >5L/min will require continuous SpO2 monitoring until target SpO2 is achieved and maintained for at least 15 minutes.
v. Only use the minimum flow rate required to achieve your target SpO2 as hyper oxygenation can cause oxygen toxicity.
vi. Close monitoring of patient on oxygen therapy is important to ensure patients safety, optimal treatment and cost-effective use of oxygen as a resource.
vii. Any patient who is on oxygen therapy should be monitored continuously or as per specific disease requirement. Monitoring can be done via peripheral oxygen measurement (SpO2) or invasive measurement of partial pressure of oxygen in arterial blood (PaO2) by using an arterial blood gas analyzer machine.

4.3.2 Patients who Deteriorate despite Oxygen Therapy (SCALE UP).

Some patients may deteriorate while undergoing treatment and such patients may present with a dropping SpO2 or increasing respiratory rate. Health care provider should respond by doing the following:

- Call for help/ask for urgent senior medical review, if available.
- Repeat ABCDE approach and, if needed, manually assist ventilation if indicated.
- Deliver increasing oxygen as per above.
- Check to make sure oxygen supply and all equipment is working properly:
    - Is the measurement correct?
    - Does the cylinder still have sufficient oxygen?
    - Check that you are using the right type of mask for the flows given.

    - Check that oxygen is flowing out of the prongs or face mask – hold the end close to your hand and you will feel the airflow.
    - Check that the reservoir of the non-rebreather mask is full.
    - Check that there are no leaks in the connections or oxygen tubing.
- If available, check arterial blood gas to evaluate ventilation.
- Consider initiation of more advanced respiratory support if available and appropriate for your patient.
- If more advanced respiratory support is not available or not indicated, positioning and comfort measures may be considered[3]

Consider early referral to higher level health facility if the patient shows no improvement.

[3] Slutsky AS. Consensus conference on mechanical ventilation. Part I. European Society of Intensive Care Medicine, the ACCP and the SCCM. Intensive Care Med 1994;20:64–79

4.3.3 Weaning Oxygen Therapy

Weaning process starts by lowering the oxygen concentration in steps of 2 L/min if the patient is clinically stable and the oxygen saturation is persistently above the target range, or if it has been in the upper zone of the target range for at least 1 hour. Weaning oxygen therapy also involves the process of stepping down the FiO2 by reducing the capacity of the oxygen devices to deliver oxygen. For example, if patient was initially on non-rebreather mask switch to simple face mask and thereafter to nasal cannula oxygen at minimum flow rates (1-2Lpm for adults, 0.5Lpm for children, 0.25Lpm for newborn).

Oxygen therapy should be stopped once a patient is clinically stable on low-concentration oxygen and the oxygen saturation is within the desired range on two consecutive observations (within a space of 4 hours). **The flow chart in Annex 9.5: "how to wean oxygen"** provide a stepwise guide on how to wean oxygen therapy.

Oxygen saturation on air should be monitored continuous or every after 5 min after stopping oxygen therapy. If it remains in

the desired range, it should be rechecked at 1 hour. If the oxygen saturation and vital signs remain within satisfactory range at 1 hour, the patient has safely discontinued oxygen therapy.

If the saturation falls below the patient's target range on stopping oxygen therapy, restart the lowest concentration that maintained the patient in the target range and monitor for 5 min. If a patient requires oxygen therapy to be restarted at higher concentration than before to maintain the same target saturation range, the patient should undergo a clinical review to establish the cause for this deterioration

4.3.4 Nursing considerations (using ADPIE)

ADPIE, also known among healthcare professionals as the nursing process, gives nurses the tools to apply their knowledge in a clinical setting, solve problems and expand their skill set. ADPIE is an acronym that represents the five stages of the nursing process: assessment, diagnosis, planning,

implementation, and evaluation.[4] Nurses use ADPIE to help improve patients' health by providing them with the appropriate level of care, resolving their problems and monitoring them on a regular, individual basis. ADPIE also guides nurses in creating and adjusting care plans for patients

Nursing diagnosis

North America Nursing Diagnosis Association (NANDA) defines impaired gaseous exchange as a condition where there is an alteration in the balance between the exchanges of gases in the lungs. Impaired gaseous exchange can be caused by physiological damage to the alveoli, circulatory compromise, lack of oxygen supply, insufficient availability of blood. This can be assessed by both subjective and objective data.

Subjective data: Restlessness, Orthopnea, Lightheadedness, Fatigue

Objective data: Cyanosis, coughing, hypoxia, abnormal ABG, hypercapnia, accessory muscles use, hypoxemia, abnormal lung

[4] https://nurse.org/education/nursing-process/

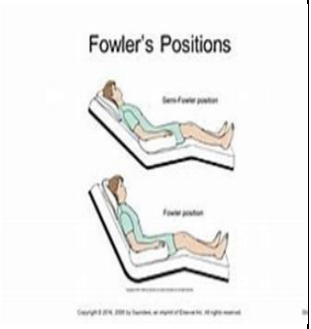
sounds, abnormal vital signs, abnormal chest x-ray, decreased hemoglobin and hematocrit, past medical history such as COPD, asthma, decreased oxygen saturation, shallow rapid breathing.

Expected outcome: Patient will demonstrate adequate oxygenation with ABGs within normal limits, patient will have vital signs within normal limits, patient will have clear lung sounds, patient will deny any difficulty in breathing, patient will be free of any signs of respiratory distress, patient will demonstrate intact mentation.

Table 14. Interventions and rationale[5]

Assessment	Nursing intervention	Rationale
Assess characteristics of respiration (rate, rhythm, depth, use	Assess respiration, (rate, rhythm, depth, use of accessory muscles, oxygen saturations, skin colour, vitals)	Baseline respiratory assessment, can see if interventions you do are effective or if

[5] http://www.mayoclinic.org/symptoms/hypoxemia

of accessory muscles)		they are getting worse
Monitor the effects of position changes on oxygenation	Position patient in high fowler's position for increased oxygenation and ventilation. Consider the position that patient's condition allows. 	Keeping the patient sitting upright helps with proper gas exchange and better oxygenation into the lungs. Frequent positioning also prevents pooling of secretions in the lungs
	Administer medication as ordered /needed e.g., pain medications, bronchodilators	Bronchodilators open the airways to allow patient to breath better. Steroids help with

		inflammation. Pain medications help in cases of chest discomforts (be careful of respiratory depression)
	Give supplemental oxygen as needed	May need to give patient supplemental oxygen if not writhing desired range
	Cough /deep breathing / encourage exercises that patient can accommodate	Proper exercises help get more oxygen to the body's cells and help keep lungs clear

	Suction equipment by bedside in emergency	This helps in cases where patient is having difficulty in clearing airway, suction to help maintain oxygenation
Note blood gas (ABG) results as available and note changes	Obtain ABG'S /Laboratory results/Possible chest Xray	ABGs can indicate if the patient is improving or deteriorating with current therapy

4.4 SAFETY CONCERNS DURING OXYGEN THERAPY

4.4.1 Oxygen toxicity

Oxygen toxicity is a condition which results from the harmful effects of inhaling molecular oxygen at increased partial pressures. Prolonged exposure to above-normal oxygen partial pressures, or shorter exposures to very high partial pressures, can cause oxidative damage to cell membranes, alveolar collapse, retinal detachment, and seizure

Central nervous system toxicity is caused by short exposure to high partial pressures of oxygen at greater than atmospheric pressure while pulmonary and ocular toxicity result from longer exposure to increased oxygen levels at normal pressure.

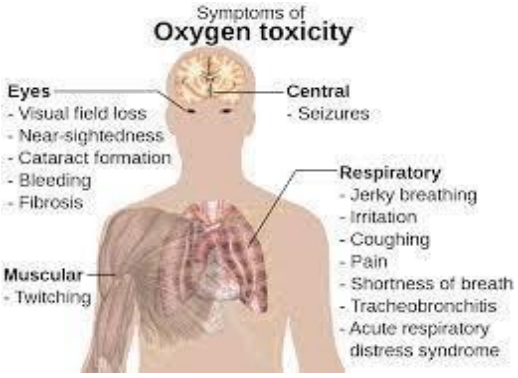


Figure 8. Symptoms of oxygen toxicity

Those at particular risk for oxygen toxicity include hyperbaric oxygen therapy patients, patients exposed to prolonged high levels of oxygen (>24 hours), premature infants, deep underwater divers undergoing hyperbaric oxygen therapy and patients using medications like amiodarone and bleomycin or exposed to radiation since there is sensitization of the lung to oxygen such that toxicity may occur at a lower FiO2 than in healthy lungs.

There is no specific therapy for pulmonary oxygen toxicity, therefore prevention remains the cornerstone of management by reducing exposure to increased oxygen levels. This can be attained by reducing FiO2 to the lowest achievable fraction to obtain the targeted arterial oxygen tension or peripheral oxygen saturation and avoid hyperoxia when practicable.

4.4.2 Other Potential complications of oxygen use

CO2 Narcosis - This occurs in patients who have chronic respiratory obstruction or respiratory insufficiency which results in hypercapnia (i.e., raised PaCO2). 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 PaCO2.

Pulmonary Atelectasis can occur in patients receiving 100% oxygen for a long time or those receiving oxygen therapy without humidification thus resulting in blockage of part of the airway by mucus plug leading to absorption of the trapped gases without recruitment of the affected alveoli.

Pulmonary oxygen toxicity - High concentrations of oxygen may damage the alveolar membrane when inhaled for more than 48 hours resulting in pathological lung changes.

Retinopathy of Prematurity (ROP) - An alteration of the normal retinal vascular development, affecting premature neonates (<32 weeks' gestation or 1250g birthweight), which can lead to visual impairment and blindness.

4.4.3 Health and Safety guidance for safe use of oxygen cylinders:

To ensure safety of both health care providers and patients, the following need to be observed during use and transportation of oxygen cylinders.

- All cylinders must be properly secured during transit.
- No smoking in the vicinity of cylinders.
- Cylinders must be checked regularly for leakage.
- Cylinders must be kept out of direct sunlight.
- Green warning triangle 'compressed gas' should be displayed on the vehicle.
- Cylinders should never be lifted by the neck.
- They should only be changed by suitably trained personnel.
- Apart from portable cylinders, all cylinders should be moved using a cylinder trolley.
- Cylinders must be turned off/fully closed when not in use.

4.4.4 Safe use, reuse and disposal of oxygen delivery devices

The use of oxygen delivery devices should follow the manufacturer instructions in orders to ensure efficient oxygen delivery and to avoid harm to the patient. Instructions of whether the device is of single use should be strictly adhered to and its disposal to according to IPC guidelines. The reusable devices should be decontaminated according to manufacturer instructions and IPC guidelines.

5. ESSENTIAL EMERGENCY AND CRITICAL CARE

Essential Emergency and Critical Care (EECC) is the effective, universal, and feasible care that should be provided to all critically ill patients in all hospitals in the world. This includes all patients who require oxygen therapy. Provision of EECC as well as oxygen therapy to these patients has the potential to save many lives at low-cost. EECC is the simple care that can save lives in critical illness – the "first tier" of care for critical illness – and should be always available in all parts of the hospital.

Patients requiring oxygen therapy, will often have other deranged vital signs that require other clinical processes of EECC, and they should be taken into consideration. The clinical processes are the treatments and actions in EECC, consisting of the *identification* of critical illness, the immediate and ongoing *essential care* of critical illness and the *general processes* of care. Ensuring ready availability of all the hospital requirements for the clinical processes will result in timely care and increase chances of survival. The clinical processes in EECC can be seen

in Annex 9.8 and the requirements for hospitals to be ready to provide EECC in Annex 9.7.

6. SPECIAL CONSIDERATIONS FOR OXYGEN THERAPY

This chapter covers oxygen needs and indications for special groups which need a slightly different approach in oxygen administration.

6.1 Oxygen Therapy for Pregnant Patients

Indications for initiation of oxygen therapy may include common conditions similar to the rest of the population, as well as obstetric emergencies such as antepartum or postpartum hemorrhage, eclampsia, etc. Due to the key physiological changes of pregnancy below, special consideration must be given to pregnant patients.

- Blood volume increases by 40–50% causing dilutional anemia.
- Cardiac output increases by 30–50%.
- Heart rate increases by 10–20 beats per minute (bpm).
- Increased oxygen consumption to 20–40% above non-pregnant levels.

- There is decreased lung residual volume and functional residual capacity by 15% and 20% respectively caused by pregnancy hormonal influence and elevation of the diaphragm.
- There is capillary engorgement of the nasal mucosa.
- Baby is completely dependent on placenta for oxygen, nutrition, and waste removal.
- Placenta is dependent on maternal blood cardiac output (500–800 mL of blood or 17% cardiac output goes to uterus every minute).

Therefore;

- Decreased oxygen reserve can lead a pregnant patient to rapid desaturation during apnea and more susceptible to effects of hypoxemia than non-pregnant individual.
- When the pregnant mother is very sick, blood flow may move away from uterus to support vital organs, and therefore put the baby in risk of hypoxemia.

- If maternal oxygen or blood pressure decreases, the placenta will not be able to maintain adequate perfusion or oxygenation and the baby will become distressed.

6.1.1 Recommendations for oxygen therapy in pregnant women

1) Pregnant women presenting with hypoxemia/hypoxia should receive oxygen therapy as any other seriously ill patients, with a target oxygen saturation of 94–98%.

2) Pregnant women above 20 weeks' gestation, should be positioned in left lateral tilt, manual uterine displacement (ideally to the left) or in full left lateral position to improve cardiac output and oxygen delivery if the patient presented with the following.

    i. *risk of cardiovascular compromise* (e.g., following trauma and vaginal bleeding).

    ii. *evidence of hypoxemia* associated with reduced consciousness or

iii. requiring cardiopulmonary support or resuscitation.

3) Pregnant woman in labor should receive supplemental oxygen when there is evidence of maternal hypoxemia/hypoxia with targeted range of 94 -98 % (or 88 - 92% in women who are hypercapnic respiratory failure).

4) It should be noted that, pregnant women have tendency to desaturate and fall blood pressure during spinal anesthesia, thus supplemental oxygen should be given and initial resuscitation with fluid should be done prior spinal anesthesia.

6.2 OXYGEN THERAPY FOR NEONATES, INFANTS AND CHILDREN.

Oxygen therapy in neonates and infants, particularly when they are born preterm, should reflect the fact that in the first hours of life, their body is adapting from intrauterine life to breathing on their own.

Special consideration should be given to the following:

- Some babies may not be able to breathe on their own when they are born. In this case resuscitation with positive pressure through bag valve mask is needed. The American Academy of Pediatrics recommends.[6]
    a. During neonatal resuscitation at birth via bag valve mask:
        - ventilation at the rate of 30-60 b/min (1 breath in every 1-2 second) in room air, for term babies and
        - 10 L/min at 30% FiO_2 for preterm babies.
    b. Following initial resuscitation, FiO_2 should then be titrated with a blender, based on minutes of life and target SpO_2 levels, (note: wait 5-10 minutes to make decision).
- Babies during their first few hours have lower normal oxygen saturation than older new-born and infants. Healthy term babies usually reach oxygen saturation (SpO_2) of 90 – 95% by 15 minutes after birth. If this is

[6] Esther Kim, Margaret Nguyen; Oxygen Therapy for Neonatal Resuscitation in the Delivery Room. Neoreviews September 2019

not achieved, oxygen therapy should commence at 0.5-1L/min and target this exact range of SpO_2.

- In pre-term babies, SpO_2 should be maintained ≥ 88% and no higher than 95% to prevent eye damage (retinopathy of prematurity).
- Several conditions including apnea of prematurity that may lead to hypoxemia occur more frequently in neonates.

Oxygen therapy in children outside the neonatal period follows the same basic principles and steps outlined earlier.

Special consideration is given to

- The need for child-specific equipment's (appropriately sized masks, nasal prongs, BVM).
- The decision to initiate oxygen therapy and the monitoring of the patient on oxygen therapy, should be based on clinical parameters per age and size.
- Respiratory and systemic infectious and non-infectious conditions may cause hypoxemia.

- Lower oxygen flow requirements in children call for use of flow splitters and flow meters that provide oxygen at flows of 0-2L/min.
- Caution when using face masks in children due to interference with feeding and their high oxygen flow requirement.

Oxygen should be given to children with any of the following signs:

- SpO_2 < 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).
- Severe lower chest wall indrawing.
- Respiratory rate ≥ 70/min.
- Head nodding or bobbing.
- Obstructed or absent breathing.

- Severe respiratory distress.
- Signs of shock.
- Convulsions, coma, or reduced level of consciousness.
- Signs of severe dehydration in a child.

Therefore, it is important to deliver oxygen using systems that are capable of accurately titrating the fraction of inspired oxygen (FiO_2) that is provided. Thus, at dispensary levels, health Centre levels, and District levels where they may not have advanced oxygen delivery devices such as CPAP masks, Venturi masks, they may use Nasal prongs, Simple Face Masks, Non-rebreather facemask for titrating oxygen level (FiO2) as guided here below.

Refer to table 2 in oxygen delivery devices.

6.3 Oxygen Therapy for Patients with Type II (Hypercapnic) Respiratory Failure

Type II Respiratory Failure is defined as failure of the breathing system to remove CO_2 from the body or a measurable rise in

partial pressure of arterial carbon dioxide ($PaCO_2$) above 50 mmHg. Usually, it is associated with hypoxemia.

Patients at risk of hypercapnic respiratory failure includes:

- Patients with known or suspected COPD
- Patients with bronchiectasis.
- Severe lung scarring from old tuberculosis (especially with thoracoplasty).
- Morbid obesity (BMI>40 kg/m2).
- Patients with neuromuscular disorders
- Any patient on home mechanical ventilation
- Overdose of opioids, benzodiazepines or other drugs causing respiratory depression.

Due to their high risk of hypercapnic failure and respiratory acidosis, these patients should be managed cautiously, aiming for oxygen saturations of 88-92%. Targets should increase to 92-96% only when hypercapnia has been ruled out. Identification of these patients require through history and physical examination, blood gas analysis and/or capnography. Management may require early escalation to non-invasive

ventilation when and where this is deemed appropriate and likely to increase chance of survival.

6.4 Oxygen Therapy in Anesthetized patient.

Oxygen is an essential part of safe anesthesia. Hypoxemia occurs in about 30% of all surgical cases in the early postoperative period, and it is recommended that all anesthetized patients receive supplemental oxygen, which has been demonstrated to reduce the incidence of postoperative hypoxemia by over 90%.[7]

Oxygen is used during surgery and in recovery to prevent or treat acute hypoxemia, which may be brought on by compromised ventilation or by respiratory depression from medications, including anesthetics, and which may have worsened effects due to postoperative inflammatory response.

[7]Mangipudi, S, Leather A, Seedat A, Davies J. Oxygen availability in sub-Saharan African countries: a call for data to inform service delivery. Lancet Global Health. 2020;8(9):e1123–e1124.

It is recommended that

- In any operating theatre there should be two or more sources of Oxygen and airway equipment as back up for induction and maintenance of anesthesia during Surgery and in the recovery room.
- Patients who are subjected to General anesthesia must be preoxygenated prior to Intubation. Preoxygenation depends on the spontaneous breathing of 100% oxygen, which denitrogenates the functional residual capacity (FRC) of the lungs.[8]

Postoperative patients are susceptible to hypoxemia because of

- incomplete lung re-expansion, reduced chest wall and diaphragmatic activity caused by surgical injury and pain,
- consequences of hemodynamic impairment,

[8] Kang H, Park HJ, Baek SK, Choi J, Park SJ. Effects of preoxygenation with the three minutes tidal volume breathing technique in the elderly. Korean J Anesthesiol. 2010 Apr;

- residual effects of anesthetic drugs (most notably neuromuscular blockade) which may result in atelectasis, ventilation–perfusion mismatch, alveolar hypoventilation, and impaired upper airway patency among others
- Postoperative shivering may also increase oxygen consumption, thereby increasing the risk of hypoxemia
- Prolonged hypoxemia may promote serious consequences, including arrhythmias, myocardial ischemia, and cognitive dysfunction.

Thus, a post operative care unit/ recovery room must have two or more oxygen sources.[9]

6.5 Oxygen Therapy in Palliative Care

When the curative measures of the underlying conditions are not possible, options of care considered should include:

[9] Suzuki, S. Oxygen administration for postoperative surgical patients: a narrative review. j intensive care 8, 79 (2020).

- Curative-focused goals, aiming to treat any potentially reversible conditions, i.e., antibiotics for infections.
- Comfort-focused goals, aiming to manage symptoms where death is the anticipated outcome of the natural course.
- It may be at the hospital or at home-based care after clinical evaluation.
- The decision for home-based oxygen therapy must be made in a tertiary or specialized hospital by a specialist.

Thorough counseling of the patient and caretakers or family should be conveyed of the natural course of the illness and the role of oxygen therapy in palliative care. There is evidence that oxygen may have a useful role in the palliation of breathlessness as intervention with either oxygen or air induces some sense of relief. [10]

Recommendations

[10] Fardy HJ. Oxygen therapy in palliative care. NPJ Prim Care Respir Med. 2016 Jan

- Oxygen use in palliative Care patients should be restricted to patients with SPO2 consistently < 90% or patients who report significant relief of breathlessness from Oxygen. In non-hypoxemic patients, opioids and Nonpharmacological measures should be tried before oxygen.
- In general, there is no rule for the monitoring oxygen saturation or PaO2 in comfort focused care in the last few days of life. If the patient appears comfortable oxygen levels are irrelevant and should not influence care.
- When death is imminent, in the absence of respiratory distress, oxygen should not be routinely given even when severe hypoxemia is present.

Oxygen therapy for the symptomatic relief of breathlessness in palliative care patients is more complex than the simple correction of hypoxemia, Thus, consider the following issues:

- Early involvement of palliative care specialists and physiotherapists.

- As breathlessness is a multifactorial sensation, a comprehensive assessment of contributing factors (such as anxiety) should be carried out.
- Low-dose opioids should be considered because they are effective for the relief of breathlessness in palliative care patients.
- A trial of a hand-held fan to help relieve breathlessness is recommended prior to trial of oxygen.
- Oxygen use must be tailored to the individual and a formal assessment made of its efficacy for reducing breathlessness and improving quality of life for that person.
- Oxygen therapy should not be continued in the absence of patient benefit or where its disadvantages (e.g., discomfort of masks or nasal cannulae, drying of mucous membranes) outweigh any symptomatic benefit.

6.6 Oxygen Therapy During Patient Transport.

All clinical staff providing direct clinical care for patients during transportation should have immediate access to oxygen and an oximeter. It is recommended the following oxygen delivery devices should be available in pre-hospital settings where oxygen is administered.

- High concentration reservoir mask (non-rebreather mask) for high-dose oxygen therapy.
- Nasal cannula (preferably) or simple face mask for medium dose oxygen therapy.
- Venturi mask for patients with known previous hypercapnic respiratory failure with inappropriately high arterial blood oxygen values.
- Tracheostomy masks for patients with tracheostomy or previous laryngectomy.

Ambulance personnel should plan how much volume (amount) of oxygen will be needed by a patient while considering the distance (or specifically time) to be covered by the referral and

the oxygen flow rate (L/min) that will need to be given to the patient.

> e.g., An ambulance from Musoma to Mwanza will take 222 km to be covered on 3 hours at an oxygen flow rate 10 L/min to maintain SpO2 >90%, will need a minimum of 1800 Liters of oxygen in a cylinder.

The oxygen saturation should be monitored continuously until the patient is stable or arrives at hospital for a full assessment. The oxygen concentration should be adjusted upwards or downwards to maintain the target saturation range. Document the oxygen consumption of the patient, assessment, vital signs and event(s) occurred enroute for proper handover at the receiving facility.

7. ADVANCED OXYGEN THERAPY TECHNIQUES

7.1 HYPERBARIC OXYGEN THERAPY (HBOT)

This is the type of oxygen therapy used to speed up healing of tissue which are starved for oxygen. The goal is to fill the blood with enough oxygen to repair tissues and restore normal body function.

7.1.1 Types of hyperbaric oxygen chambers.

Monoplace chamber.

This is a chamber built for 1 person. It's a long plastic tube that looks like MRI machine. The patient slips into the chamber. It's slowly pressurized with 100% oxygen. These services can be provided from zonal level hospitals.

Multi-place chamber

This chamber or room can fit two or more people at once. The treatment is largely the same, the difference is that people breath pure oxygen through masks or hoods. These services can be provided from zonal level hospitals.

Indications

- Carbon monoxide poisoning or cyanide poisoning
- Severe anemia
- Decompression sickness
- Air or gas embolism
- Crush Injury, compartment syndrome and thermal injury
- Clostridial myositis and myonecrosis (gas gangrene)
- Arterial insufficiencies for example in central retinal artery occlusion
- Intracranial abscess
- Necrotizing soft tissue infection
- Chronic ulcers e.g., diabetic foot ulcer
- High altitude sickness

Contraindications

- Un-treated pneumothorax
- Upper respiratory infections like otitis media and sinusitis
- In COPD patients, HBOT may cause apnea, and increase risk of seizure.

7.2 EXTRA-CORPOREAL MEMBRANE OXYGENATION (ECMO)

Extracorporeal Membrane Oxygenation (ECMO) is one of the most advanced techniques of oxygen therapy used in the care of critically ill patients with acute respiratory and/or circulatory failure. During ECMO the patient blood is drained, pumped, and oxygenated outside of the body, then returned to the body thus, allowing the patient's heart and lungs to rest. ECMO is provided using an ECMO machine which temporarily replace the function of the heart and lungs recovering from severe damage or failure.

ECMO care is an important component of any health care facility that serves as a tertiary center for complex cardio-

pulmonary pathologies. Ideally, such facilities need to have the capacity to provide ECMO services to cater for patients in need of this service.

Indications for ECMO therapy

ECMO is used as rescue oxygenation modality in various clinical care setting including the following:

- Acute respiratory failure unresponsive to lung protective mechanical ventilation.
- Cardiogenic shock caused by pump failure unresponsive to conventional medical therapy.
- ECMO catheterization support following surgery for congenital heart disease
- Elective use of ECMO to support pediatric ablation procedures

The GoT is in the process of establishing this service in the country in the near future.

8. CONSIDERATIONS FOR OXYGEN THERAPY DURING DISASTER AND PANDEMICS

To ensure effective coordination and optimal availability of oxygen during the pandemics, there is a need to ensure availability of adequate plans and effective coordination structures. In case of rapid surge of oxygen use during the epidemic or pandemic, contingency planning at the facility should be as follows:[11,12]

- All Infection prevention and control efforts should be mobilized to halt the transmission cycle further thus decrease the surge of cases e.g., masking, avoiding mass gathering, physical distancing, hand hygiene and mass immunization of available vaccines.
- Judicial use of oxygen, in acutely ill patients, there are strong recommendations to titrate oxygen therapy to

[11] Shrestha GS, Lamsal R. Rational Use of Oxygen in COVID-19 Pandemic - Are We Doing Enough? JNMA J Nepal Med Assoc. 2021

[12] PAHO/WHO. Good Practices in the Rational and Effective Use of Oxygen. Preliminary document 3.1, December 2021

target peripheral oxygen saturation (SpO_2) no higher than 96% and to avoid starting oxygen therapy if SpO_2 is already 93% or higher. The above target may be reduced even further to 88-92% in a rapidly evolving surge.

- Maintain oxygen flows <15L/min. In a rapidly evolving surge, all flows given through a standard delivery interface (not high-flow device) may be further reduced to a maximum of 10 L/min.
- Encourage use oxygen concentrators. Where needed, more than one oxygen concentrators can be connected to provide higher flows.
- Adoption of neuraxial anesthesia and peripheral nerve blocks to obviate the need for general anesthesia, saving valuable resources, including oxygen, and to decrease the risk of exposure to the infective aerosol.
- Routine maintenance to minimize oxygen circuit and pipeline leaks in a facility.
- Strict adherence to low-flow anesthesia whenever feasible, use of medical air if available, and using a low FiO_2 if possible.

- Elective surgeries may be deferred except for emergency surgeries only.
- In acute respiratory failure, maintaining a target SpO_2 of only more than 90% is enough.
- More supply should be directed to acute and critical care settings of the health facility e.g., EMDs, ICUs, HDUs, Respiratory wards, pediatric acuity ward.
- Management should identify training needs and provide the means to train key people in all stages of hospital oxygen use: determination of patients' oxygen needs, specifications, purchase, receipt, storage, distribution, and administration. In cases where the hospital produces its own oxygen, a training program on quality control and maintenance of the gas produced is recommended.
- Ensure all critically ill patients receive at least essential emergency and critical care
- Maintain at least a 72-hour supply of medical gases as a reserve.
- The engineering and maintenance division should have regular operations manual and preventive maintenance

records for medical gas storage, distribution, and delivery devices.

- Identify the extra supplier of medical gas who is nearby and has sufficient reserves to maintain an adequate supply chain in case of emergency. Agreement should be made among hospital management, the procurement staff and the supplier to ensure sustainability of the oxygen supply in periods of dire needs.
- In the epidemic or pandemic and upon surge of oxygen needs, facility ethics committee or quality assurance committee should be involved for decision making.

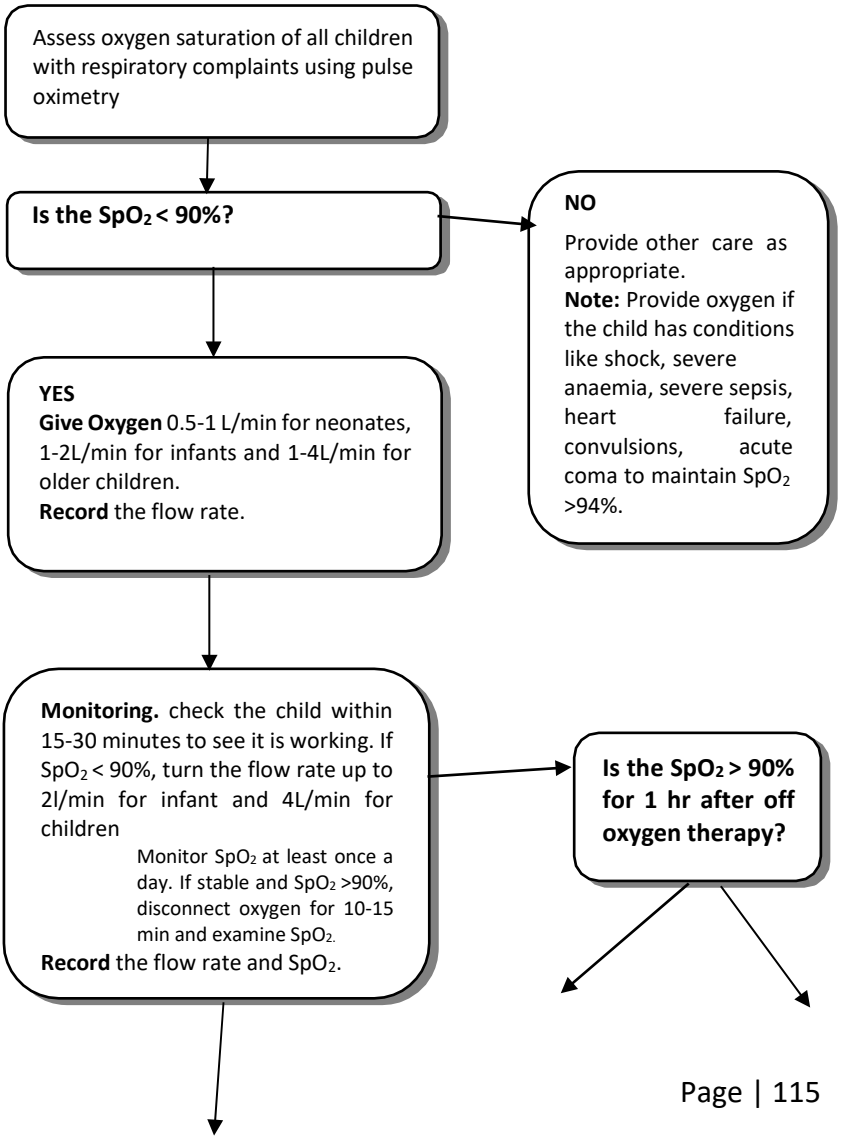
9. ANNEXES

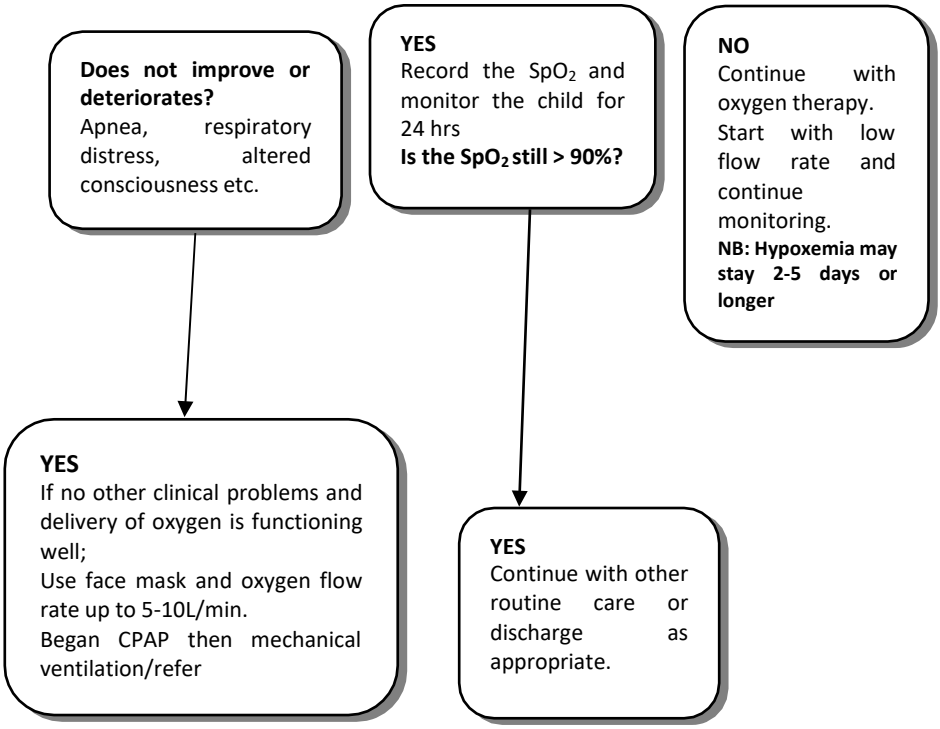
9.1 LIST OF EXPERTS WHO PARTICIPATED IN THE DOCUMENT DEVELOPMENT

Name of the Expert	Institution/Designation
MoH	
Dr. Elias M. Kwesi	Director, Emergency Preparedness and Response Unit
Dr. Erasto Sylvanus	Emergency Medicine Physician and head case management unit
Dr. Alex Sanga	Medical Officer, Emergency Preparedness and Response Unit
Dr. Erick Richard	Medical Officer, Emergency Preparedness and Response Unit
Mary Makata	Principal Nursing Officer, Emergency Preparednessand Response Unit
Catherine Marimbo	Social Welfare Officer, Emergency Preparednessand Response Unit
Yustina Muhaji	Senior Nurse Officer, Emergency Preparednessand Response Unit
UNICEF	
Dr. Andrew Kigombola	Public health specialist and a consultant

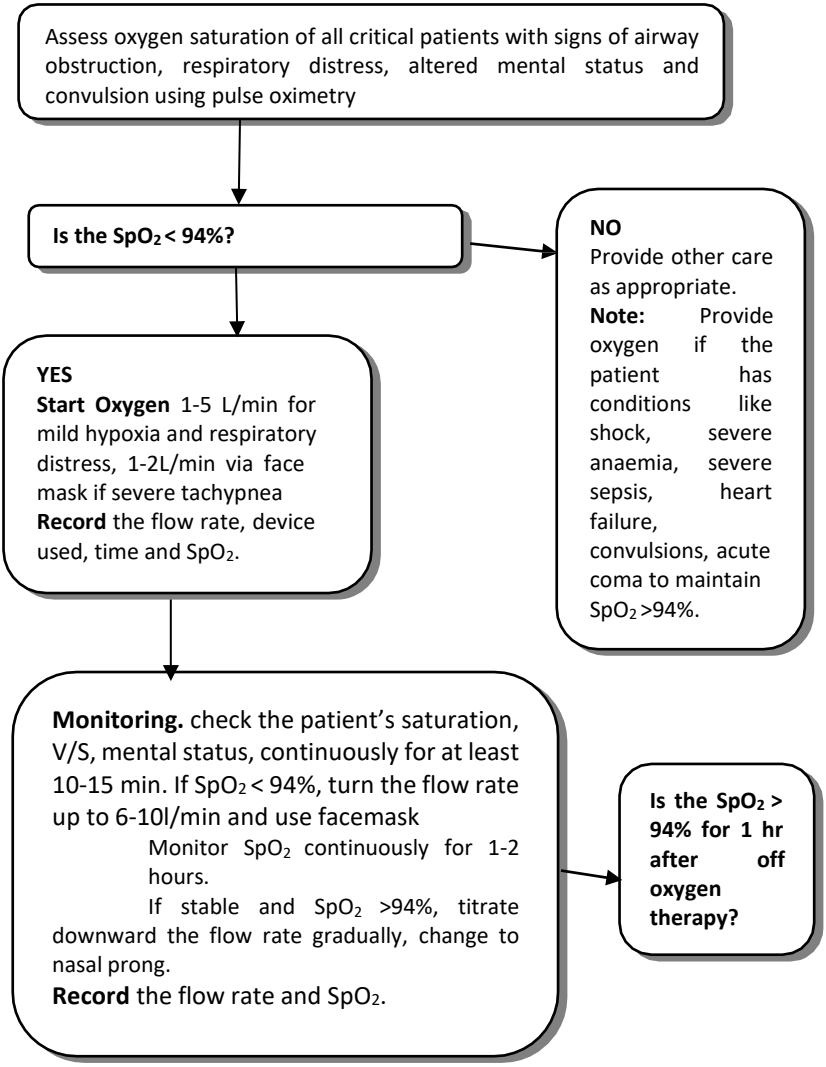
Dr. Tim Baker	Anaesthesiologist and technical advisor
Dr. Isihaka Mwandalima	Health specialist
Hospitals/Universities	
Dr Edwin Lugazia	Consultant Anaesthesiologist, MUHAS
Dr. Said Kilindimo	Emergency Medicine Physician, MUHAS
Dr. Karima Khalid	Anaesthesiologist MUHAS/MOI
Dr. Lugano Wilson	Anaesthesiologist, Benjamin Mkapa Hospital
Dr. Albert Muniko	Emergency Medicine Physician, Bugando hospital
Dr. Ally Akrabi	Emergency Medicine Physician, Bugando hospital
Adela Venance	Critical care nurse, JKCI
Dr. Tamery Henry	Physician, Kibong'oto Hospital

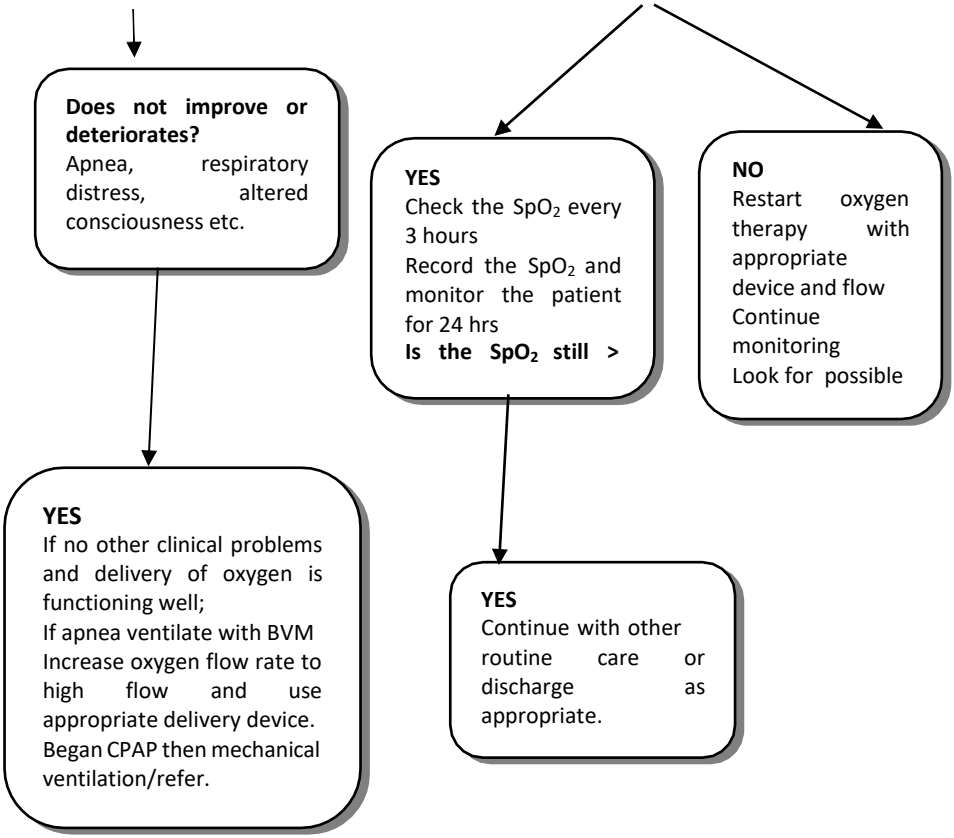
9.2 FLOWCHART OXYGEN THERAPY IN CHILDREN




Does not improve or deteriorates?
Apnea, respiratory distress, altered consciousness etc.
YES
Record the SpO_2 and monitor the child for 24 hrs
Is the SpO_2 still > 90%?
NO
Continue with oxygen therapy.
Start with low flow rate and continue monitoring.
NB: Hypoxemia may stay 2-5 days or longer
YES
If no other clinical problems and delivery of oxygen is functioning well;
Use face mask and oxygen flow rate up to 5-10L/min.
Began CPAP then mechanical ventilation/refer
YES
Continue with other routine care or discharge as appropriate.

9.3 FLOWCHART OXYGEN THERAPY IN ADULTS




Does not improve or deteriorates?
Apnea, respiratory distress, altered consciousness etc.
YES
If no other clinical problems and delivery of oxygen is functioning well;
If apnea ventilate with BVM
Increase oxygen flow rate to high flow and use appropriate delivery device.
Began CPAP then mechanical ventilation/refer.
YES
Check the SpO2 every 3 hours
Record the SpO2 and monitor the patient for 24 hrs
Is the SpO2 still >
YES
Continue with other routine care or discharge as appropriate.
NO
Restart oxygen therapy with appropriate device and flow
Continue monitoring
Look for possible

9.4 HOW TO GIVE INCREASING OXYGEN

How to give oxygen

➡ How to deliver increasing oxygen

Place prongs inside the nostril . Hook tubing behind ears. Flow rates higher than 5 litres will dry mucous membranes.

- Start **oxygen at 5 litres/minute**
- Use nasal prongs
- Assess response

- If increasing respiratory distress or SpO_2 <90

Secure mask firmly on face over nose and mouth. Pull strap over head.

- Use face mask
- **Increase oxygen to 6–10 litres/minute**
- Assess response

- If increasing respiratory distress or SpO_2 <90

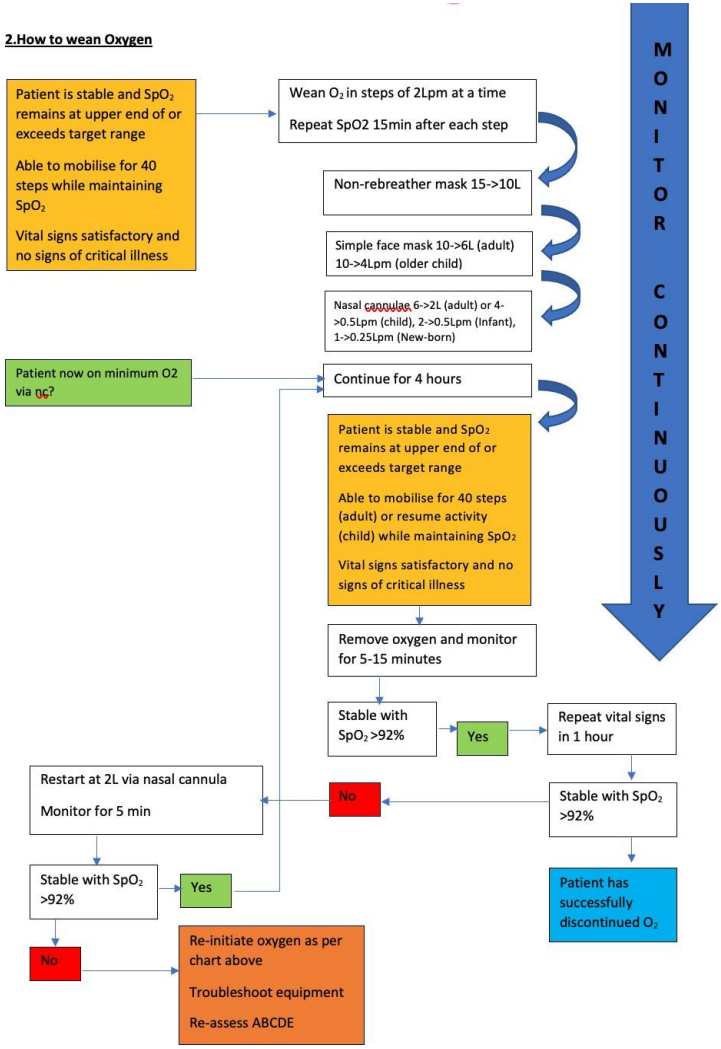
Make sure bag is full to deliver highest oxygen concentration. An empty bag is dangerous.

- Use face mask with reservoir
- **Increase oxygen to 10–15 litres/minute**
- Make sure bag inflates
- Call for help from district clinician
- Assess response

- If increasing respiratory distress or SpO_2 <90
  or
- If not improving with BVM on high flow oxygen
  AND
- Patient has an easily reversible condition (e.g. drug overdose, snakebite) and manual ventilation (bagging – p. 35) possible
  or
- Transfer to a hospital with available invasive mechanical ventilator possible. See Referral and transfer of severely ill patients, p. 37.

- Call for help from district clinician for possible tracheal intubation – see advanced airway management, p. 31
- **Start manual ventilation (bagging) with high flow oxygen** – see p.35

9.5 HOW TO WEAN OXYGEN



9.6 Common Cylinder Sizes in Health Facilities.

Cylinder size	D	E	F	G	J
Nominal content/oxygen capacity (L)	340	680	1360	3400	6800
Water capacity (L)	2.3	4.7	9.4	23.6	47.2
Dimensions (height x diameter) (mm)	535 x 102	865 x 102	930 x 140	1320 x 178	1520 x 229
Approximate full weight (kg)	3.9	6.5	17	39	78
Valve outlet connection (and specification)	Pin index (ISO 407)	Pin index (ISO 407)	Bullnose (BS 341)	Bullnose (BS 341)	Pin index side spindle (ISO 407)
Nominal service pressure (kPa/bar/psi)	13 700 kPa (137 bar/1987 psi)	13 700 kPa (137 bar/1987 psi)	13 700 kPa (137 bar/1987 psi)	13 700 kPa (137 bar/1987 psi)	13 700 kPa (137 bar/1987 psi)
Health facility use	Emergency and ambulance transport	Emergency and ambulance transport	Stand-alone	Stand-alone	Manifold connection and stand-alone

9.7 LIST OF REQUIREMENTS FOR EECC SERVICES PROVISION

Below are the resources required for hospitals to be ready to provide Essential Emergency and Critical Care (EECC). This includes the identification of critical illness and the essential care of critical illness. The resources are divided into categories of equipment, consumables, drugs, human resources, training, routines[13], guidelines[14], and infrastructure. Each resource item appears only once.

9.7.1 Identification of Critical Illness

CATEGORY	ITEM
1.1 EQUIPMENT	1.1.1 Clock with second hand 1.1.2 Pulse oximeter & probe

[13] "Routines" refers to the system in the hospital for managing critically ill patients. ie. there are routines for the identification of critical illness, rather than patients being managed ad hoc.

[14] "Guidelines" refers to written material (eg. a wall chart or a booklet) that describes how critically ill patients should be identified and managed.

	1.1.3 Blood pressure measuring equipment (eg. sphygmomanometer with a stethoscope) 1.1.4 Blood pressure cuffs of different paediatric and adult sizes 1.1.5 Light source (lamp or flashlight) 1.1.6 Thermometer
1.2 CONSUMABLES	1.2.1 Soap or hand disinfectant 1.2.2 Examination gloves
1.3 DRUGS	None
1.4 HUMAN RESOURCES	1.4.1 Health workers with the ability to identify critical illness 24h/day
1.5 TRAINING	1.5.1 The health workers are trained in the identification of critical illness
1.6 ROUTINES	1.6.1 Routines for the identification of critical illness

1.7 GUIDELINES	1.7.1 Guidelines for the identification of critical illness
1.8 INFRASTRUCTURE	1.8.1 Designated triage area (area for the identification of critical illness) in the Out-Patient Department or Emergency Unit (area of the hospital where patients arrive) 1.8.2 Running water

9.7.2 Care of Critical Illness

CATEGORY	**ITEM**
2.1 EQUIPMENT	2.1.1 Suction machine (electric or manual) 2.1.3 Oxygen supply 24h/day (cylinder, concentrator (with electricity supply) or piped oxygen) 2.1.4 Flow meter (if using cylinder or piped oxygen) 2.1.5 Leak-free connectors from oxygen source to tubing 2.1.6 Bag Valve Mask (resuscitator) – neonatal, paediatric and adult sizes 2.1.7 Sharps disposal container 2.1.8 External heat source

2.2 CONSUMABLES	2.2.1 Suction catheters of paediatric and adult sizes 2.2.2 Guedel airways of paediatric and adult sizes 2.2.3 Pillows 2.2.4 Oxygen tubing 2.2.5 Oxygen nasal prongs 2.2.6 Oxygen face masks of paediatric and adult sizes 2.2.7 Oxygen face masks with reservoir bags of paediatric and adult sizes 2.2.8 Masks for Bag Valve Mask (resuscitator) – neonatal, paediatric and adult sizes 2.2.9 Compression bandages 2.2.10 Plasters or tape 2.2.11 Gauze 2.2.12 Intravenous cannulas of paediatric and adult sizes 2.2.13 Intravenous giving sets 2.2.14 Skin disinfectant for cannulation 2.2.15 Syringes 2.2.16 Nutrition 2.2.17 Nasogastric tubes 2.2.18 Lubricant for nasogastric tube insertion 2.2.19 Intramuscular needles 2.2.20 Intraosseous cannulas of different sizes 2.2.21 Blankets 2.2.22 Facemasks for Infection Prevention and Control 2.2.23 Aprons or gowns 2.2.24 Charts/notes for documentation 2.2.25 Pens

2.3 DRUGS	2.3.1 Oral rehydration solution 2.3.2 Intravenous crystalloid fluids (eg. normal saline or Ringer's Lactate) 2.3.3 Intravenous dextrose fluid (eg. 5%, 10% or 50%) 2.3.4 Oxytocin 2.3.5 Adrenaline 2.3.6 Appropriate antibiotics 2.3.7 Diazepam 2.3.8 Magnesium sulphate 2.3.9 Paracetamol 2.3.10 Local anaesthetic (eg. 2% lignocaine) (eg. for intraosseous cannulation)
2.4 HUMAN RESOURCES	2.4.1 Health workers with the ability to care for critically ill patients 24hrs/day 2.4.2 Senior health worker who can be called to assist with the care of critically ill patients 24hrs/day

9.8 List of Clinical processes in EECC

IDENTIFICATION OF CRITICAL ILLNESS

Critical illness is identified as soon as possible so timely care can be provided.

1. The hospital uses vital signs-based triage to identify critical illness

1.1 Triage/identification of critical illness includes the use of these vital signs

1.1.1 Pulse rate

1.1.2 Blood pressure

1.1.3 Respiratory rate

1.1.4 Oxygen saturation (SpO2)

1.1.5 Temperature

1.1.6 Level of consciousness (eg. “AVPU”, “ACVPU” or Glasgow Coma Scale)

1.1.7 Presence of abnormal airway sounds heard from the bedside (eg. snoring, gurgling, stridor)

1.1.8 The overall condition of the patient (health worker’s concern that the patient is critically ill)

1.2 Triage/identification of critical illness is conducted at these times

1.2.1 When a patient arrives at hospital seeking acute care

1.2.2 For hospital in-patients, at least every 24 hours, unless otherwise prescribed, with increased frequency for patients who are at risk

ofbecoming critically ill or who are critically ill, and then less frequently again when patients are stabilising

1.2.3 When a health worker, or the patient or guardian, is concerned that a patient may be critically ill

1.2.4 During and after surgery or anaesthesia

1.2.5 During and after transport/transfer of a patient who is critically ill or at risk of becoming critically ill

1.2.6 Following a treatment or action (re-evaluation)

CARE OF CRITICAL ILLNESS

Essential care of critical illness is initiated as soon as critical illness is identified and involves these clinical processes when appropriate:

AIRWAY **Care for a blocked or threatened airway**	2. Placing the patient in the recovery position (lateral position) 3. Age-appropriate airway positioning (eg. chin lift or jaw thrust in adults, neutral position in young children) 4. Removal of any visible foreign body from the mouth or use of age-appropriate chest thrusts/ abdominal thrusts/ back blows in choking 5. Suction for secretions that are obstructing the airway 6. Insertion of an oro-pharyngeal (Guedel) airway

BREATHING **Care for hypoxia or respiratory distress**	7. Optimizing the patient's position (eg. sitting-up 8. or prone) Oxygen therapy using nasal prongs, facemask, 9. or mask with a reservoir bag (non re-breathing mask) Bag-valve-mask ventilation in threatened or manifest respiratory arrest
CIRCULATION **Care for a threatened circulation or shock**	10. Optimizing the patient position (eg. lying flat, 11. head-down, raised-legs, lateral tilt in 12. pregnancy) 13. Compression and elevation to stop bleeding 14. Appropriate bolus of intravenous fluid 15. Oral rehydration solution or other appropriate oral fluids for dehydration without shock Intramuscular adrenaline for anaphylaxis Uterine massage and/or oxytocin when indicated
REDUCED CONSCIOUS LEVEL **Care for a reduced level of consciousness**	16. Treating an unconscious patient as having a 17. threatened airway (eg. recovery position etc) Dextrose (iv or buccal) in unconsciousness or 18. seizures unless bedside blood glucose testing 19. rules out hypoglycaemia or there is a clear alternative cause 20. Protecting patients with a seizure from harm Quick-acting anti-seizure medication (eg. intravenous/rectal diazepam, or magnesium sulphate in pregnancy/post-partum) Cooling in severe hyperthermia with a reduced level of consciousness

OTHER CARE IN EECC	21. Insertion of an intravenous cannula when 22. critical illness is identified 23. Insertion of an intraosseous cannula, if 24. indicated, if an intravenous cannula is not 25. possible 26. Stabilizing the cervical spine in possible cervical 27. spine injury Appropriate antibiotics for sepsis 28. Treatment of pain and anxiety (eg. with needs- 29. based psychological support, medication) 30. Keeping the patient warm using blankets and other means (including skin-to-skin care for babies) Feeding (including breastfeeding for babies), naso-gastric feeding and dextrose for nutrition and to avoid hypoglycaemia Prevention of delirium (eg. sleep hygiene, provision of the patient's glasses or hearing aid) Regular turning of immobilised patients Mobilising the patient as early as possible
Other immediate or ongoing care of critical illness	

GENERAL PROCESSES

Care is provided according to these general processes:

1. Assistance from additional or senior staff is sought when a critically ill patient is identified
2. Essential Emergency and Critical Care (EECC) is respectful and patient-centred
3. EECC is provided without considering the patient's ability to pay
4. Critically ill patients are cared-for in locations that facilitate observation and care (eg. designated beds, a bay or a unit for critically ill patients)
5. Infection, Prevention and Control (IPC) measures are used including hand hygiene and separation of patients with a suspected or confirmed contagious disease from those without
6. Communication is clear, including:
    - Within the care team when a patient is identified as critically ill (eg. verbal communication, at staff handovers, visible colour-coding)
    - Within the care team about the planned EECC (eg. continue oxygen therapy, give intravenous fluids)
    - Documentation in the patient notes about the vital signs, when critical illness has been identified and the treatments and actions conducted
    - Effective and respectful communication with the patient and family
7. If there is poor response to treatment, or if the patient deteriorates, other indicated EECC clinical processes are used
8. Clinical processes are discontinued that are no longer indicated (eg. if a patient improves or if they are deemed to no longer be in the patient's best interest)

9. It is recognised when EECC alone is not sufficient to manage the critical illness
10. EECC is integrated with care that is outside the scope of EECC (eg. the need for prompt investigations,
definitive treatment of underlying conditions including following disease-specific best-practice guidelines,
end-of-life care, referral)

Addendum: Extended identification of critical illness

To maintain feasibility of the EECC package, only a limited number of signs for the identification of critical illness are
included. However, if time and expertise allow, there are additional signs that are not part of EECC that aid the
identification of critical illness:

- Presence of respiratory distress (eg. unable to complete sentences; accessory muscle use; chest recessions; grunting or head nodding)
- Cyanosis
- Capillary refill time
- Cold or warm extremities
- Presence of severe dehydration (eg. decreased skin turgor; dry mucous membranes; sunken fontanelle)
- Confused, agitated or disoriented mental state
- Presence of prostration or lethargy
- Presence of a generalized seizure
- Inability to stand or walk without help
- Inability to breastfeed or feed in a young child
- Presence of severe acute malnutrition