NEST-ED

Clinical Modules

June 2020

Newborn Essential Solutions and Technologies-Education (NEST-ED) Clinical Modules provide educational support for each of the technologies included in the NEST360° bundle for newborn care. These materials are intended to strengthen locally developed neonatal and technical trainings in pre-and in-service settings and are not intended to be comprehensive clinical guidelines or targeted towards intensive care of the newborn.

FACILITATING THE CLINICAL USE OF TECHNOLOGIES FOR NEWBORN CARE IN LOW-RESOURCE SETTINGS
Newborn Essential Solutions and Technologies–Education
Clinical Modules: Oxygen Therapy

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verify recommendations for use and/or operating instructions.

In addition, all forms, instructions, checklists, guidelines, and examples are intended as resources to be used
and adapted to meet national and local health care settings’ needs and requirements.
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This series has been designed with the intent of supporting the clinical use of technologies in newborn care units.

Newborn Essential Solutions and Technologies-Education (NEST-ED) Clinical Modules provide educational support for each of the technologies included in the NEST360° bundle for newborn care. These materials are intended to strengthen locally developed neonatal and technical trainings in pre- and in-service settings. Of note, these materials are not intended to be comprehensive clinical guidelines or targeted towards intensive care of the newborn. They are to be used to facilitate the implementation of comprehensive newborn care, including bubble CPAP, in a resource limited setting.

The NEST-ED Clinical Modules were developed through a combination of international standard review, international expert feedback, and multinational NEST360° expert consensus opinion. NEST-ED Modules form the backbone of all lectures, power points, job aids, and other supportive education materials supplied by NEST360°.
ABBREVIATIONS

ABC  Airway, Breathing, Circulation
bCPAP  Bubble continuous positive airway pressure
dL  Decilitre
FiO₂  Increased Fractional Concentration of Oxygen
Fr  French size
HAI  Hospital acquired infections
HCWs  Healthcare workers
HFNC  High flow nasal cannula
IV  Intravenous
KMC  Kangaroo mother care
LBW  Low birth weight
LCD  Liquid crystal display
LED  Light emitting diode
mm Hg  Millimeters of mercury
NEST360°  Newborn Essential Solutions and Technologies
NEST-ED  Newborn Essential Solutions and Technologies-Education
NGT  Nasogastric tube
nm  Nanometer
O₂  Oxygen
OGT  Orogastric tube
ppm  Parts per million
ROP  Retinopathy of Prematurity
SpO₂  Peripheral blood oxygen saturation
UPS  Uninterruptible power supply
WASH  Water, sanitation and hygiene
WHO  World Health Organization
wks  Weeks

NOMENCLATURE

bCPAP prongs  bCPAP patient interface
Cot  Bassinet, infant crib
Christmas tree nozzle  Barbed oxygen fitting, nipple and nut adapter
Flow splitter  Oxygen splitter, flow meter stand
Glucometer  Glucose meter
Hospital Acquired Infection  Iatrogenic infection, nosocomial infection
Nasal prongs  Oxygen catheter, oxygen cannula, oxygen prongs
Positive Pressure  Positive end expiratory pressure, positive airway pressure
Radiant warmer  Resuscitaire, resuscitation table
Suction pump  Suction machine
Introduction

This NEST-ED Clinical Module has been prepared to help healthcare staff & students understand when & how to use oxygen therapy in newborn care. This is one module in a series of NEST-ED Clinical and Technical modules available that may be used by teaching institutions to supplement current newborn care curricula or by hospitals, clinical departments, and individuals to update their knowledge and to better facilitate the effective and safe use of newborn care equipment.

Whilst reading this series, navigate to the Table of Contents by clicking the NEST360° logo that appears at the bottom right corner of each page: NEST360°

Every module has a similar structure with sections and subsections. The sections have similar headings and subheadings to make it easy for the user to navigate them. However, words may have different meanings for the various cadres of staff reading them and so to reduce misinterpretation, the heading titles are explained below.

An exception to this structure is the Infection Prevention & Control: General Infection Prevention module. This module describes general infection prevention measures in relation to the use of equipment in the ward. There are also sections on reprocessing of single use items and a useful table of suitable disinfectants.

CLINICAL PROBLEM

This describes the situations in which a piece of equipment may be clinically useful. It does not include all the clinical background in making that decision, as this should be covered in country-specific neonatal care protocols & clinical training materials.

ASSESSMENT

This section explains how a piece of equipment works, as well as how it may be useful in certain patient care settings (e.g., why an overhead radiant heater is useful for short term warming in the labour ward while resuscitating a newborn).

MANAGEMENT

Step by step preparation for setting up, checking, and using the equipment is described. This is followed by explanations of how to remove the equipment from a baby when it is no longer needed, how to clean it, and how to store it safely until further need.

INFECTION PREVENTION

In this section infection prevention measures are described for the equipment when in use, followed by instructions on how to disinfect the equipment both during and after use.
COMPLICATIONS

The complications described in this section are those relating to the use of the equipment and do not include all clinical complications that may arise from underlying medical problems. These are beyond the scope of the modules and should be covered in clinical training materials.

CARE & MAINTENANCE

Advice is given on where to place equipment for use, how to safely handle such devices and their consumables, and how to keep them functioning well by using preventive maintenance measures.

TROUBLESHOOTING & REPAIR

This section provides helpful advice on what to check if equipment is malfunctioning on the ward. It is intended to help healthcare staff deal with minor technical difficulties for which there are simple remedies. Detailed machine maintenance is beyond the scope of these modules and is covered in the technical modules that accompany these clinical ones.

ASSESSMENT QUESTIONS

A few questions are attached based on module content. These may be used, for example, during mentoring visits or to emphasise some of the points raised in teaching with the module.

REFERENCES & ALERTS

References and alert boxes are included within each module to provide clarity on areas where recommendations are governed by published standards, evidence, and/or expert opinion. This is included for the dual purpose of facilitating (1) feedback and continuous improvement of NEST-ED Education Modules and (2) implementer review of content for incorporation in local trainings.

QUERY ALERT BOXES appear where there may be controversy or disagreement. In these cases, alert boxes provide background to the recommendations that are made in the body of the document. Relevant documents are cited and brief explanation of reasoning for current module content provided.

RECOMMENDATION ALERT BOXES appear where there are recommendations based largely on expert opinion or consensus, or to emphasise an important element of care. Relevant documents are cited and brief explanation of reasoning for current module content provided.
Respiratory Support

Oxygen Therapy
1 Clinical Problem

Oxygen sources may be used to provide supplemental oxygen directly to patients, shared between patients by using a flow splitter or used with other treatment devices such as continuous positive airway pressure devices.

Supplemental oxygen is indicated for sick children, especially those with hypoxia. Hypoxia is defined as an oxygen saturation (SpO₂) < 90%. This condition has many clinical causes, including:

- Respiratory distress syndrome
- Transient tachypnoea of the newborn
- Birth asphyxia
- Meconium aspiration
- Pneumonia
- Pneumothorax
- Partial airway obstruction
- Neonatal anaemia
- Neonatal sepsis with respiratory distress
- Congenital anomalies (e.g., some types of congenital heart disease, diaphragmatic hernia)
- Persistent pulmonary hypertension of the newborn
- Seizures
- Chronic lung disease

Whilst nearly all sick infants may benefit from oxygen therapy, any concentration of oxygen administered without appropriate monitoring of peripheral blood oxygen saturation can cause harm. Carefully select between those that would benefit from oxygen delivered directly to a patient (e.g., via nasal prongs) and those that would benefit from supplemental oxygen delivered with pressure via CPAP. Monitor carefully and discontinue oxygen as soon as it becomes unnecessary.

2 Assessment

Hypoxia contributes to both morbidity and mortality. Oxygen therapy may be used to improve body tissue oxygenation, measured by SpO₂ levels and also to provide symptomatic relief.

Oxygen therapy may be delivered using oxygen concentrators, oxygen flow splitters, walled oxygen, and oxygen cylinders. Oxygen flow rates vary based on intended use and mode of delivery:

- Resuscitation with bag and mask ventilation: 10 L/min¹ (Alert 2.1)
- Flowmeter stand (Splitter): 1 – 2 L/min per oxygen port
- Prongs: up to 2 L/min
- Mask: from 3 L/min to 10 L/min
- CPAP: from 1 L/min to 6 L/min

**ALERT 2.1**

American Academy of Pediatrics resuscitation recommendations are 10 L/min of air, 21% Fraction of inspired oxygen (FiO₂) for term babies and 30% FiO₂ for preterm babies.¹ FiO₂ should then be titrated with a blender based on minutes of life and target SpO₂ levels, which may not reach 85-95% until after 5-10 minutes of life. All sick newborns who are not rapidly improving will need supplementary oxygen at increased FiO₂. In settings where blenders are not available, FiO₂ will not be able to be as tightly controlled when oxygen is required during resuscitation.

Neonatal patients should reach SpO₂ levels of 90 – 95% (Alert 2.1) by 15 minutes after birth. (Alert 2.2) If oxygen is needed it is recommended to give between 0.5-1 L/min.² Whilst on oxygen, regular monitoring should be conducted using a pulse oximeter to ensure that this saturation range is maintained for the duration of treatment. Ideally, patients suffering from severe respiratory distress should have continuous pulse oximetry monitoring throughout care.²

**ALERT 2.2: SpO₂ & Safe Oxygen Delivery**

When making this recommendation the following resources were considered:

1. According to the Textbook of Neonatal Resuscitation (NRP), 7th Ed., “After birth, the oxygen saturation gradually increases above 90%. However, even healthy term newborns may take 10 minutes or longer to reach this saturation” (p. 77).³

2. Target peripheral oxygen concentrations (SpO₂) for newborns vary depending on age and clinical condition. However, most authorities agree that saturations between 90-95% minimises the complications associated with both low and high oxygen levels including death, neurodevelopmental impairment and Retinopathy of Prematurity.³-⁶
Management of oxygen therapy covers how to use the device in a variety of settings, including patient preparation & commencement, care whilst on oxygen therapy & removal of the patient from the therapy. See the following modules on Oxygen Concentrator, Oxygen Cylinder & Flow Splitter for device specific recommendations.

### PREPARING A PATIENT

1. Assess the condition of the baby. Ensure all clinical management measures are taken of which oxygen delivery is only one. Check the ABC and assess:

   - **Airway:** suction if secretions are present
   - **Breathing:**
     - Respiratory rate: is it >60b/min
     - SpO2: peripheral blood oxygen saturation level, is it <90%
     - Work of breathing: e.g., grunting, fast breathing, chest indrawing
     - Chest auscultation
   - **Circulation:**
     - Perfusion: cool limbs and prolonged capillary refill time (>3 sec)
     - Heart sounds
   - **Seizures**
   - **Temperature**

2. If CPAP is available assess whether the patient would benefit more from bubble CPAP than from oxygen alone. If so, prepare the patient for bubble CPAP.

### STARTING A PATIENT

1. Collect:
   - Appropriately sized nasal prongs (should fit loosely in the nostrils)
   - Tape
   - Cotton wool

2. Check that the end of the prong tubing is secured to the oxygen port on the concentrator, flow has been set and that oxygen is coming out of the nasal prongs.

3. Insert the nasal prongs and secure in place on both cheeks with tape. Adjust loop adjustment slider to hold nasal prongs looped above the ears in place securely. Protect the sides of the nose and cheek where the tubing could rub and injure the skin. (3.1)

4. Consider labelling nasal prongs to more easily determine which patients are being treated with which oxygen ports. This will make it easier for future staff to adjust oxygen levels & prevent incorrect changes from being made to the patient’s treatment due to port misidentification. (3.2)
1 After starting on oxygen, monitor saturations using continuous pulse oximetry. Titrate oxygen up and down until normal saturation limits (SpO₂ 90 – 95)³–⁶ are reached. If patient requires more than 2 L/min of oxygen, nasal prongs should be changed to either CPAP or facemask (3.7) oxygen depending on the underlying clinical condition. (Alert 3.2)

2 Monitor according to clinical condition, or in accordance to local policy:
   - Vital signs, including oxygen saturation, respiratory rate, heart rate, blood pressure and temperature
   - Work of breathing (see above)
   - Nostril patency

3 Administer nasal saline drops to prevent mucosal drying, every four hours or more frequently depending on need.

3.5 Appropriately insert and secure nasal prongs.
3.6 Avoid tangling tubing around the patient.
3.7 Switch nasal prongs for a facemask when needed.
Guidance on when to administer low flow oxygen versus bCPAP in neonates is a complex decision which should be made on an individualised basis for each country implementing comprehensive neonatal units with bCPAP. It is a decision which must account for potential harms, benefits, staff training, staff to patient ratio, infrastructure and allocation of care within the health system.

NEST is aimed at implementing comprehensive neonatal care units with bCPAP in low resource settings in order to reduce facility-based mortality by 50% while also minimising morbidity. In light of potential harms associated with hyperoxia, high burden of premature and low birthweight infants in these types of units, and high patient to nurse ratios, 2L/min on nasal cannula was felt to be a reasonable level at which to consider moving a patient to bCPAP. This decision depends also on their clinical condition and is consistent with WHO recommendations for “standard flow rates” for neonates. At 2L/min from an oxygen cylinder, a 2kg infant may be receiving close to 100% FiO$_2$ and smaller infants may additionally be receiving some amount of positive pressure$^{2-4}$ which could be better regulated by CPAP than by a low flow oxygen device.

### Removing a Patient

1. Once patients can maintain normal oxygen saturations and are clinically stable, the oxygen flow rate should be reduced based on clinical response:
   - Reduce oxygen flow by 0.25 L/min, rechecking saturations and clinical condition after 15 minutes.
   - If saturations and clinical condition remain stable, continue reducing oxygen flow by increments of 0.25 L/min, rechecking saturations 15 minutes after each reduction and then every 4 hours or as clinically indicated.
   - If saturations drop below 90% or the patient clinically deteriorates, increase the oxygen until normal saturations are obtained and the patient clinically improves.

2. Once saturations are consistently above 90 – 95% at 0.25 L/min and the patient is clinically stable, remove patient from oxygen by gently removing the tape and taking the prongs out of the patient’s nostrils. Recheck the saturations after 15 minutes:
   - If saturations have **dropped or there is a clinical deterioration**, recommence oxygen.
   - If saturations and clinical condition are **stable**, remove patient from oxygen.

### Infection Prevention

Routine and adequate cleaning of medical devices is critical to prevent hospital-acquired infections in newborn care units. If devices and equipment are not disinfected or reprocessed promptly or adequately between patients, they may pose a significant infection risk.
GENERAL INFECTION PREVENTION

1. Clean hands with soap and water or alcohol before and after placing a patient on oxygen or handling any tubing that will be used on a patient.

2. Ensure that all patient-related tubing and consumables (including prongs and humidifier bottles) are new or have been cleaned thoroughly before use. Any patient-related tubing must be cleaned before it is used to place another patient on oxygen. The Reprocessing Respiratory Tubing Algorithm details reprocessing tubing for reuse.

3. Tubing should be hung to dry after disinfection and should not touch the floor or other unsanitary surfaces whilst drying. (4.2) It should be clearly labelled as having been cleaned.

4. All patient-related cleaned and new consumables should be stored in a clean, dry location. Tubing should be stored in loose rolls, preventing sharp bends or kinks which will decrease the lifetime of the tubing.

DISINFECTION AFTER USE

1. Remove end of prong tubing from oxygen port. If reusing, immediately begin hospital protocol for disinfection of tubing. Delay in initiating cleaning of reused medical devices can lead to the need for more intensive cleaning procedures to remove pathogens. If not reusing, discard appropriately. (Alert 4.1)

2. If using a humidifier in the oxygen circuit, change water after each patient or daily, if being used on the same patient.

ALERT 4.1 Reprocessing Single Use Devices

Respiratory circuits and humidifiers associated with oxygen delivery are generally intended as single use devices. However, in areas with limited resources or challenging supply chains, this equipment is often re-used. When re-processing single use devices it is extremely important that the cleaning process is not delayed following completion of use. There should be a detailed standard of practice as well as oversight processes for ensuring timely and high-quality re-processing. If equipment is not re-processed promptly or adequately between patients, it poses a significant infection risk. Please refer to the Reference Manual for Health Care Facilities with Limited Resources Infection Prevention and Control, Module 6 for more detailed guidance on the re-processing of single use devices.
Reprocessing Respiratory Tubing

Reprocessing patient tubing should be started immediately after use. All bleach solutions must be made daily to retain disinfection properties. Follow the 3 P’s to reprocess:

**PREPARE**
- Collect Supplies
  - Non-foaming detergent
  - Small brush
  - 10 L bucket / sink
  - Syringe
  - 5% bleach solution
  - Clean storage container
  - Clean water
- Collect & Don PPE
  - Glasses
  - Mask
  - Gown
  - Gloves

**PROCESS**

1. **CLEAN**
   - Use non-foaming detergent
   - Brush prongs & tubing underwater to remove visible particles
   - Flush tubing with washing liquid using syringe

2. **RINSE**
   - Flush tubing with clean water using syringe
   - Flush tubing with air using syringe

3. **DISINFECT**
   - Flush tubing with 5% bleach solution using syringe
   - Soak tubing in solution for 30 minutes
   - Rinse tubing with clean water & flush using syringe

4. **DRY**
   - Hang to dry in a location labelled as Cleaned Tubing
   - OR
   - Attach tubing to oxygen source for 15 minutes & blow dry

**PUT AWAY**
- Store in loose rolls in a clean, dry location
- Label as Cleaned

**STORE**
5 Complications

Introduction of equipment in newborn care units poses clinical and device complications for patients. Awareness of potential complications is critical to maximise patient safety.

CLINICAL COMPLICATIONS

- **Hypoxia**: if the nasal prongs become dislodged or blocked, the oxygen concentrator malfunctions or is turned off there is a risk that the baby will not receive enough oxygen. Hypoxia can cause:
  - Damage to the brain (e.g. periventricular leukomalacia – damage to the white matter of the brain)
  - Multi-organ failure
  - Death

  Reference Alert 2.3 for a full discussion of oxygen saturation level targets and recommendations.

- **Hyperoxia**: if the peripheral blood oxygen saturations (SpO₂) are not monitored appropriately or the flow rate is inadvertently changed there is a risk that the baby will receive too much oxygen. Whilst oxygen can be lifesaving, peripheral blood oxygen saturations (SpO₂) above 95% on oxygen therapy can cause morbidities in premature babies, including:
  - Retinopathy of prematurity: in premature babies, high blood oxygen levels can result in development of abnormal blood vessels on the retina, causing potential visual impairment or even blindness.
  - Chronic lung disease: prolonged use (although sometimes unavoidable) of oxygen in premature babies causes lung fibrosis through inflammatory processes.

- **Nasal blockage**: the nasal prongs and nostrils can become blocked with mucus which may result in increased respiratory distress and hypoxia.

- **Necrotic septum**: incorrectly sized or applied nasal prongs may result in pressure on the nasal septum with resultant necrosis (tissue breakdown). Nasal septum should be checked twice daily.

- **Nasal prongs**: prongs may become displaced, critically affecting the amount of oxygen received by the patient. All health workers, including the parents/guardians involved in the infant’s care should be aware of and watch out for this.

DEVICE COMPLICATIONS

- **Inadequate oxygen concentrations**: all forms of delivered oxygen therapy are subject to issues with oxygen concentration. This may result in inadequate levels of oxygen to treat respiratory distress directly or through another device (e.g., CPAP).
6 Care & Maintenance

Power source, location and preventive maintenance will vary by oxygen therapy type. See the following modules on Oxygen Concentrator, Oxygen Cylinder & Flow Splitter for device specific recommendations relating to power source, ward location and pertinent user preventive maintenance.

7 Troubleshooting & Repair

Typical failures and repair mechanisms will vary by oxygen therapy type. See the following modules on Oxygen Concentrator, Oxygen Cylinder & Flow Splitter for device specific recommendations.

Assessment Questions

1. The nasal prongs have just been removed from a baby and need to be cleaned and stored. How will you do this?
   
   Wash and clean in soapy water; rinse thoroughly in clean water; hang up in a clean place where the tubing will not touch the wall or other dirty surfaces. Allow to dry.
Respiratory Support

Oxygen Therapy

Oxygen Concentrator
1 Clinical Problem

An oxygen concentrator is used on its own when oxygen needs to be delivered to one or two patients. Concentrators may also be used to share oxygen between multiple patients using a flow splitter or used with other treatment devices such as continuous positive airway pressure devices.

Supplemental oxygen is indicated for sick children, especially those with hypoxia (SpO₂ < 90%) which has many clinical causes. Possible causes are outlined in Oxygen Therapy: Clinical Problem.

2 Assessment

Oxygen concentrators (2.1) provide a source of oxygen at flows from 2 to 10 litres per minute (L/min). Maximum flow delivered per device depends on the model and can range from 5, 8 or 10 L/min.

Oxygen concentrators are one of the most commonly used sources of oxygen therapy, concentrating 85-95.5% oxygen from ambient air using two sieve beds made of a substance that captures nitrogen.
- Intermittent/pulse flow: provides puffs of oxygen into nasal passageway at typical breathing rates.
- Continuous: provides constant oxygen delivery at a steady rate.

In intermediate care neonatal units, concentrators with continuous oxygen delivery are preferred for most applications. Common components of an oxygen concentrator are outlined in 2.2.

Neonatal patients should reach SpO₂ levels of 90 – 95% by 15 minutes after birth. (Alert 2.1) If oxygen is needed it is recommended to give between 0.5–1 L/min.² Whilst on oxygen, regular monitoring should be conducted using a pulse oximeter to ensure that this saturation range is maintained for the duration of treatment. Ideally, patients suffering from severe respiratory distress should have continuous pulse oximetry monitoring throughout care.²

2.2 Oxygen concentrator components.

2.3 SpO₂ levels should be monitored regularly and remain between 90 – 95%.
ALERT 2.1: SpO₂ & Safe Oxygen Delivery

When making this recommendation the following resources were considered:

1. According to the Textbook of Neonatal Resuscitation (NRP), 7th Ed., “After birth, the oxygen saturation gradually increases above 90%. However, even healthy term newborns may take 10 minutes or longer to reach this saturation” (p. 77).¹

2. Target peripheral oxygen concentrations (SpO₂) for newborns vary depending on age and clinical condition. However, most authorities agree that saturations between 90-95% minimizes the complications associated with both low and high oxygen levels including death, neurodevelopmental impairment and Retinopathy of Prematurity.³⁻⁶

3 Management

Management of an oxygen concentrator covers how to use the device in a variety of settings, including set up for a patient, patient preparation & commencement, care whilst on the device & removal of the patient from the device.

SETTING UP FOR A PATIENT

1. Plug oxygen concentrator’s power cable into the oxygen concentrator (3.1a) & into wall and turn on power at socket. Turn on concentrator. (3.1b)

2. Set flow to desired rate. If machine has not been turned on, allow to run for 5 minutes or until indicator light (3.2) shows that concentrator is providing appropriate concentrations of oxygen for treatment. Check that no alarms sound on the machine.
3. Assess whether your patient requires humidified flow. If oxygen needs are greater than 4 L/min, connect a humidifier.\(^2,^3\)

4. Connect correctly sized nasal prongs to oxygen port on machine (3.3) or to humidifier (if using).

5. Test that oxygen flow has begun by placing your finger near the nasal prongs, ensuring that flow commences. This can also be tested by the submerging the nasal prongs in clean water and checking for bubbles (3.4), also known as the “Bubble Test.”\(^1^1\)
Infection Prevention

Routine and adequate cleaning of medical devices is critical to prevent hospital-acquired infections in newborn care units. If devices and equipment are not disinfected or reprocessed promptly or adequately between patients, they may pose a significant infection risk.

GENERAL INFECTION PREVENTION

1. Housing of the oxygen concentrator should be cleaned according to ward guidelines for disinfecting surfaces.

DISINFECTION AFTER USE

1. Turn off and unplug the oxygen concentrator, if not using with another patient. If reusing tubing, immediately begin hospital protocol for disinfection as outlined in Oxygen Therapy: Infection Prevention.

2. Disinfect the oxygen flowmeter controls using gauze and 70% alcohol. (4.1)

3. Housing of the oxygen concentrator should be cleaned according to ward guidelines for disinfecting surfaces. Flowmeter controls and LEDs should be cleaned using 70% alcohol after every use.

4.1 Disinfect oxygen flowmeter control valve with gauze soaked in alcohol.
5 Complications

Introduction of equipment in newborn care units poses clinical and device complications for patients. Awareness of potential complications is critical to maximise patient safety.

DEVICE COMPLICATIONS

- **Inadequate oxygen concentrations**: If the oxygen concentrator indicates inadequate concentrations of oxygen (5.1), machine maintenance is needed. Replace the concentrator if possible; if not available, increase monitoring frequency to ensure clinical stability until concentrator can be replaced or maintained.

5.1 The “Low Oxygen” indicator light demonstrates that produced concentrations are appropriate.

6 Care & Maintenance

Users are responsible for basic first-line care and maintenance to ensure equipment lasts to their potential lifetime.
POWER SOURCE

Oxygen concentrators may be powered via mains or grid power with a voltage protector in line, or a rechargeable battery, depending on model.

WARD LOCATION

The concentrator should be located in a clean, dry, well-ventilated space close to any oxygen splitters that are in use and in a location that is easily viewed and accessed by neonatal staff. The back of the concentrator should be 30 – 35 centimetres away from the nearest wall to ensure that airflow can be sucked into the concentrator.

USER PREVENTIVE MAINTENANCE

Oxygen concentrators typically have two filters that should be cleaned as part of preventive maintenance:

- Gross particle filter: this filter is external to the machine and looks like a black or grey sponge. (6.1) To clean:
  1. Pull the gross particle filter gently from the back of the oxygen concentrator. Replace with spare filter.
  2. Put the filter in cool, soapy water and swirl gently to remove debris.
  3. Remove from soapy water and place in shaded area until completely dry. Store as spare filter until next cleaning is needed.

- Bacterial filter: this filter is internal to the machine and is made up of either filter papers or a thick white felt filter. (6.2) Do not wash this filter in water. This filter should be cleaned by your maintenance department.
Bacterial (internal) and gross particle (external) filters should be checked weekly, with cleaning provided every 2 weeks or more frequently as needed. **Never put a wet filter in place on an oxygen concentrator.**

The oxygen concentrator should be turned on and allowed to run for at least 15 minutes every week if it has not been in use. Sieve beds within concentrators can become contaminated with ambient water molecules if not regularly used; turning on the concentrator will prevent this contamination.

Due to concentrator wear, maximum flow (L/min) while maintaining appropriate oxygen concentration may decrease over time by as much as 3 L/min. If oxygen concentration at maximum flow begins to decrease or the low oxygen concentrator indicator light consistently shows at high flow rates, alert your maintenance department to organise and conduct repairs. All preventive maintenance and cleaning should be recorded in a logbook.

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**7 Troubleshooting & Repair**

Although users are not responsible for repairing their devices, there are steps that may be taken to troubleshoot first-line errors that may occur before contacting maintenance or engineering support.

1. **The device does not turn on**

   Check that the power cable is securely attached to the concentrator, the cable is plugged completely into the socket, and the socket is turned on.

   If the concentrator still does not turn on, push the reset button (7.1) on the front of the concentrator.

   If the concentrator still does not turn on, contact your maintenance department.

   ![Reset button on oxygen concentrator](image)

   **7.1 Press the reset button on the front of the concentrator.**
2 **The device turns on, but no flow is produced**

Connect a Christmas tree nozzle to the oxygen port. *(7.2)*
If flow still cannot be felt, check the port for debris or blockages. If debris are seen, clean using an ear swab or forceps wrapped in gauze soaked in 70% alcohol. *(7.3)*
If flow still cannot be felt, contact your maintenance department.

3 **The device turns on, but a ‘Low Oxygen’ indicator is displayed or audible**

Check the gross particle and bacterial filters for dust and debris. If dust and debris are present, replace the filters with spare, clean filters. Allow the machine to run for 10 minutes.
If the alarm still sounds, check that your set flowrates (L/min) are within the maximum machine specifications. If they exceed the machine requirements, readjust your settings to within the specifications and monitor the alarm and light indicator.
If the low oxygen concentration alarm still sounds, reduce the flow further. If the low oxygen concentration alarm still sounds after reducing the flow to more than 50%, contact your maintenance department.
Assessment Questions

1. Label the image below.
Respiratory Support

Oxygen Therapy

Oxygen Cylinder
1 Clinical Problem

Oxygen cylinders may be used to provide supplemental oxygen directly to hypoxic patients, to be shared between patients using a flow splitter or used with other treatment devices such as continuous positive airway pressure devices.

Possible causes of hypoxia are outlined in Oxygen Therapy: Clinical Problem.

2 Assessment

Hypoxia contributes to both morbidity and mortality. Oxygen cylinders (2.1) deliver oxygen concentration of up to 99.5% and may be used as backup to oxygen concentrators in case of power outage or as a primary source of oxygen, particularly in a walled oxygen system.

Oxygen cylinders are usually made of a steel or aluminium alloy and are distinguished from other cylinders by having a black body with white shoulders and top. The capacity of oxygen is rated in litres which indicates the amount of oxygen the tank can store. Cylinder sizing follows an alphabetical system. Each letter corresponds to the capacity in litres of that particular cylinder.

2.1 Typical oxygen cylinders.

2.1 A typical transport cylinder.
Unlike oxygen concentrators, oxygen cylinders do not concentrate their own oxygen from ambient air, they are durable storage vessels for oxygen. Cylinders must be filled with oxygen under high pressure. At the oxygen generation plant, the oxygen cylinder is filled with oxygen up to a pressure of about 137–200 bar. Once a cylinder’s stop valve is in an open position, the pressure in the cylinder pushes the oxygen out. It passes through the stop valve to the pressure gauge and then the flow regulator. From the flow regulator the oxygen can then be delivered to a patient through a flow splitter, CPAP, or other oxygen delivery device. Oxygen cylinders are especially useful when high flow oxygen is required or as back up to concentrators when the power source fails.

Since neonates require low flows, flow meters with precision of at least 0.1 L/min should be utilised. There are special ultra-low flowmeters available for use with neonates with precision adjustments of 0.02–0.03 L/min which, especially in settings which do not utilise blenders, can be particularly useful to provide necessary oxygen to neonates and minimising hyperoxia. However, ultra-low flowmeters are not always available and great care must be taken when adjusting the oxygen flow through a standard flowmeter to monitor saturations and avoid hyperoxia which does not allow for very low flow titrations.

Neonatal patients should reach SpO2 levels of 90 – 95% by 15 minutes after birth. If oxygen is needed it is recommended to give between 0.5-1 L/min. Whilst on oxygen, regular monitoring should be conducted using a pulse oximeter to ensure that this saturation range is maintained for the duration of treatment. Ideally, patients suffering from severe respiratory distress should have continuous pulse oximetry monitoring throughout care.
2.3 SpO₂ levels should be monitored regularly and remain between 90 – 95%.

** ALERT 2.1: SpO₂ & Safe Oxygen Delivery **

When making this recommendation the following resources were considered:

1. According to the Textbook of Neonatal Resuscitation (NRP), 7th Ed., “After birth, the oxygen saturation gradually increases above 90%. However, even healthy term newborns may take 10 minutes or longer to reach this saturation” (p. 77).¹

2. Target peripheral oxygen concentrations (SpO₂) for newborns vary depending on age and clinical condition. However, most authorities agree that saturations between 90-95% minimises the complications associated with both low and high oxygen levels including death, neurodevelopmental impairment and Retinopathy of Prematurity.³⁻⁶

### Management

Management of an oxygen concentrator covers how to use the device in a variety of settings, including set up for a patient, patient preparation & commencement, care whilst on the device & removal of the patient from the device.

** SETTING UP FOR A PATIENT **

1. Clean hands with soap and water or 70% alcohol before and after placing a patient on oxygen or handling any tubing that will be used on a patient.

2. Make sure the oxygen cylinder is in an upright position and is secured to a wall or stable object.
3. Assemble the pressure regulator and the flowmeter and connect them to the cylinder using the pin index connector. The flowmeter **must be upright** (vertical to the floor) to be read correctly. Tighten all connections and make sure there are no leaks.

4. Open the on/off valve and the pressure regulator assembly. Check the amount of oxygen in the cylinder by reading the pressure gauge.

5. Connect the oxygen delivery device. Adjust the flowrate required with the flowmeter regulator.

6. Assess whether your patient requires humidified flow. If oxygen needs are greater than 4 L/min, connect a humidifier.²,³

7. Test that oxygen flow has begun by listening for a hissing sound at the patient end of the delivery device (e.g., nasal prongs). This can also be tested by submerging the nasal prongs in clean water and checking for bubbles (3.4), also known as the “Bubble Test.”²,³

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**REMOVING A PATIENT**

1. Once patients are clinically ready to be removed from the oxygen cylinder therapy as defined in *Oxygen Therapy: Assessment*, follow steps to remove the patient from oxygen. Close the flowmeter on the cylinder.

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### 4 Infection Prevention

Routine and adequate cleaning of medical devices is critical to prevent hospital-acquired infections in newborn care units. If devices and equipment are not disinfected or reprocessed promptly or adequately between patients, they may pose a significant infection risk.
GENERAL INFECTION PREVENTION

1. Clean hands with soap and water or 70% alcohol before and after placing a patient on oxygen or handling any tubing that will be used on a patient.

2. The housing of the oxygen cylinder should be cleaned according to ward guidelines for disinfecting surfaces, or by wiping down with soapy water.

3. Ensure the stop valve is tightly shut in between patients and whilst being stored.

DISINFECTION AFTER USE

1. Close the flowmeter on the cylinder. If reusing tubing, immediately remove and begin hospital protocol for disinfection as outlined in Oxygen Therapy: Infection Prevention.

2. Clean the flowmeter, gauge and dials using 70% alcohol after every use.

5 Complications

Irresponsible use of high pressurised oxygen cylinders could easily result in a disaster, serious injury or death for patients or staff on the ward. Strict adherence to safety protocol, maintenance and proper use is critical when using oxygen cylinders.

DEVICE COMPLICATIONS

- **Fire**: oxygen is an agent of combustion, meaning fire will burn more readily in its presence. Never use grease or oil to lubricate parts of the oxygen cylinder.

- **Pressurised gas**: oxygen cylinders are filled at very high pressures and **must be chained** to secure in place. Accidentally tipping over a high-pressurised oxygen cylinder can easily dislodge the cap, creating a high-speed projectile. This projectile moves with sufficient speed and strength to break through cement walls. This poses an extreme danger to surrounding patients, health staff and hospital infrastructure.

- **Cylinder empty**: the stop valve on the cylinder must be turned off tightly when the cylinder is not in use. It is not uncommon for the valve to be left partially open and the cylinder will slowly empty.

- **Cylinder unstable**: the cylinder is very heavy and if not secured in an upright position can fall over and cause serious injury to a baby or member of staff. If it falls the flowmeter or pressure gauge may also be damaged.
6 Care & Maintenance

Users are responsible for basic first-line care and maintenance to ensure equipment lasts to their potential lifetime.

POWER SOURCE

Not powered.

WARD LOCATION

Oxygen cylinders should always be kept well-secured and safe from tipping or dropping, ideally along a wall with securing chains anchored into the wall. Oxygen cylinders should not be placed precariously, tilted or located without securing chains in the middle of walking areas.

Store in well ventilated, clean and dry conditions. Oxygen cylinders should be well labelled and easily distinguishable from other cylinders. Keep away from contaminants like oil and grease and sources of heat or ignition. Always use a secure trolley when transporting cylinders.

USER PREVENTIVE MAINTENANCE

Set up the oxygen cylinder for use. Open the flow meter & allow the oxygen cylinder to release oxygen for 1 minute every week if not in use.

7 Troubleshooting & Repair

Although users are not responsible for repairing their devices, there are steps that may be taken to troubleshoot first-line errors that may occur before contacting maintenance or engineering support.
**1 No flow is emitted from the oxygen cylinder**

Ensure flowmeter knob and cylinder flow valve are open.
Cylinder empty. Check the pressure gauge. If empty send for refill.
If not functioning, close the stop valve tightly and send to maintenance. Replace with a full cylinder.

**2 The cylinder is making an audible hiss**

Check for leakages by listening for any hissing sounds.
Loose fittings. Check the connection between the pressure regulator and the oxygen cylinder. Tighten all fittings.
If still not functioning well, close the stop valve tightly and send to maintenance. Replace with a full cylinder.

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**Assessment Questions**

1. The cylinder pressure gauge is reading 20%. What actions should you take?
   Close stop valve & send to maintenance for refill. Replace with a full cylinder if available.

2. What colours label a cylinder as containing oxygen?
   Black with white shoulders

3. Label the image below.
Respiratory Support

Oxygen Therapy

Flow Splitter
1 Clinical Problem

Flow splitters are used when oxygen from one source needs to be delivered to more than one hypoxic patient at low flows.

Possible causes of hypoxia are outlined in Oxygen Therapy: Clinical Problem.

2 Assessment

Hypoxia contributes to both morbidity and mortality. Flow splitters are accessory devices that divide oxygen from one source to give to several patients at independent, adjustable flow rates.

Flow splitters (2.1) may be used with an oxygen concentrator, oxygen cylinder or walled oxygen to provide standard flow supplemental oxygen to patients. Flow splitters may also be combined with CPAP if the flowmeter allows the required flow rate.

A flow splitter has internal tubing with individual flow regulators that split incoming oxygen flow coming from an oxygen source (i.e., oxygen concentrator or cylinder) (2.2) Oxygen flow splitters generally provide precise low flow rates, from 0.1 up to a maximum of 2 L/min from each port. The oxygen concentration delivered through an oxygen flow splitter remains unchanged from that of the source.
Neonatal patients should reach SpO₂ levels of 90 – 95% by 15 minutes after birth. **(Alert 2.1)** If oxygen is needed it is recommended to give between 0.5-1 L/min. Whilst on oxygen, regular monitoring should be conducted using a pulse oximeter to ensure that this saturation range is maintained for the duration of treatment. Ideally, patients suffering from severe respiratory distress should have continuous pulse oximetry monitoring throughout care.**2**
ALERT 2.1: SpO2 & Safe Oxygen Delivery

When making this recommendation the following resources were considered:

1. According to the Textbook of Neonatal Resuscitation (NRP), 7th Ed., “After birth, the oxygen saturation gradually increases above 90%. However, even healthy term newborns may take 10 minutes or longer to reach this saturation.” (p. 77)

2. Target peripheral oxygen concentrations (SpO2) for newborns vary depending on age and clinical condition. However, most authorities agree that saturations between 90-95% minimises the complications associated with both low and high oxygen levels including death, neurodevelopmental impairment and Retinopathy of Prematurity. 3-6

3 Management

Management of an oxygen concentrator covers how to use the device in a variety of settings, including set up for a patient, patient preparation & commencement, care whilst on the device & removal of the patient from the device.

SETTING UP FOR A PATIENT

1. Ensure oxygen flow splitter is secured in a location where it cannot be easily dislodged and where staff can easily adjust the flowmeter regulators on the splitter. (3.1) Make sure flow regulators are open.

2. Connect oxygen splitter tubing from oxygen outlet source to oxygen splitter inlet port. (3.2)
3 Assess level of oxygen needed from oxygen source. The source of oxygen (e.g., the concentrator) must be adjusted to provide a flow of at least 1L/min oxygen more than the total requirement from all the ports that are in use. (3.3)

For example: If 2 ports are in use (one port is set at 1L/min, one port is set at 0.5 L/min) and three ports are shut, the total supply of oxygen required from the concentrator is 2.5 L/min (i.e., 0 + 0.5 + 0 + 1 + 0 (+1 extra L) = 2.5 L/min)

4 Turn on oxygen at source. The flowmeter beads on the oxygen splitter should pop up.

5 Adjust each of the port flow meter regulators individually to the required flow rate (3.4), observing the L/min at eye level. (3.5) The other outlet ports should not change as each port is individually adjusted. If being used with an oxygen concentrator, some variation may occur cyclically.

6 Check that the ports have been numbered and number oxygen tubing to prevent infants receiving an incorrect flow. When changing flows for one patient, ensure that any other patients also on the flow splitter are receiving the correct amounts of oxygen.
4 Infection Prevention

Routine and adequate cleaning of medical devices is critical to prevent hospital-acquired infections in newborn care units. If devices and equipment are not disinfected or reprocessed promptly or adequately between patients, they may pose a significant infection risk.

**GENERAL INFECTION PREVENTION**

1. Clean hands with soap and water or 70% alcohol before and after placing a patient on oxygen or handling any tubing that will be used on a patient.

2. The housing of the flow splitter should be cleaned according to ward guidelines for disinfecting surfaces, or by wiping down with soapy water followed by 70% alcohol. Flow splitter oxygen ports should be cleaned using forceps wrapped in gauze and soaked in 70% alcohol.

3. Clean any used equipment that has been in contact with patient or staff.

**DISINFECTION AFTER USE**

1. Turn off the oxygen source. Disconnect oxygen tubing from source and flow splitter. If reusing tubing, immediately remove and begin hospital protocol for disinfection as outlined in Oxygen Therapy: Infection Prevention.

2. Clean the flow splitter housing and regulators using 70% alcohol after every use.

5 Complications

Introduction of equipment in newborn care units poses clinical and device complications for patients. Awareness of potential complications is critical to maximize patient safety.

**DEVICE COMPLICATIONS**

- **Device positioning:** Flow splitters are heavy devices and are frequently positioned on walls or shelves. This is appropriate if well secured. If improperly secured, flow splitters may fall onto patients, causing potential permanent or fatal injury.
**Independent flows:** flow splitters should be designed to have independent flow regulation. If the flow splitter is not designed correctly, flows may be dependent; as one port flow is changed, other port flows may change. These splitters should be exchanged for one that has independent flow. Even if an independent flow splitter is available, nursery staff should take care when changing flows for one patient and ensure that any other patients also on the flow splitter are receiving the correct amounts of oxygen.

**Flow delivery:** staff should always check the oxygen prongs for oxygen flow before placing patient on machine. If there is no flow, follow steps to troubleshoot in *Flow Splitter: Troubleshooting & Repair.*

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**6  Care & Maintenance**

Users are responsible for basic first-line care and maintenance to ensure equipment lasts to their potential lifetime.

### POWER SOURCE

Not powered.

### WARD LOCATION

Flow splitters should be mounted and secured in a location where nursing staff can regulate and view flows easily, e.g., mounted on a wall with easy and reachable access. The splitter should be able to be adjusted at eye level. If possible, the surface on which the splitter is mounted should have a raised edge to prevent falls. Tubing can be fixed to the wall to distribute oxygen to several cots without the tubing being trailed across the floor. It is a good idea to number the ports and the tubing to prevent infants receiving an incorrect flow.

### USER PREVENTIVE MAINTENANCE

The oxygen flow splitter should be connected to an oxygen source and used for at least 15 minutes once a week. Each flowmeter dial should be turned on and allowed to flow at its max flow for this period of time.
7 Troubleshooting & Repair

Although users are not responsible for repairing their devices, there are steps that may be taken to troubleshoot first-line errors that may occur before contacting maintenance or engineering support.

1. No flow is emitted from all ports of the flow splitter

   Check that the oxygen source is on and that oxygen is flowing from the outlet port of the source. (7.1)
   Check that the oxygen splitter tube is securely connected to the oxygen source and to the flow splitter and that there are no leakages.
   Check for kinks or blockages in the tubing. If the flowmeter bead pops up but there is no flow at the prongs; then the prong tubing is either blocked or has a leak.
   If oxygen still does not flow, contact your maintenance department.

2. No flow is emitted from one port of the flow splitter, but the other ports are functional

   Check the outlet port of the flow splitter for visible blockages like dirt or other debris. If debris are visible, use a test tube brush or thin rod covered with gauze to remove. Disinfect with 70% alcohol after debris have been removed.
   If oxygen still does not flow, contact your maintenance department. Meanwhile, label the non-functioning port and continue to use the others until a replacement is found.

3. Oxygen is flowing from the flow splitter port, but not from the oxygen tubing or prongs

   Visually check the tubing for kinks, blockages or bends. (7.2) If you see any of these obstructions, replace the tubing or prongs.

7.1 Test oxygen flow at the flow splitter port.

7.2 Kinks in the tubing prevent flow.
Assessment Questions

1. You are starting a patient on oxygen using a dual-port oxygen concentrator and a flow splitter. The oxygen concentrator being used has a capacity of **10 L/min** and has been connected to a flow splitter with two patients attached: the first patient is receiving **1 L/min** of oxygen and the second is receiving **2 L/min** of oxygen. What is the max oxygen flow rate that you can give the third patient whilst maintaining clinically therapeutic concentrations?

   **7 L/min**

2. Several other patients have been connected to the oxygen splitter, with L/min set as follows:
   - Patients 1, 4 and 5: **1 L/min**
   - Patients 2 and 3: **2 L/min**

   A sixth patient is connected to the second port of the oxygen concentrator and is receiving **3 L/min** of oxygen. You need to provide an additional patient with oxygen and connect that patient to the flow splitter at **1 L/min**. Will this have an effect on the oxygen being provided to the other patients? If so, what?

   It will have an effect on the oxygen being provided to other patients. Patients 1 through 6 are in total receiving a total of **10 L/min** of oxygen. Adding an additional patient to this system would make the total load on the oxygen concentrator **11 L/min**. This would overwork the oxygen concentrator and make the total oxygen concentration delivered decrease.
References