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: Pulse Oximeter

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The authors have made every effort to check the accuracy of all information and instructions for use of any devices or equipment. As knowledge base continues to expand, readers are advised to check current product information provided by the manufacturer of each device, instrument, or piece of equipment to 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

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

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

This NEST-ED Clinical Module has been prepared to help healthcare staff & students understand when & how to use bubble CPAP 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 on a digital device, download and open the document in Adobe Acrobat, on the toolbar click View, Navigation Panes, and then click Bookmarks. Use the Bookmarks pane to navigate between sections of the document:

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.
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.

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.

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.

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 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.
Respiratory Support

Pulse Oximeter
1 Clinical Problem

Assessment of oxygen saturation with a pulse oximeter should be used as part of routine assessment for all infants on admission.

Pulse oximeters should also be used during treatment for all sick or at-risk patients, or those being treated with oxygen therapy (1.1a, 1.1b), CPAP (1.2), or any form of assisted ventilation. (1.3)
2 Assessment

Peripheral pulse oximetry is a non-invasive & painless process of measuring heart rate and oxygen saturation (oxygen bound to haemoglobin in the capillaries).

Pulse oximeters may be used to help determine the severity of an infant’s illness by evaluating if blood oxygen saturation is low and if respiratory support is needed. Pulse oximeters also may be used to assess the success of treatment and determine a need for increasing or decreasing respiratory interventions to achieve target SpO₂.

Pulse oximeters have one red- and one infra-red light-emitting diode and a photodetector. (2.1) The light emitted by the diodes is absorbed by tissues, and amount of absorption is measured by the photodetector. Functional haemoglobin bound with oxygen is called oxyhaemoglobin. Percent saturation of oxygen bound to haemoglobin is called SpO₂. A microprocessor within the pulse oximeter determines the percent of oxygen in the blood by comparing the concentration of deoxyhaemoglobin to oxyhaemoglobin at two different light wavelengths. (2.2)

When using a pulse oximeter, several factors impact the stability of the patient’s trace. Examples of a “normal signal” & potential “poor traces” are below. (2.3)

When using a pulse oximeter, several factors impact the stability of the patient’s trace. Examples of a “normal signal” & potential “poor traces” are below. (2.3)

Pulse oximeters may be:
- Fixed (2.4) (for continuous reading of one patient)
- Handheld (2.5) (for spot reading vital signs between patients, or the same patient at intervals)
- Finger clip (2.6) (for continuous or spot reading of vital signs; only appropriate for adult or older paediatric patients. NOT recommended for use in neonatal patients)
The same pulse oximeter can be used for adult, paediatric, and neonatal patients. The alarm settings should be changed on the oximeter and appropriately sized probes must be used. Probe size will vary depending on patient age.

Normal SpO₂ for neonatal patients should be:

- **90% – 100% if not on oxygen**
- **90–95% on oxygen (Alert 2.1)**

If SpO₂ readings are less than 90%, the patient should be considered for supplemental oxygen therapy (see oxygen concentrator module).

**Oxygen saturations, heart rate, and clinical condition should all correspond.**

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**ALERT 2.1: Oxygen targets in newborns**

Exact oxygen saturation targets for premature newborns remains an area of controversy. However, most authorities agree that saturations between 90-95% are reasonable to minimise complications associated with low and high oxygen levels, including death, neurodevelopmental impairment, and Retinopathy of Prematurity.¹⁻⁴
3 Management

Management of a pulse oximeter 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. Follow hand washing procedures.
2. Collect:
   - Pulse oximeter
   - Pulse oximeter probe
   - 70% alcohol solution (Alert 3.1)
   - Cotton swab
3. Turn on pulse oximeter by pressing and holding the power button. (3.1) The display should turn on.
4. Connect the probe. (3.2)
   - Check the shapes of the pulse oximeter port & external probe sensor. If these are not the same size, you need an adapter. This should be provided with the pulse oximeter.
   - Connect the probe connector to the pulse oximeter probe port. Careful not to bend the pins.
5. Check for a red light on the probe. If the probe displays a red light, take steps to prepare patient for device. If the probe does not display a red light, follow the guidelines in Pulse Oximeter: Troubleshooting & Repair. If the pulse oximeter is turning on, but no trace is showing.
6. Clean the pulse oximeter probe thoroughly using alcohol and a cotton swab.
**ALERT 3.1: Low level disinfection solutions**

Disinfection of equipment should always comply with manufacturer guidelines. General guidance on environmental cleaning and disinfection of equipment was taken from Infection Prevention and Control: Reference Manual for Health Care Facilities with Limited Resources, Jhpiego. Module 6 which lists isopropyl alcohol (70-90%), sodium hypochlorite (0.05% or >100ppm available chlorine), quaternary ammonium, and Iodophor germicidal detergent as appropriate for low level disinfection. Phenolic germicidal detergent is also listed in this category but should not be used in neonatal wards since affordable, effective alternatives are available; and, there are concerns it may cause hyperbilirubinemia and/or neurotoxicity in neonates.

**PREPARING A PATIENT**

1. Follow hand washing procedures.
2. Always explain the purpose, risks, and benefits of a procedure to guardians BEFORE performing the procedure.
3. Collect:
   - Neonatal clip or wrap probe
   - Pulse oximeter
   - Gauze
   - 70% Alcohol
4. Select best location on patient to collect reading:
   - Wrist or foot (wrap probe); fingers or toes (clip probe)
   - Well perfused, warm and with intact tissue
5. Clean location with alcohol & gauze.
6. Position the patient in a neutral position (3.3) to ensure airway patency.

3.3 Position the patient in a neutral position.
STARTING A PATIENT

1 Adhesive (one-use) wrap probe:
   - Remove the wrap probe from its packaging and peel from its plastic base.
   - Place the part of the tape with the sensor, sensor side down, on the wrist whilst palm-side up or on the sole of the foot. The wrist is only suitable for preterm babies.
   - Wrap the adhesive strip around the wrist or foot to secure in place.

2 Rubber (reusable) wrap probe: (3.4)
   - Place the part of the wrap probe with the sensor, sensor side down, on the wrist whilst palm-side up or on the sole of the foot (3.5)
   - Wrap the rubber connecting strip around the wrist or foot (3.6), thread through hole & tighten to secure in place (3.7) Ensure the light and sensor are opposite each other.

3 Clip probe:
   - Squeeze the tips of the clip probe to open.
   - Place gently on the patient’s fingers or toes and release.

Wrap and clip probes should be firmly placed without need to be held. The probe should not be so tight that it is causing pressure on the skin or impairing circulation.
CARING FOR A PATIENT

1. Allow the patient’s trace to establish before reading SpO₂ and heart rate. (3.8) These should correspond to patient’s clinical condition. If they do not correspond, reposition the probe to ensure good contact with the patient.

2. Record SpO₂ and heart rate in patient documentation. Pulse oximeters are inaccurate for readings under 70%; readings between 20% and 60% do not correlate to clinical deterioration or improvement. **(Alert 3.2)** A low reading should alert you to look for a problem with the probe fixation, baby or oximeter.

3. If continuously monitoring patient, periodically check the sensor site (3.9) during monitoring for evidence of skin damage.

4. Keep the parents informed of baby’s progress.
ALERT 3.2 Accuracy thresholds for pulse oximeters

*WHO Technical Specifications for Oxygen Devices* lists accuracy between 70-100% $\text{SpO}_2$ as a minimum requirement for all types of pulse oximeters. Additionally, during NEST360˚ technical testing and review, most (if not all) devices were only tested by the manufacturer to guarantee accuracy within a certain precision between 70-100%.

**REMOVING A PATIENT**

Removing the probe from the patient varies based on the type of probe in use:

1. **If using an adhesive wrap probe:** peel adhesive away from patient & pull probe away from patient. Disinfect probe site on patient & wrap probe with 70% alcohol if reusing.
2. **If using a rubber wrap probe:** unthread rubber connecting strip through the hole. Pull probe away from patient. Disinfect probe site on patient & the wrap probe with 70% alcohol.
3. **If using a clip probe:** press on the tips of the clip probe to open. Gently pull away from patient. Disinfect probe site on patient and clean probe with 70% alcohol.

**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 assessing a patient using a pulse oximeter or handling any probes that will be used on a patient.

2. Ensure that all patient-related consumables (including probes) are new or have been cleaned thoroughly before use. Any patient-related consumables must be cleaned before they are used to assess another patient using the pulse oximeter.

3. All patient-related consumables should be stored in a clean, dry location. Keep cleaned probes separate from those waiting to be cleaned. Any cables should be loosely wrapped & secured, preventing sharp bends, pinches or kinks, which will decrease their lifetime.

**DISINFECTION AFTER USE**

1. Clean reusable probes with alcohol. Adhesive probes are specified for single-use; if reusing disinfect sensor with alcohol. *(Alert 4.1)*

2. If pulse oximeters or patient consumables (including probes) are not cleaned thoroughly before use, infection can be transmitted. Care should be taken particularly for consumables marked as single-use but are reused (such as adhesive wrap probes).

3. Between patients, wipe down the pulse oximeter with alcohol. *(4.1)* Be careful not to submerge or drip alcohol onto the pulse oximeter or any of its cables.

![](image)

**4.1** Wipe down the pulse oximeter probe with alcohol-soaked gauze between patients.

**ALERT 4.1**

While many pulse-oximeter probes are designed to be single use devices, cost and logistical constraints make this unrealistic in many low resource settings. Recommendations for cleaning single use devices were taken from *Infection Prevention and Control: Reference Manual for Health Care Facilities with Limited Resources, Jhpiego.* Vigilance by healthcare workers to assess that pulse-oximeter readings correlate to patient’s heart rate and clinical condition is especially critical when re-using probes meant for single-use. It is not known how rapidly pulse-oximeter probes degrade or become inaccurate with re-use.
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**

- **Misdiagnosis:** a poor trace (5.1) may contribute to misdiagnosis and can result from:
  - **Hypovolaemia/hypotension:** poor peripheral perfusion or movement may cause a false reading.
  - **Peripheral cyanosis/anaemia:** poor oxygen delivery to the tissues, compromises measured saturation. Saturation readings below 70% are not reliable as clinical guides.
  - **Hypothermia:** causes poor peripheral perfusion which in turn can provide an inaccurate representation of the oxygen saturation within the blood.

- **Pressure sores:** if the pulse oximeter probe is attached too tightly, inappropriately or too long at one site, pressure sores may develop. The warmth of the light may irritate the skin of a premature baby which is why the probe needs regular repositioning.

- **Poorly fitting probes can lead to inaccurate saturation measurements:** if the probe is too large for the patient, the probe will shift in place, creating issues both in terms of inconsistent measurement due to multiple contact points as well as the potential to have no direct contact points with the skin. If the probe is too small for the patient, blood flow may be constricted and the reading affected. Also, the light and sensor must be positioned opposite each other.

- **Patient movement:** as the patient moves, the contact point between the probe and the patient moves along the patient’s skin. This movement provides an inconsistent measurement because it samples from various contact points in the skin, rather than remaining in the same contact point of tissue.

- **Strong light:** if strong light (e.g., phototherapy, exam lights, or sunlight) is on a probe sensor, the light signal from the pulse oximeter probe may be drowned out by the
stronger environmental light, leading to incorrect results. A cloth covering of the sensor site will protect it from bright light.

- **Oximeter alarm settings:** pulse oximeters may have adult, paediatric, and neonatal settings in the same device. (5.2) Pulse oximeters are usually set to a default adult setting. If the pulse oximeter is not set to neonatal parameters, alarms may sound inappropriately.

![Pulse oximeter set to adult.](image)
6 Care & Maintenance

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

POWER SOURCE

A pulse oximeter is powered by replaceable or rechargeable (6.1) batteries. If using a rechargeable device, the users should regularly charge the pulse oximeter when not in use to ensure power in the event of a power outage.

WARD LOCATION

When using the pulse oximeter, the device should be placed in a secure location to prevent drops and breakages. The device and associated probes should be stored in a clean, dry, and secure area. The device should never be placed inside a cot or bassinet.

USER PREVENTIVE MAINTENANCE

Preventive maintenance should be conducted to ensure that the pulse oximeter is in good working order for emergency use.

1. Turn on the pulse oximeter. Connect the probe and check for a red light.
2. Connect a clip probe and test readings on your finger for normal saturations (above 90%). (6.2)
## 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 pulse oximeter is not turning on:**
   - Check the batteries or charge on the pulse oximeter.
   - Install new batteries and try again, spare batteries should be available on the ward.
   - Make sure you press and hold the power button for at least 5 seconds.
   - If the pulse oximeter is still not turning on, contact your maintenance department for assistance.

2. **Pulse oximeter is turning on, but no trace is showing:**
   - Check the probe for a flashing red light. If there is no light, check that the pulse oximeter probe is still connected to the pulse oximeter.
   - If the pulse oximeter probe is still connected and no light is showing, try replacing the probe (and adapter, if using) with a different probe (and adapter, if using).
   - If after replacing the probe (and/or adapter) there is still no light, contact your maintenance department for assistance.

3. **If there is a red light flashing but no trace is showing:**
   - Wait at least one minute for signal to improve.
   - Ensure that the probe is dry and clean, skin is dry and that the extremity used for assessment is warm and well perfused. Try an alternate extremity.
   - If after addressing above issues you are still unable to obtain a trace contact your maintenance department for assistance.

4. **If pulse oximeter is turning on but taking time to stabilise trace:**
   - Check that no powerful light sources are shining on the pulse oximeter probe.
   - Confirm that the patient is not moving and that the probe is still securely attached.
   - Confirm the probe is dry and clean.
   - Choose an extremity that is warm, dry, well perfused and wait at least one minute for the signal to stabilise before trying an alternate extremity.
   - If after addressing above issues you are still unable to obtain a trace contact your maintenance department for assistance.
All pulse oximeters have a users’ manual. These should be accessible online. If not available for download online, contact the manufacturer to request access to a copy.

Assessment Questions

1. Why is regular cleaning of the probes so important?
   Probes are reused for multiple patients. If the probes are not adequately cleaned, they have the potential to spread infections to multiple patients on the ward.

2. What is the most common failure seen in pulse oximeters?
   Batteries or power issues.

3. Select the wave form that best represents a good quality, normal trace.

4. A 32-week premature baby is receiving oxygen. What is the target oxygen saturation for this baby?
   90 – 95%.

5. Match the probe type with the correct pulse oximeter.

(a)  
(b)  
(1)  
(2)
References


6 Sharma, G. Infection Prevention and Control at Neonatal Intensive Care Units. 134.