



# 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

This series reflects the work of the NEST360° team through a joint effort with partner organisations. Some rights reserved. This work is available under the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International license (CC BY-NC-SA 4.0; <https://creativecommons.org/licenses/by-nc-sa/4.0/>).

Under the terms of this license, you may copy, redistribute and adapt the work for non-commercial purposes, provided the work is appropriately cited, as indicated below. In any use of this work, there should be no suggestion that NEST360° endorses any specific organisation, products, or services. The unauthorised use of the NEST360° names or logos is not permitted. If you adapt the work, then you must license your work under the same or equivalent Creative Commons license. If you create a translation of this work, you should add the following disclaimer along with the suggested citation: *"This translation was not created by Newborn Essential Solutions and Technologies (NEST360°). NEST360° is not responsible for the content or accuracy of this translation. The original English edition shall be the binding and authentic edition"*.

**Suggested citation.** NEST360°. *Newborn Essential Solutions and Technologies-Education – Clinical Modules*. (June 2020). License: CC BY-NC-SA 4.0.

**Rights and licensing.** For queries on rights and licensing, see the full legal code for the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International Public License (<https://creativecommons.org/licenses/by-nc-sa/4.0/legalcode>).

Please contact [nest360@rice.edu](mailto:nest360@rice.edu) to obtain a version of the series that may be more easily adapted and integrated into other materials.

**Third-party materials.** If you wish to reuse material from this work that is attributed to a third party, such as tables, figures or images, it is your responsibility to determine whether permission is needed for reuse and to obtain permission from the copyright holder. The risk of claims resulting from infringement of any third-party-owned component in the work rests solely with the user.

**General disclaimers.** All reasonable precautions have been taken by NEST360° to verify the information contained in this publication. The mention of specific companies or of certain manufacturers' products does not imply that they are endorsed or recommended by NEST360° in preference to others of a similar nature that are not mentioned. The published material is being distributed without warranty of any kind, either expressed or implied. The responsibility for the interpretation and use of the material lies with the reader. In no event shall NEST360° or affiliated partner institutions be liable for damages arising from its use.

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.

## ACKNOWLEDGMENTS

We are grateful to the NEST360° Education Writing Team of Sara Liaghati-Mobarhan, Josephine Langton, Elizabeth Molyneux, and Jennifer Werdenberg, who contributed to content, evidence review, and coordination of publication of this document. We would also like to thank the NEST360° Education Group who contributed substantially to preparation of this content: Angela Okolo (Nigeria), Chinyere Ezeaka (Nigeria), Danica Kumara (USA), Edith Wathira Gichecha (Kenya), Ekran Rashid (Kenya), Emmie Mbale (Malawi), George Banda (Malawi), Georgina Msemu (Tanzania), Grace Irimu (Kenya), Harold Chimphepo (Malawi), Karim Manji (Tanzania), Kondwani Kawaza (Malawi), Maria Oden (USA), Maureen Majamanda (Malawi), Mustapha Bello (Nigeria), Nahya Salim (Tanzania), Rebecca Ngalande (Malawi), Rebecca Richards-Kortum (USA), Robert Tillya (Tanzania), and Steve Adudans (Kenya).

We thank the following people who reviewed the manual to provide expert opinion and guidance: Aggrey Wasunna, Alexandra Pledge, Alfred Gest, Alick Vweza, Andreas Hansmann, Andrew McArdle, Anne Hansen, Antke Züchner, Audu Lamidi Isah, Bev Bradley, Caroline Noxon, Carolyn MacLennan, Christabel Enweronu-Laryea, David Gathara, Edwin S. Palmer, Haika Mariki, Hamish Graham, Hans-Joerg Lang, Heloise Buys, Isa Abdulkadir, Jalemba Aluvaala, Jean Bowyer, Karim Manji, Kate Goldberg, Kathryn Maitland, Kouya Francine, Laila Hassan, Louisa Pollock, Louise Day, Manjari Quintanar-Solares, Mary Waiyego Kariuki, Maxwell Kroon, Melissa Medvedev, Mustapha Bello, Mwanamvua Boga, Natasha Rhoda, Neil Kennedy, Odessa Omany, Ornella Lincetto, Peter Moons, Peter Olupot-Olupot, Priscilla Wobil, Quique Bassat, Rachel Musoke, Rashmi K. Kumar, Sara Loetz, Sarah Kiguli, Sarah Kotsias-Konopelska, Sarah Rylance, Simon Nguranyang Phemoi, Simon Pius, Tayo Olaleye, Tim Baker, and Victor Tumukunde.

We also thank Daphne Flowers, Sara Desai, Raj Mankad, CORE Design Studio, Esalee Andrade-Guerrero, and An Le for preparing the design and illustrations in this document.

NEST360° is made possible by generous commitments from the John D. and Catherine T. MacArthur Foundation, the Bill & Melinda Gates Foundation, The ELMA Foundation, the Children's Investment Fund Foundation, The Lemelson Foundation, the Ting Tsung and Wei Fong Chao Foundation, and individual donors to NEST360°.

# TABLE OF CONTENTS

|                                           |           |
|-------------------------------------------|-----------|
| <b>NEST-ED</b>                            | <b>1</b>  |
| <b>CLINICAL MODULES</b>                   | <b>1</b>  |
| DISCLAIMER                                | 2         |
| ACKNOWLEDGMENTS                           | 3         |
| PREFACE                                   | 7         |
| ABBREVIATIONS                             | 8         |
| NOMENCLATURE                              | 8         |
| INTRODUCTION                              | 9         |
| <b>INFECTION PREVENTION &amp; CONTROL</b> | <b>11</b> |
| GENERAL INFECTION PREVENTION              | 11        |
| 1 Introduction                            | 12        |
| 2 Ward Infection Prevention               | 12        |
| 3 Environment                             | 14        |
| 4 Reprocessing Single-Use Devices         | 17        |
| Assessment Questions                      | 17        |
| References                                | 18        |
| <b>RESPIRATORY SUPPORT</b>                | <b>19</b> |
| PULSE OXIMETER                            | 19        |
| 1 Clinical Problem                        | 20        |
| 2 Assessment                              | 21        |
| 3 Management                              | 22        |
| 4 Infection Prevention                    | 26        |
| 5 Complications                           | 28        |
| 6 Care & Maintenance                      | 29        |
| 7 Troubleshooting & Repair                | 30        |
| Assessment Questions                      | 31        |
| References                                | 33        |
| SUCTION PUMP                              | 34        |
| 1 Clinical Problem                        | 35        |
| 2 Assessment                              | 35        |
| 3 Management                              | 37        |
| 4 Infection Prevention                    | 41        |
| 5 Complications                           | 42        |
| 6 Care & Maintenance                      | 43        |
| 7 Troubleshooting & Repair                | 44        |
| Assessment Questions                      | 45        |
| References                                | 46        |
| OXYGEN THERAPY                            | 47        |

|                            |        |
|----------------------------|--------|
| 1 Clinical Problem         | 48     |
| 2 Assessment               | 48     |
| 3 Management               | 50     |
| 4 Infection Prevention     | 52     |
| 5 Complications            | 55     |
| 6 Care & Maintenance       | 56     |
| 7 Troubleshooting & Repair | 56     |
| Assessment Questions       | 56     |
| <br>OXYGEN CONCENTRATOR    | <br>57 |
| 1 Clinical Problem         | 58     |
| 2 Assessment               | 58     |
| 3 Management               | 60     |
| 4 Infection Prevention     | 62     |
| 5 Complications            | 63     |
| 6 Care & Maintenance       | 63     |
| 7 Troubleshooting & Repair | 65     |
| Assessment Questions       | 67     |
| <br>OXYGEN CYLINDER        | <br>68 |
| 1 Clinical Problem         | 69     |
| 2 Assessment               | 69     |
| 3 Management               | 71     |
| 4 Infection Prevention     | 72     |
| 5 Complications            | 73     |
| 6 Care & Maintenance       | 74     |
| 7 Troubleshooting & Repair | 74     |
| Assessment Questions       | 75     |
| <br>FLOW SPLITTER          | <br>76 |
| 1 Clinical Problem         | 77     |
| 2 Assessment               | 77     |
| 3 Management               | 79     |
| 4 Infection Prevention     | 81     |
| 5 Complications            | 81     |
| 6 Care & Maintenance       | 82     |
| 7 Troubleshooting & Repair | 83     |
| Assessment Questions       | 84     |
| References                 | 85     |
| <br>BUBBLE CPAP            | <br>86 |
| 1 Clinical Problem         | 87     |
| 2 Assessment               | 90     |
| 3 Management               | 91     |
| 4 Infection Prevention     | 101    |
| 5 Complications            | 102    |
| 6 Care & Maintenance       | 103    |
| 7 Troubleshooting & Repair | 103    |

|                                                     |            |
|-----------------------------------------------------|------------|
| Assessment Questions                                | 105        |
| Heated & Humidified Air in Non-Invasive Ventilation | 106        |
| References                                          | 107        |
| <b>POINT-OF-CARE DIAGNOSTICS</b>                    | <b>110</b> |
| GLUCOMETER                                          | 110        |
| 1 Clinical Problem                                  | 111        |
| 2 Assessment                                        | 111        |
| 3 Management                                        | 112        |
| 4 Infection Prevention                              | 116        |
| 5 Complications                                     | 117        |
| 6 Care & Maintenance                                | 118        |
| 7 Troubleshooting & Repair                          | 120        |
| Assessment Questions                                | 120        |
| References                                          | 121        |
| <b>THERMAL MANAGEMENT</b>                           | <b>122</b> |
| RADIANT WARMER                                      | 122        |
| 1 Clinical Problem                                  | 123        |
| 2 Assessment                                        | 124        |
| 3 Management                                        | 125        |
| 4 Infection Prevention                              | 129        |
| 5 Complications                                     | 130        |
| 6 Care & Maintenance                                | 132        |
| 7 Troubleshooting & Repair                          | 134        |
| Assessment Questions                                | 135        |
| References                                          | 136        |
| <b>JAUNDICE MANAGEMENT</b>                          | <b>137</b> |
| PHOTOTHERAPY                                        | 137        |
| 1 Clinical Problem                                  | 138        |
| 2 Assessment                                        | 138        |
| 3 Management                                        | 141        |
| 4 Infection Prevention                              | 145        |
| 5 Complications                                     | 146        |
| 6 Care & Maintenance                                | 147        |
| 7 Troubleshooting & Repair                          | 148        |
| Assessment Questions                                | 149        |
| References                                          | 150        |

## PREFACE

**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

|                        |                                                        |
|------------------------|--------------------------------------------------------|
| <b>ABC</b>             | Airway, Breathing, Circulation                         |
| <b>bCPAP</b>           | Bubble continuous positive airway pressure             |
| <b>dL</b>              | Decilitre                                              |
| <b>FiO<sub>2</sub></b> | Increased Fractional Concentration of Oxygen           |
| <b>Fr</b>              | French size                                            |
| <b>HAI</b>             | Hospital acquired infections                           |
| <b>HCWs</b>            | Healthcare workers                                     |
| <b>HFNC</b>            | High flow nasal cannula                                |
| <b>IV</b>              | Intravenous                                            |
| <b>KMC</b>             | Kangaroo mother care                                   |
| <b>LBW</b>             | Low birth weight                                       |
| <b>LCD</b>             | Liquid crystal display                                 |
| <b>LED</b>             | Light emitting diode                                   |
| <b>mm Hg</b>           | Millimeters of mercury                                 |
| <b>NEST360°</b>        | Newborn Essential Solutions and Technologies           |
| <b>NEST-ED</b>         | Newborn Essential Solutions and Technologies-Education |
| <b>NGT</b>             | Nasogastric tube                                       |
| <b>nm</b>              | Nanometer                                              |
| <b>O<sub>2</sub></b>   | Oxygen                                                 |
| <b>OGT</b>             | Orogastric tube                                        |
| <b>ppm</b>             | Parts per million                                      |
| <b>ROP</b>             | Retinopathy of Prematurity                             |
| <b>SpO<sub>2</sub></b> | Peripheral blood oxygen saturation                     |
| <b>UPS</b>             | Uninterruptible power supply                           |
| <b>WASH</b>            | Water, sanitation and hygiene                          |
| <b>WHO</b>             | World Health Organization                              |
| <b>wks</b>             | Weeks                                                  |

## NOMENCLATURE

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

---

# Introduction

The NEST-ED Clinical Modules have been prepared to help healthcare staff & students understand when & how to use equipment essential to newborn care. Modules 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.



### ALERT 0.0 Subject

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.



### ALERT 0.0

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

---

# Infection Prevention & Control

---

## General Infection Prevention

# 1 Introduction

**Introduction of essential devices to newborn care units is critical to improving newborn survival. However, devices can increase hospital acquired infections if adequate disinfection and cleaning measures are not put into place.**

This module focuses on infection control measures associated specifically with the essential devices, staff and visitors. A comprehensive discussion of infection prevention and control measures for a newborn care unit is beyond the scope of this document. Please refer to local and WHO guidelines for more detailed practice guidance.

# 2 Ward Infection Prevention

**Hospitals, wards, equipment and staff are all sources of infection for a baby. These infections are called Hospital Acquired Infections (HAI).**

HAIs are often caused by bacteria that are resistant to commonly available antibiotics – multidrug resistant bacteria – and are difficult to treat or eradicate from the nursery. Meticulous care is required to prevent infections from spreading from one baby to another in the ward. The prevention and control of all infections include:

- Hand hygiene
- Environmental cleanliness
- Medical equipment maintenance and cleaning
- Waste disposal

Water, Sanitation and Hygiene (**WASH**) are key elements in preventing and controlling infections.<sup>1</sup>

Infections are a major cause of morbidity and increased mortality. They often result in prolonged hospital stays and increased costs to the family. Sick and small neonates are at higher risk than other patients of acquiring HAIs due to the number of devices they may come into contact with in neonatal units. Lowering rates of HAIs means less use of antibiotics and ultimately fewer infections with multidrug resistant bacteria which are very difficult to treat in newborns.

While there are a number of critical elements associated with infection prevention and control in newborn units that will be discussed here, the **two most important** forms of infection control are always **hand washing** and **health screening**.

## HANDWASHING

Hand hygiene is the **single most important** measure to reduce transmitting infections between people and from one site to another on the same patient. All guardians, health care workers (HCWs), or visitors should be taught thorough handwashing (using the WHO technique).

- When entering a unit all HCWs and guardians must thoroughly wash their hands and arms up to the elbow with soap and water. Hands should be air-dried or dried using single-use towels that are then washed, dried and ironed before reuse.
- Hands should be washed whenever visibly soiled. Otherwise alcohol-based hand sanitiser is acceptable.

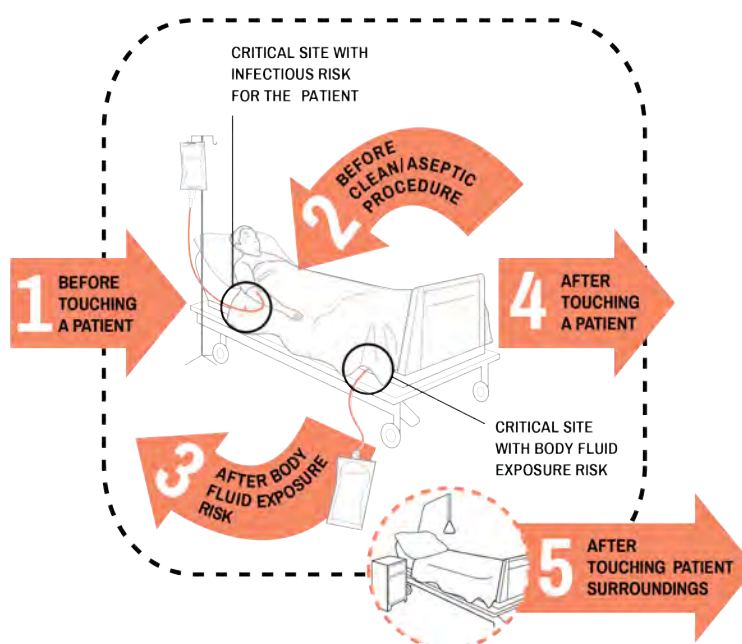
Hand washing or sanitising should be the **last** thing you do before touching a patient and the **first** thing you do after completing tasks on a patient.

## GLOVES

Gloves are worn to protect **both** HCWs and patients by reducing the spread of infection from bacteria on the hands. Gloves **do not** change the need to wash or sanitise one's hands between patient interactions. Gloves should be worn **only when necessary and disposed of immediately after use**, such as when:

- Touching bodily fluids, non-intact skin, and mucous membranes.
- Performing invasive procedures.
- Touching contaminated objects or surfaces.

**Repeat hand washing** or sanitising promptly after removing gloves.



2.1 WHO 5 Moments for Hand Hygiene.

## DRESS CODE

All hospital staff (including HCWs, maintenance and cleaning staff) should wear clean clothes with bare arms below the elbow when entering the neonatal ward. Department policy should be followed; this usually includes that no jewellery (apart from plain wedding bands) is worn, and that nails are kept short, natural, and unvarnished.

Gowns are not a standard precaution for HCWs or families in most neonatal units; if gowns are used, they should not be shared or reused until re-washed.

## HEALTH SCREENING

Any HCW or guardian with an acute or transmissible infection should not be on the ward to minimise the spread of infection. Mothers or guardians who have an acute illness should be isolated with their infants, if possible. Any guardian who has an acute respiratory illness should wear a mask and be especially careful about hand washing.

---

# 3 Environment

## PATIENT ISOLATION

Departmental isolation policies should cohort at-risk patients with similar infections in an isolation area within the nursery (e.g., babies with multi-drug resistant infections, highly contagious infections, babies born before arrival with signs of infection or any patients with airborne infections). Strict hand hygiene measures should be followed on entry and exit from this area. If equipment is used in any areas where patients are isolated, it should not be returned to the main neonatal care ward until it has been thoroughly cleaned and disinfected according to ward protocol.

Patients should not share cots or radiant warmers. If circumstances mandate that such a practice is unavoidable, cohorting patients with similar illnesses is preferred.

## EQUIPMENT CLEANING

All neonatal medical equipment (suctions, CPAP, vital sign monitors, radiant warmers, etc.) should be cleaned regularly in accordance with the training modules and equipment manuals. WHO recommends 0.5% dilution of chlorine as the standard disinfectant for materials and surfaces contaminated by blood or body fluids.<sup>2</sup> For metal and rubber surfaces which may be corroded by chlorine, 70% alcohol is also commonly utilised for low level disinfection. **Table 3.1** below provides more information on low-level disinfectants appropriate for neonatal wards.<sup>3</sup> Cleaning should be carried out when the equipment power source is switched off and it is unplugged. Care must be taken not to let water or other liquid enter internal to a device. Diluted disinfectants have various lifespans; ward guidelines should include accurate lifespans and dilution schedules for those in standard of practice.

**TABLE 3.1 CLEANING SOLUTIONS**

| Disinfectant<br>Common Name                                                                                                                      | Recommended Use                                                                                                                                                                                                                                                          | User & Equipment<br>Precautions                                                                                                                                                                                                                                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Sodium Hypochlorite,<br/>0.5% or 1%</b><br>liquid bleach                                                                                      | General disinfectant<br>Kills bacteria, fungi,<br>mycobacteria, spores & viruses<br>Not affected by hard water (e.g.,<br>high mineral content water)<br>Use 0.5% concentration for<br>disinfection of surfaces &<br>equipment contaminated with<br>blood and body fluids | Use in well-ventilated area<br>Respiratory irritant (can cause<br>breathing problems)<br>Appropriate PPE required while<br>handling & using because it can<br>cause skin irritation and burns<br>Should not be mixed with strong<br>acids or ammonia to avoid<br>release of chlorine gas                 |
| <b>Alcohol, 70%</b><br>isopropyl, ethyl alcohol,<br>surgical spirit                                                                              | Use on smooth surfaces, table<br>tops, aprons & other small<br>surfaces on which bleach<br>cannot be used (e.g., metal,<br>rubber)<br>Can be used for surfaces<br>including rubber stoppers on<br>medication vials<br>Does not leave residue                             | Use in well ventilated area and<br>avoid inhalation<br>Keep away from active heat<br>sources, electrical equipment,<br>flames, hot surfaces. Alcohol<br>must always completely dry on<br>equipment prior to use as<br>otherwise it could result in fire.<br>Allow to dry completely before<br>using area |
| <b>Quaternary<br/>ammonium compound</b><br>listed as % concentration of<br>QUAT on different cleaning<br>solutions                               | General disinfectant for<br>surfaces/equipment<br>contaminated with blood &<br>body fluids<br>Kills bacteria, fungi and some<br>enveloped viruses (HIV)<br>Has persistent antimicrobial<br>activity when undisturbed                                                     | Use in correct dilution and pour<br>only enough for current use<br>Does not kill spores, TB or non-<br>enveloped viruses<br>Hard water, cotton/gauze,<br>organic matter reduce its<br>effectiveness                                                                                                      |
| <b>Iodophor</b>                                                                                                                                  | More commonly used as an<br>antiseptic than a disinfectant                                                                                                                                                                                                               | Causes damage to silicone<br>catheters                                                                                                                                                                                                                                                                   |
| <b>Improved hydrogen<br/>peroxide</b>                                                                                                            | General disinfectant for<br>surfaces or equipment<br>contaminated with blood &<br>body fluids<br>Unaffected by organic matter<br>Non-corrosive & safe for workers                                                                                                        | Can be expensive, particularly if<br>purchasing large quantities                                                                                                                                                                                                                                         |
|  <b>Phenolic germicidal<br/>detergent</b><br>Dettol, Triclosan | Should <b>not be used in neonatal<br/>wards</b> since affordable,<br>effective alternatives are<br>available                                                                                                                                                             | May cause <b>hyperbilirubinemia</b><br>and/or <b>neurotoxicity</b> in<br>neonates <sup>4</sup>                                                                                                                                                                                                           |

Bleach is one of the most common substances used to disinfect medical devices. **Diluted bleach solutions have a lifespan of 24 hours and should be prepared daily.** Possible products are presented in **Table 3.2** with appropriate ratios to dilute to a 5% solution.

**TABLE 3.2 BLEACH PREPARATION**

| Product                                              | % Chlorine Available | Diluting to 5% Solution                                            |
|------------------------------------------------------|----------------------|--------------------------------------------------------------------|
| <b>Sodium Hypochlorite</b><br>liquid bleach          | 5.25 – 6.15%         | 1-part bleach to 9 parts clean water<br><b>RATIO [1 : 9]</b>       |
| <b>Sodium Hypochlorite</b><br>liquid bleach          | 3.5%                 | 1-part bleach to 6 parts clean water<br><b>RATIO [1 : 6]</b>       |
| <b>NaDCC (Sodium Dichloroisocyanurate)</b><br>Powder | 60%                  | 8.5 grams to 1-liter clean water<br><b>RATIO [8.5 g : 1 L]</b>     |
| <b>NaDCC, 1.5 g/tablet</b><br>tablet                 | 60%                  | 6 tablets to 1-liter clean water<br><b>RATIO [6 tablets : 1 L]</b> |

## ROUTINE CLEANING

All horizontal surfaces, including bedside equipment (bed rails, bedside tables, trolleys, commodes, taps, weighing scales, etc.) are cleaned and disinfected with a hospital-approved detergent OR disinfectant such as 0.5% chlorine or 70% alcohol solution **at least daily** and whenever visibly soiled.

Between patient admissions, all cots and patient beds should be cleaned thoroughly (including all surfaces of incubators) with a hospital-approved detergent/disinfectant such as 0.5% chlorine or 70% alcohol solution.

Floors, surfaces, and handles in the neonatal unit should be cleaned daily with appropriate solutions and according to departmental policy.

## SAFE HANDLING OF SHARPS

To prevent injuries, use extreme caution when handling sharps. This is particularly pertinent whilst drawing blood during glucometer reading.

- DO NOT RECAP used needles.
- Do not remove used needles from disposable syringes by hand.
- Do not bend or break used needles.

Place disposable syringes, lancets, needles, and other sharp items *promptly* in appropriate puncture-resistant containers.

---

# 4 Reprocessing Single-Use Devices

**In general, all single use devices should be used as such. However, in resource limited settings consumables meant for one-time use are commonly reused due to cost and supply chain limitations.**

Departmental policy for disinfecting and reprocessing single-use-devices must always be strictly followed in order to prevent infection spreading between patients.

When reprocessing 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 reprocessing. If equipment is not reprocessed 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<sup>3</sup>** for more detailed guidance on reprocessing of single-use devices.

Respiratory circuits, tubing and equipment are the most commonly reprocessed single-use devices. **Syringes, needles, and disposable gloves must never be reprocessed.**

---

## Assessment Questions

- 1 What disinfectant does WHO recommend using for cleaning surfaces and the housing of equipment?

**0.5% dilution of chlorine**

- 2 What surfaces and types of equipment does diluted bleach corrode?

**Metal/rubber and electronic equipment; 70% alcohol**

What is an alternative low-level disinfectant that might be used on these surfaces?

**70% alcohol**

- 3 What is the first action to take before handling a baby and what is the last action you take after completing a task?

**Wash hands; remove and dispose of gloves.**

---

# References

- 1 Water, sanitation, hygiene and health: a primer for health professionals. Geneva: World Health Organization; 2019 (WHO/CED/PHE/WSH/19.149). Licence: CC BY-NC-SA 3.0 IGO.
- 2 World Health Organization, Regional Office for the Western Pacific, World Health Organization & Regional Office for South-East Asia. *Practical guidelines for infection control in health care facilities*. (World Health Organization, Regional Office for Western Pacific ; World Health Organization, Regional Office for South-East Asia, 2004).
- 3 Sharma, G. Infection Prevention and Control at Neonatal Intensive Care Units. 134.
- 4 Curless MS, Ruparelia CS, Thompson E, and Trexler PA, eds. 2018. Infection Prevention and Control: Reference Manual for Health Care Facilities with Limited Resources. Jhpiego: Baltimore, MD.

---

# 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)**



**1.1a** Oxygen concentrator.



**1.1b** Oxygen cylinder.



**1.2** bubble CPAP.



**1.3** Assisted ventilation.

## 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 SpO<sub>2</sub>.

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 SpO<sub>2</sub>. 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)**



**2.1** Typical pulse oximeter probe.



**2.2** Light of pulse oximeter perfusing through skin.

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)**



**2.3** Trace examples.

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.



2.4 Fixed pulse oximeter



2.5 Handheld pulse oximeter



2.6 Finger clip oximeter

Normal SpO<sub>2</sub> for neonatal patients should be:

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

If SpO<sub>2</sub> 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.**



### 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.<sup>1-4</sup>

## 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.



**3.1** Turn on pulse oximeter



**3.2** Connect probe.

- 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,<sup>5</sup> 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.<sup>6</sup>

## **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.**



3.4 Rubber wrap probe.



3.5 Rubber wrap probe is placed sensor-side down on the sole of the foot.



3.6 Rubber connecting strip is wrapped around the foot.



3.7 Thread through hold & tighten to secure in place.

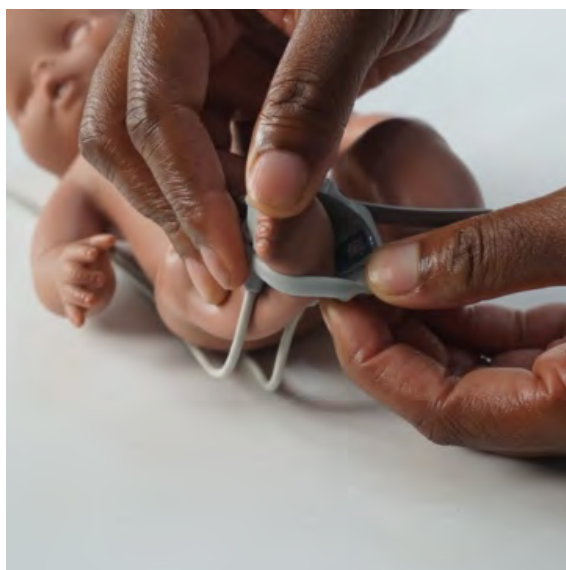
## CARING FOR A PATIENT

- 1 Allow the patient's trace to establish before reading SpO<sub>2</sub> 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 SpO<sub>2</sub> 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.



3.8 Allow the patient's trace to establish.



3.9 Check the sensor site for evidence of skin damage.



### ALERT 3.2 Accuracy thresholds for pulse oximeters

*WHO Technical Specifications for Oxygen Devices<sup>7</sup>* lists accuracy between 70-100% SpO<sub>2</sub> 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.



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.](#)<sup>5</sup> 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.



5.1 Examples of poor or inaccurate traces.

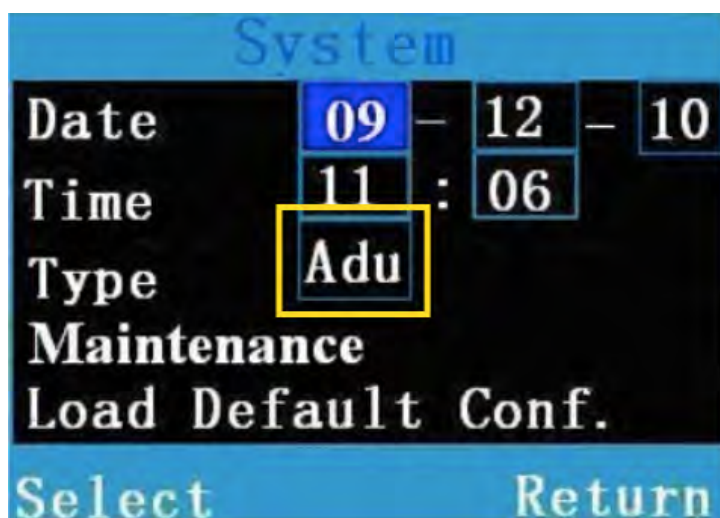
- **Pressure sores:** if the pulse oximeter probe is attached too tightly, inappropriately or too long at one site, pressure sores may develop. The warmth of the light may irritate the skin of a premature baby which is why the probe needs regular repositioning.

## DEVICE COMPLICATIONS

- **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.



5.2 Pulse oximeter set to adult.

---

## 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)



6.1 Rechargeable pulse oximeter with power port and charging cable.



6.2 Test readings on your finger for normal saturation.

# 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 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.



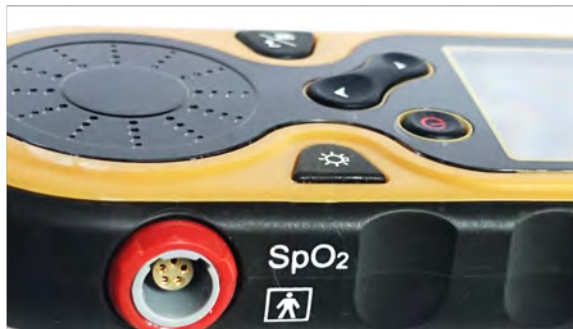
(a)



(b)



(1)



(2)

---

# References

- 1 Bancalari, E. & Claure, N. Oxygenation Targets and Outcomes in Premature Infants. *JAMA* **309**, 2161 (2013).
- 2 Cummings, J. J., Polin, R. A. & Committee on Fetus and Newborn. Oxygen Targeting in Extremely Low Birth Weight Infants. *Pediatrics* **138**, e20161576 (2016).
- 3 Manja, V., Lakshminrusimha, S. & Cook, D. J. Oxygen Saturation Target Range for Extremely Preterm Infants: A Systematic Review and Meta-analysis. *JAMA Pediatrics* **169**, 332 (2015).
- 4 Polin, R. A. & Bateman, D. Oxygen-Saturation Targets in Preterm Infants. *New England Journal of Medicine* **368**, 2141–2142 (2013).
- 5 Curless MS, Ruparelia CS, Thompson E, and Trexler PA, eds. 2018. Infection Prevention and Control: Reference Manual for Health Care Facilities with Limited Resources. Jhpiego: Baltimore, MD.
- 6 Sharma, G. Infection Prevention and Control at Neonatal Intensive Care Units. 134.
- 7 WHO-UNICEF technical specifications and guidance for oxygen therapy devices. (World Health Organization and the United Nations Children's Fund (UNICEF), 2019).

---

# Respiratory Support

---

## Suction Pump

# 1 Clinical Problem

**Obstruction of the nostrils, mouth or upper airway with secretions or blood will cause respiratory compromise and potential hypoxia.**

Suction pumps can be used in patients to clear secretions, vomitus, and blood from the mouth, nostrils, or upper airway.

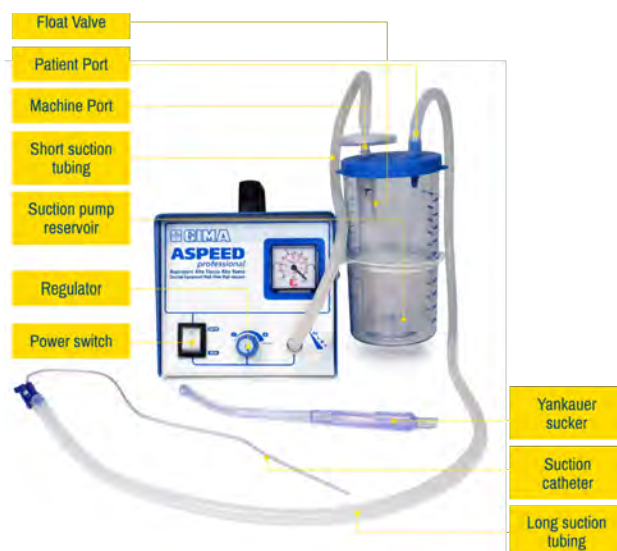
## LABOUR & OBSTETRIC NOTE

If meconium stained liquor is present at delivery and the baby is not vigorous or has not taken a breath, inspect the nose and mouth for obstruction. If meconium is present, gentle suctioning is recommended.<sup>1</sup> Routine suctioning is not recommended.

# 2 Assessment

**A suction pump (2.1) uses a negative vacuum created by an internal pump to remove blood or secretions from oral and nasopharyngeal cavities.**

A bacterial filter is used in circuit with the suction pump to filter out any aerosolised particles or bacteria from the blood and secretions suctioned from a patient.



2.1 A typical suction pump.

A suction pump may be tailored to adults **(2.2)** or paediatric patients. **(2.3)** Although an adult suction pump can be used on paediatric or neonatal patients, the vacuum range is much higher which makes it more difficult to control for the low ranges required for neonatal patients. **Use of an adult pump to treat neonatal patients is not encouraged.**



**2.2** Adult suction pump.



**2.3** Paediatric suction pump.

Penguin suckers are reusable devices made of a flexible silicone, which can be used to provide low pressure suctioning. **(2.4) Penguin suckers are autoclavable.** Although suction bulbs **(2.5)** may also be used, they are not autoclavable, are difficult to clean, and are not recommended due to greater infection risk between patients.



**2.4a** Penguin sucker.



**2.4b** Open penguin sucker.



**2.5** Suction bulb.

Neonatal patients should be suctioned gently, no deeper than the eye can see and only within a range of 60 to 100 mmHg of negative pressure and for a period less than 10 seconds. **(Alert 2.1)**



### ALERT 2.1 Suction Efficacy

In the referenced document, WHO recommends a range of 50-100 mmHg for suctioning for no more than 10 seconds. Based on expert feedback, it was felt that 60-100 mmHg is likely a more effective range and still within the WHO recommendation.<sup>2</sup>

# 3 Management

Management covers how to use the suction pump, 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 Collect: (3.1)

- Suction pump with collection reservoir
- Suction pump filter (if not already attached to pump)
- Short suction tubing
- Long suction tubing
- Suction catheter or Yankauer sucker
- Water in a suitable container (e.g., kidney dish, bowl)



3.1 Materials needed to use a suction pump.



3.2 Reservoir full of fluid.

- 2 Visually inspect the suction pump's collection reservoir. If it is full or there are secretions present (3.2), dispose of the secretions appropriately, clean the reservoir and place it back in place with the lid firmly closed.
- 3 If a filter is not attached to the collection reservoir, place the filter in the lid of the collection reservoir at the port labelled "Vacuum". Using the short suction tubing, connect the inlet of the suction filter on the suction pump collection reservoir to the suction pump outlet port. (3.3)
- 4 Connect long suction tubing to the collection reservoir outlet port labelled "Patient." (3.4)
- 5 Plug the power cable in the device. (3.5) Plug the power cable into the wall and turn on suction pump.



**3.3** Connect short tubing to filter & inlet port.



**3.4** Connect long suction tubing to collection reservoir outlet labelled "patient."



**3.5** Connect power cable to device.

- 6** Connect the suction catheter or Yankauer sucker to the long suction tubing. **(3.6)**
- 7** Using the suction regulator, adjust the suction vacuum to the desired level within safe neonatal levels (60 to 100 mm Hg). Test the suction functionality with some water. **(3.7)**



**3.6** Connect suction catheter or Yankauer sucker to long sucker tubing.



**3.7** Adjust suction vacuum to desired safe level and test by suctioning water from container.

## PREPARING A PATIENT

- 1** Collect: **(3.1)**
  - Suction pump with collection reservoir
  - Suction pump filter (if not already attached to pump)
  - Short suction tubing
  - Long suction tubing
  - Suction catheter or Yankauer sucker

- Water in a suitable container (e.g., kidney dish, bowl)
- 2 Always explain the purpose, risks, and benefits of a procedure to guardians BEFORE performing the procedure. Follow handwashing protocol and put on gloves.
  - 3 Suctioning is only required when there is airway obstruction. Visually inspect the patient's oral and nasopharyngeal cavities for secretions or blood.
  - 4 Assess whether to use a suction catheter or Yankauer sucker.
    - For thicker secretions it may be necessary to use a Yankauer sucker but do not use in the nares of a newborn.
    - For thinner secretions, use an appropriately sized suction catheter (typically Fr sizes 6, 8 or 10). A correctly sized suction catheter should be the approximate size of the nostril. Nasogastric tubes are not recommended as a substitute for a suction catheter.
  - 5 If secretions, blood, or meconium are visible, collect:
    - Clean suction catheter or Yankauer sucker
    - Tape
  - 6 If using a suction catheter: determine suction depth by measuring from the nose to the ear and halfway back. Mark this distance with a small piece of tape. **(3.8)**
  - 7 If using a Yankauer sucker, no measurement is required. **Suctioning should only be conducted as far as can be visually assessed.**
  - 8 Place the infant in a neutral position to ensure effective suctioning. **(3.9)**



**3.8** For the suction catheter, measure from nose to ear and halfway back and mark with tape. This is the suction depth.



**3.9** Place the infant in a neutral position.

## STARTING A PATIENT

- 1 Collect: **(3.1)**
  - Suction catheter marked with appropriate suction depth or Yankauer sucker
  - Suction pump with collection reservoir and tubing in place
  - Water in a container

- 2 Always explain the purpose, risks, and benefits of a procedure to guardians BEFORE performing the procedure.
- 3 Follow handwashing protocol.
- 4 Plug suction machine into power outlet and turn on.
- 5 Connect suction catheter marked with appropriate suction depth or Yankauer sucker to long suction tubing. **(3.11)**
- 6 Using the suction regulator, adjust the suction vacuum to the desired level, maintaining safe vacuum levels for neonates. Test the suction functionality by suctioning the water.
- 7 **When using a suction catheter:** pinch the catheter and insert **gently** into the patient's mouth or nostril to the point marked by the tape. When introducing catheter into the nose do so following the floor of the nose. Release the pinch on the catheter slowly as you withdraw the catheter from the mouth or nostril, gently rotating until it is completely removed. **(3.12)**
- 8 **If using a Yankauer sucker:** for thicker secretions or meconium, it may be necessary to use a Yankauer sucker.
  - Suctioning should only be conducted as far as can be visually assessed when using a Yankauer sucker. If secretions are thick, application of 1-2 drops of normal saline to both nostrils may assist suctioning and reduce nasal trauma.
  - Some Yankauer suckers may require a hole at the hub of the sucker to be occluded for suctioning pressure.
- 9 Allow the patient to visibly recover from the procedure. While waiting, rinse the catheter with water. **(3.13)** Repeat this process on the other side of the mouth or nostril.
- 10 Repeat steps 5 through 7 until all secretions are removed. **Remember: suctioning should be a gentle procedure. Do not suction too vigorously and do not suction too long.** Suction only until the reservoir is  $\frac{3}{4}$  full; if it reaches this point, remove collection jar, dispose of contents and reattach to complete suctioning.



**3.11** Connect suction catheter or Yankauer sucker to long sucker tubing.



**3.12** Pinch catheter and insert gently in nostril to point marked by tape.



**3.13** Rinse catheter with water.

## CARING FOR A PATIENT

Observe suctioned contents carefully whilst suctioning procedure is taking place:

- If fresh blood starts to be suctioned, trauma may have been caused to the oral or nasopharyngeal cavities. Decrease the force with which the suction catheter is being inserted into the patient's nose or mouth.
- If stomach contents are being suctioned, the patient's suction catheter is being inserted into the oesophagus. Recheck the suction depth measurement.

## REMOVING A PATIENT

Gently withdraw the suction catheter from the patient's passageway.

# 4 Infection Prevention

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

## GENERAL INFECTION PREVENTION

- 1 Clean hands with soap and water or alcohol before and after initiating treatment using a suction pump or handling any tubing that will be used on a patient.
- 2 Ensure that all patient-related tubing and consumables (including suction catheters and collection reservoirs) are new or have been cleaned thoroughly before use (if following re-use guidelines). Any patient-related tubing must be cleaned (following the ward protocol) before it is used to suction another patient. Tubing should be hung to dry after disinfection and should not touch the floor or other unsanitary surfaces whilst drying.
- 3 When re-using suction tubing there is a risk of infection if inadequately cleaned. If the machine is not cleaned after each use, it can become a source of infection for patients in the ward. **Suction catheters should never be reused.**
- 4 All patient-related consumables should be stored in a clean, dry location. Tubing should be stored in loose rolls, preventing sharp bends and kinks, which will decrease its lifetime.

### ALERT 4.1



Electrical suction pumps and associated equipment, if not re-processed or cleaned appropriately between patients, pose a significant infection risk. Please refer to [WHO Technical Specifications for Resuscitation Equipment](#) chapter 2.6 or [Infection Prevention and Control: Reference Manual for Health Care Facilities with Limited Resources](#), Jhpiego Module 6 for more detailed guidance on reprocessing of equipment associated with suction pumps.<sup>2,3</sup>

## DISINFECTION AFTER USE

- 1 Gently disconnect the suction catheter from the suction tubing and dispose of catheter appropriately. 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 safely.
- 2 Turn off and unplug the suction pump, if not using with another patient. Check filter. If filter is obviously dirty, replace. **(4.1)** Refer to user manual for specific instructions on when to change the filter.
- 3 Disinfect the suction pump pressure gauge controls using gauze and 70% alcohol.
- 4 The housing of the suction pump should be cleaned according to ward guidelines for disinfecting surfaces.
- 5 All tubing and collection reservoir should be cleaned after each patient.
  - Remove the collection reservoir from suction pump. **(4.2)** Dispose of contents and disinfect reservoir appropriately, **wearing gloves, a mask and apron to ensure staff safety**. Return collection reservoir to suction pump and store in secure location until next use.
  - Remove short and long suction tubing pieces. Follow hospital protocol for disinfection of tubing.



4.1 Check if the filter is dirty.



4.2 Remove the collection reservoir.

## 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 a patient is on oxygen, it may be necessary to remove oxygen treatment during suctioning, especially when suctioning the oropharynx. This interruption in treatment may worsen patient's hypoxia. Place the patient back on oxygen as soon as oral and nasopharyngeal cavities are clear.
- **Trauma:** incorrect or excessive suctioning of the nose and mouth may cause trauma to mucosal surfaces. If bleeding occurs, stop suctioning, assess severity, and restart when safe.
- **Vomiting:** incorrect measurement of the suction catheter or suctioning too far may stimulate the gag reflex and induce vomiting. This also risks potential aspiration.
- **Vagal stimulation:** inappropriately deep suctioning can cause vagal stimulation resulting in apnoea or bradycardia.

## DEVICE COMPLICATIONS

- **Positioning:** suction pumps are not heavy devices but are frequently positioned on walls / shelves. This is appropriate if well secured during use. If improperly secured, suction pumps may fall, causing potential permanent or fatal injury, particularly to neonatal patients.

# 6 Care & Maintenance

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

## POWER SOURCE

Suction pumps may be powered by mains or battery power **(6.1)** or manually via a foot or hand pump. **(6.2)** If a suction pump is battery powered, it should be taken off its charger **only as necessary** to ensure that it is charged for use in the event of a power blackout.



6.1 Battery-powered suction machine.



6.2 Foot-powered suction machine.

## WARD LOCATION

Suction pumps should be secured in an accessible location where nursing staff can regulate and view vacuum easily, but where the pump is not at risk of falling. Suction consumables should be kept nearby for easy access in case of emergency.

## USER PREVENTIVE MAINTENANCE

The suction pump should be turned on and allowed to run for 15 minutes every week.

# 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 machine's power cable is firmly secured **(7.1)** and that the power at the socket is on. If it is loose, secure the power cable.
- ☐ If the machine still does not turn on, contact your maintenance team.

### 2 The device stops suctioning

- ☐ Suction pumps often have a fail-safe valve installed in the lid of the collection reservoir to ensure that fluid is not sucked into the machine's internal pump. Check that the collection reservoir is not full **(7.2)**; if it is, empty and continue procedure.
- ☐ Check that the tubing is not loose and leaking. If the machine still does not suction, contact your maintenance team.



7.1 Check that power cable is securely attached.



7.2 Check that the collection reservoir is not full.

# Assessment Questions

- 1 Label the image below.



- 2 What is the appropriate range of negative pressures that can be used with neonatal patients?  
**60–100mmHg**
- 3 What is the purpose of the filter in the suction pump circuit?  
**The bacterial filter filters out bacteria that exhausts off blood & secretions whilst suctioning a patient.**
- 4 What are 2 complications that may occur due to suctioning? Please describe how you would manage each.  
(1) **Hypoxia; place the patient back on oxygen as soon as oral and nasopharyngeal cavities are clear**  
(2) **Trauma: stop suctioning, assess severity & restart when safe, using a gentler suctioning style**

---

# References

- 1 *Helping babies breathe provider guide.* (American Academy of Pediatrics, 2016).
- 2 *WHO technical specifications for neonatal resuscitation devices.* (World Health Organization, 2016).
- 3 Curless MS, Ruparelia CS, Thompson E, and Trexler PA, eds. 2018. *Infection Prevention and Control: Reference Manual for Health Care Facilities with Limited Resources.* Jhpiego: Baltimore, MD.

---

# 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 ( $\text{SpO}_2$ ) < 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.<sup>1</sup> 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  $\text{SpO}_2$  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/min<sup>1</sup> (**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 (FiO<sub>2</sub>) for term babies and 30% FiO<sub>2</sub> for preterm babies.<sup>1</sup> FiO<sub>2</sub> should then be titrated with a blender based on minutes of life and target SpO<sub>2</sub> 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 FiO<sub>2</sub>. In settings where blenders are not available FiO<sub>2</sub> will not be able to be as tightly controlled when oxygen is required during resuscitation.

Neonatal patients should reach SpO<sub>2</sub> 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.<sup>2</sup> 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.<sup>2</sup>



2.2 SpO<sub>2</sub> levels should be monitored regularly and remain between 90 – 95%.



## ALERT 2.2: SpO<sub>2</sub> & 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).<sup>1</sup>
- 2 Target peripheral oxygen concentrations (SpO<sub>2</sub>) 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.<sup>3-6</sup>

# 3 Management

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)**



3.5 Appropriately insert and secure nasal prongs.



3.6 Avoid tangling tubing around the patient.



## CARING FOR A PATIENT

- 1 After starting on oxygen, monitor saturations using continuous pulse oximetry. Titrate oxygen up and down until normal saturation limits ( $\text{SpO}_2$  90 – 95)<sup>3-6</sup> 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.



3.7 Switch nasal prongs for a facemask when needed.



## ALERT 3.2

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<sub>2</sub><sup>7</sup> and smaller infants may additionally be receiving some amount of positive pressure<sup>2,7-9</sup> 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.

# 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 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. **(4.1)** 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.



4.1 Hang tubing to dry.

## 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.<sup>2</sup>

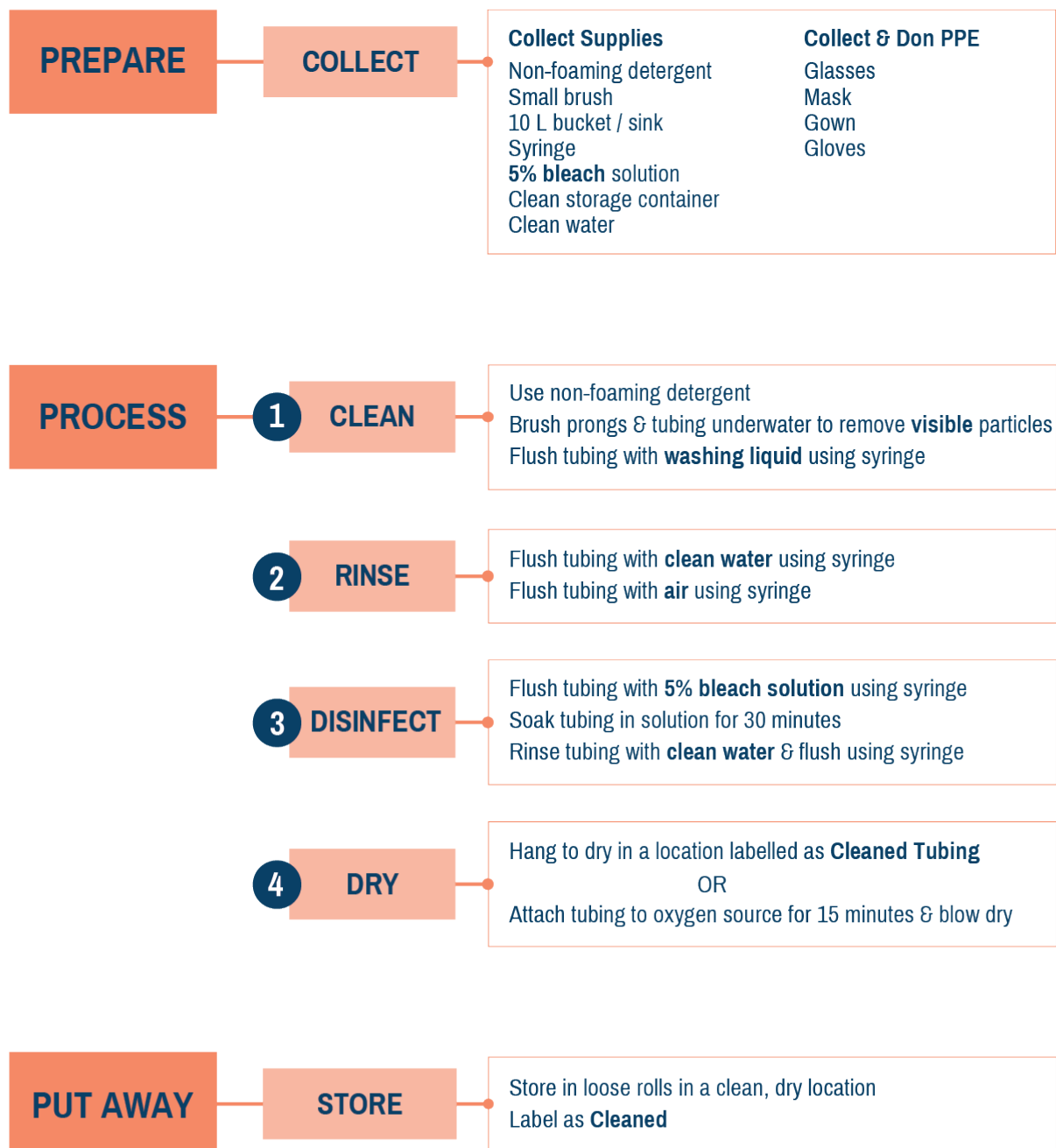


### ALERT 4.1 Reprocessing Single Use Devices

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](#)<sup>10</sup> 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:



# 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 ( $\text{SpO}_2$ ) 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 ( $\text{SpO}_2$ ) 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 ( $\text{SpO}_2 < 90\%$ ) 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.

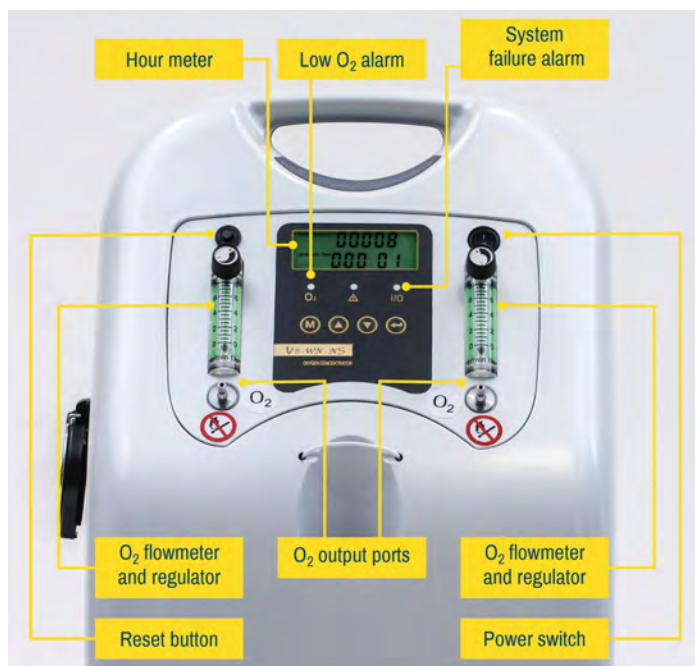


2.1 A typical oxygen concentrator.

Oxygen concentrators may provide oxygen via two types of flow:

- 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**.



**2.2** Oxygen concentrator components.

Neonatal patients should reach SpO<sub>2</sub> 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.<sup>2</sup> 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.<sup>2</sup>



**2.3** SpO<sub>2</sub> levels should be monitored regularly and remain between 90 – 95%.



## ALERT 2.1: SpO<sub>2</sub> & 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).<sup>1</sup>
- 2 Target peripheral oxygen concentrations (SpO<sub>2</sub>) 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.<sup>3-6</sup>

# 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)**



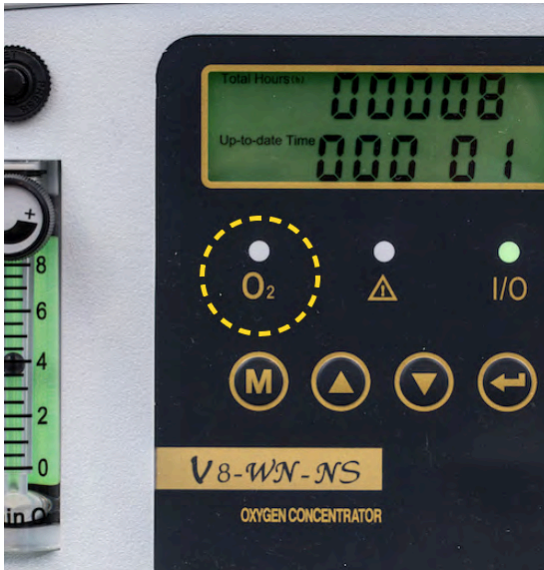
**3.1 (a)** Plug in the oxygen concentrator.



**3.1 (b)** Turn on the oxygen concentrator.

- 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.<sup>211</sup>
- 4 Connect correctly sized nasal prongs to oxygen port on machine **(3.3)** or to humidifier (if using).

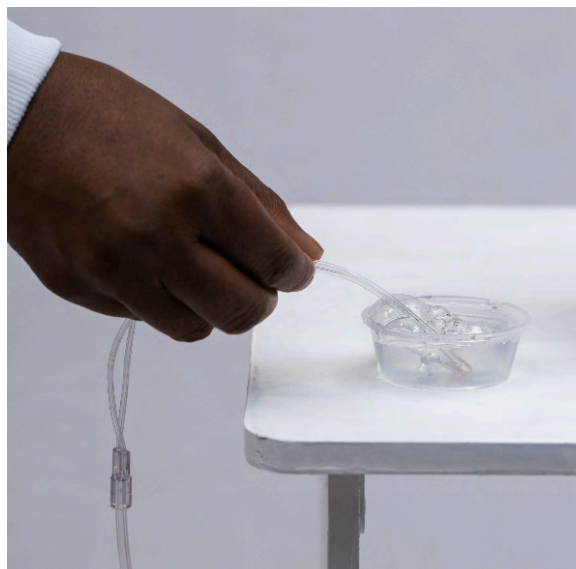


**3.2** The “Low Oxygen” indicator light demonstrates that produced concentrations are appropriate.



**3.3** Connect correctly sized nasal prongs to oxygen port.

- 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.”<sup>11</sup>



**3.4** Submerging the nasal prongs in water should produce bubbles.

## 4 Infection Prevention

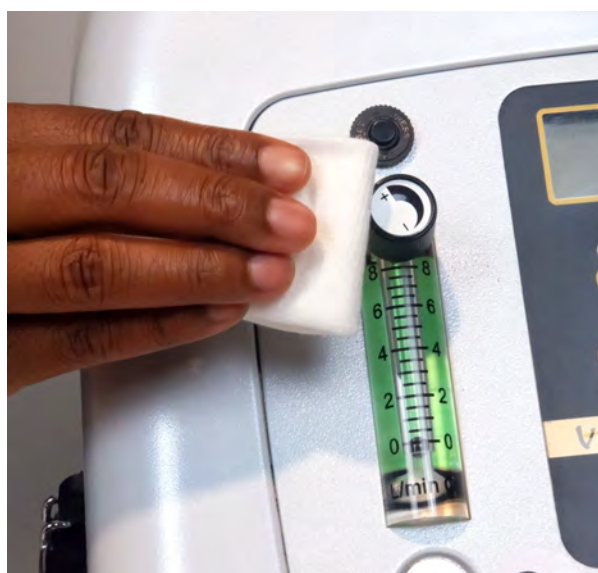
Routine and adequate cleaning of medical devices is critical to prevent hospital-acquired infections in newborn care units. If devices and equipment are not disinfected or reprocessed promptly or adequately between patients, they may pose a significant infection risk.

### GENERAL INFECTION PREVENTION

- 1 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.

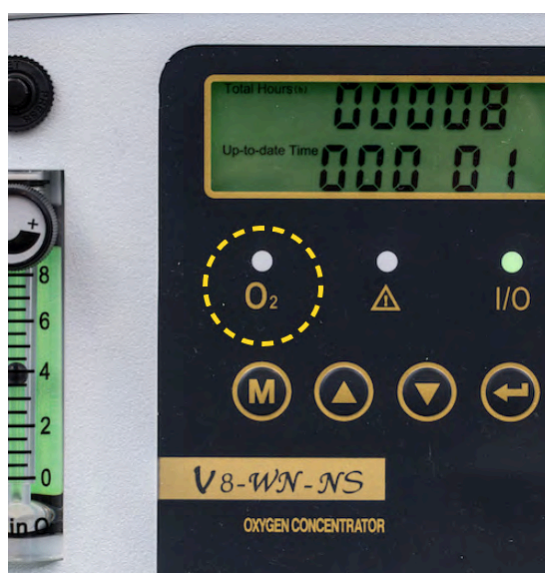
---

## 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.

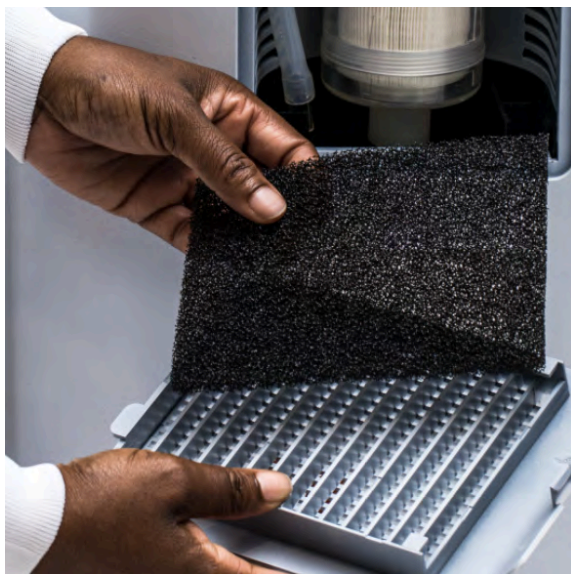
## WARD LOCATION

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.



6.1 Gross particle filter.



6.2 Bacterial filter.

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.

## 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.



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.



**7.2** Connect a Christmas tree nozzle to feel for flow.



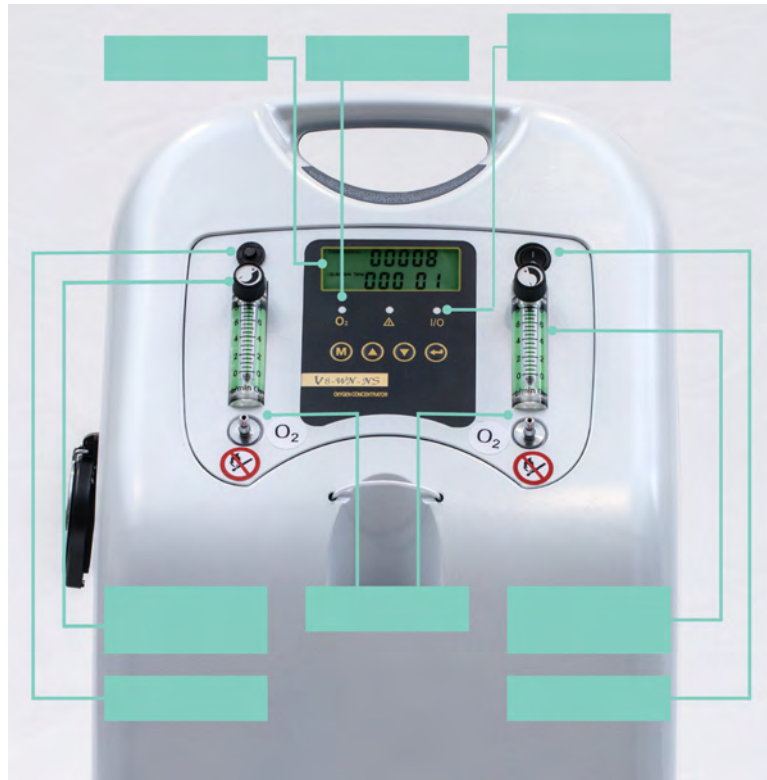
**7.3** Insert forceps wrapped in 70% alcohol-soaked gauze to clean debris.

## 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.

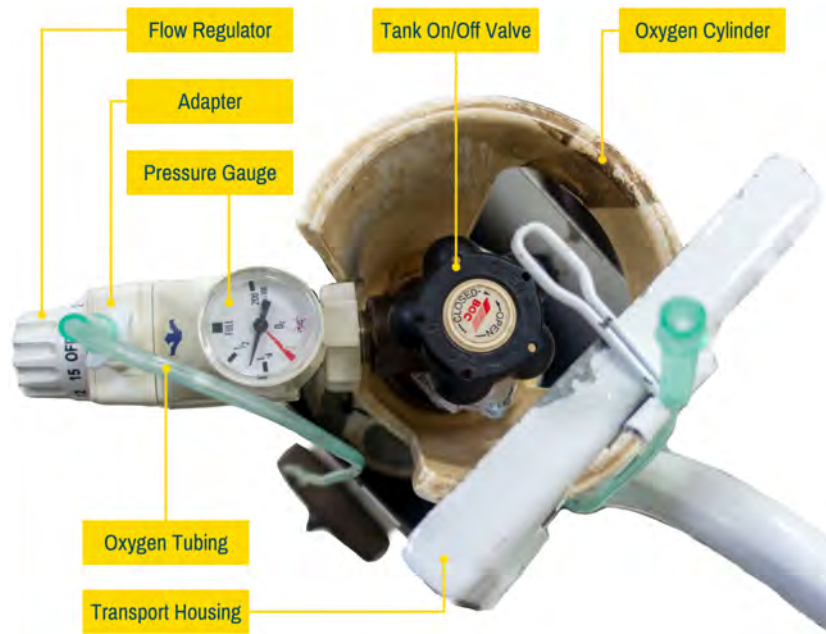


2.1 Typical oxygen cylinders.



2.2 A typical transport oxygen 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.



2.3 Oxygen cylinder components.

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 SpO<sub>2</sub> levels of 90 – 95% by 15 minutes after birth. **(Alert 2.1)**<sup>1,3–6</sup> If oxygen is needed it is recommended to give between 0.5–1 L/min.<sup>2</sup> 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.<sup>2</sup>



2.3 SpO<sub>2</sub> levels should be monitored regularly and remain between 90 – 95%.



### ALERT 2.1: SpO<sub>2</sub> & 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).<sup>1</sup>
- 2 Target peripheral oxygen concentrations (SpO<sub>2</sub>) 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.<sup>3-6</sup>

## 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 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.<sup>2,11</sup>
- 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”.<sup>11</sup>



3.4 Submerging the nasal prongs in water should produce bubbles.

## 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.

# 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.

### ALERT 5.1



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.**

## 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 hall- or walkways.**

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

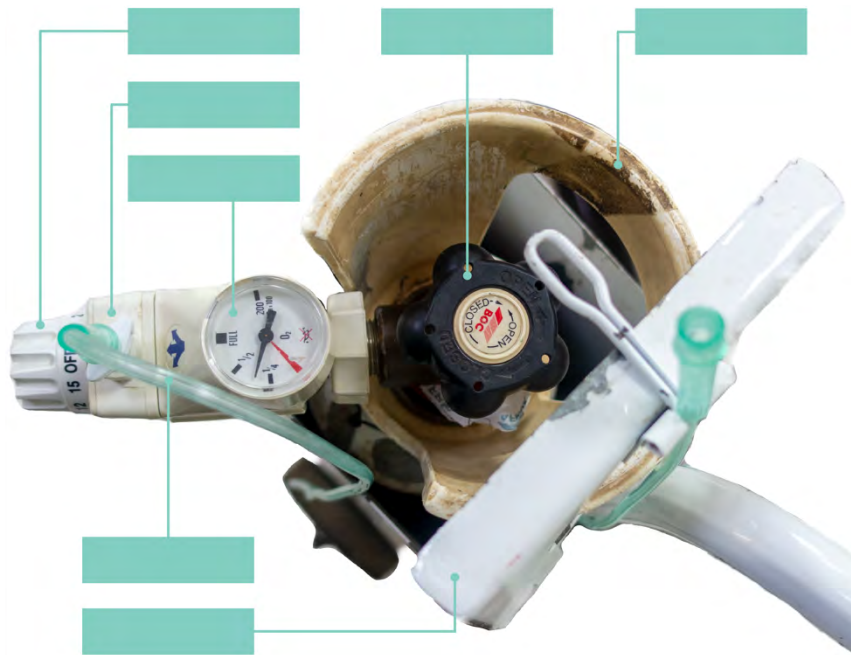
- ☐ Check for leakages by listening for any hissing sounds.
- ☐ Loose fittings. Check the connection between the pressure regulator and the oxygen cylinder. Tighten all fittings.
- ☐ If still not functioning well, close the stop valve tightly and send to maintenance. Replace with a full cylinder.

# Assessment Questions

- 1 The cylinder pressure gauge is reading 20%. What actions should you take?

**Close the stop valve and send to maintenance for refill. Replace with a full cylinder if available.**

- 2 Label the image using options from the word bank below.



- 3 What colours label a cylinder as containing oxygen?

**Black with white shoulders**

---

# 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

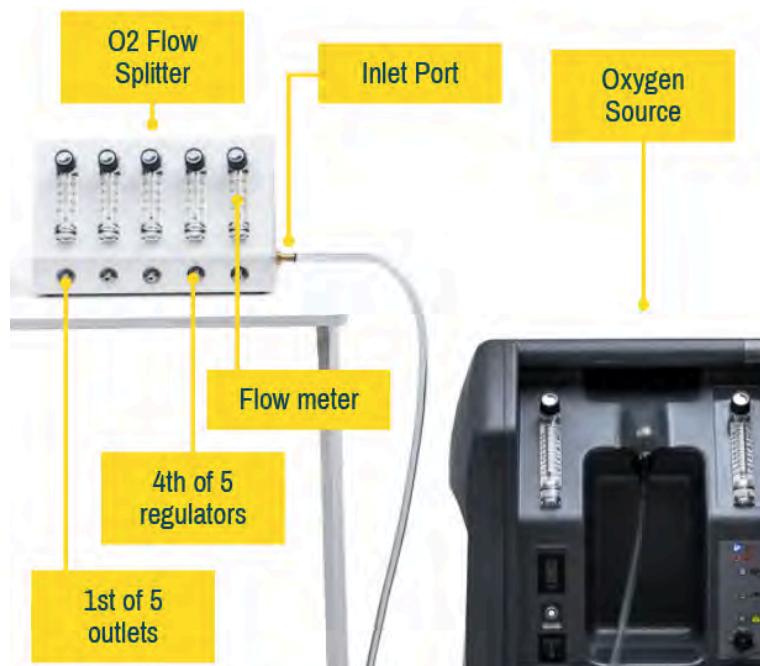
Hypoxia contributes to both morbidity and mortality. Flow splitters are accessory devices that divide oxygen from one source to give to several patients at independent, adjustable flow rates.

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.



2.1 A typical flow splitter.

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.**



2.2 Flow splitter components.

Neonatal patients should reach SpO<sub>2</sub> levels of 90 – 95% by 15 minutes after birth. **(Alert 2.1)**<sup>1,3-6</sup> If oxygen is needed it is recommended to give between 0.5-1 L/min.<sup>2</sup> 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.<sup>2</sup>



2.3 SpO<sub>2</sub> levels should be monitored regularly and remain between 90 – 95%.



## ALERT 2.1: SpO<sub>2</sub> & 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)<sup>1</sup>
- 2 Target peripheral oxygen concentrations (SpO<sub>2</sub>) 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.<sup>3-6</sup>

# 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.



**3.1** The oxygen splitter is securely placed with easy access to flow regulators.

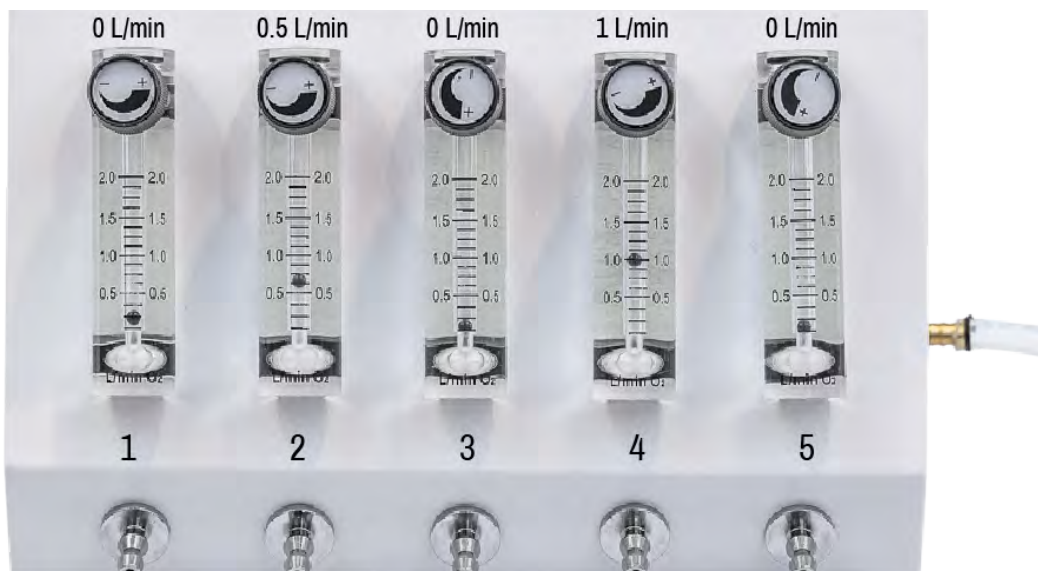


**3.2** Connect flow splitter tubing from oxygen outlet to flow splitter inlet port.

- 2 Connect oxygen splitter tubing from oxygen outlet source to oxygen splitter inlet port. **(3.2)**

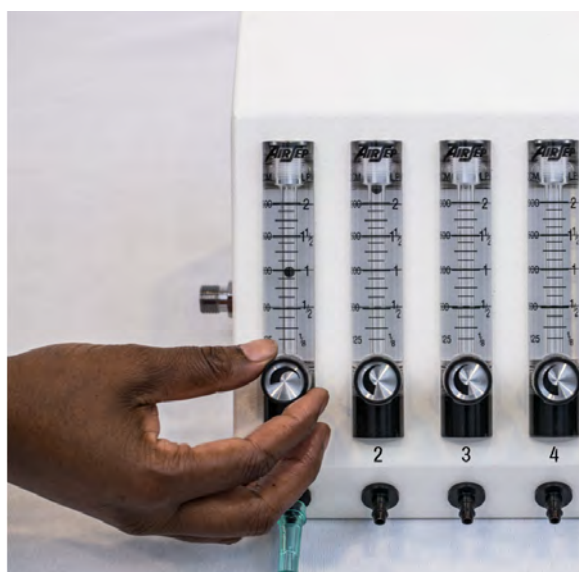
- 3 Assess level of oxygen needed from oxygen source. The source of oxygen (e.g., the concentrator) must be adjusted to provide a flow of at least 1L/min oxygen more than the total requirement from all the ports that are in use. **(3.3)**

**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**)

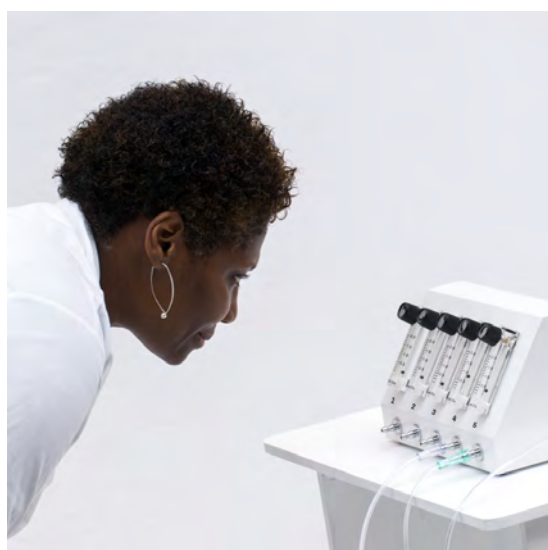


**3.3** Assess level of oxygen needed from oxygen source.

- 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 eyelevel. **(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.



**3.4** Adjust flow meter regulators individually.



**3.5** Observe provided L/min at eye level.

---

## 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**.

---

## 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

- 1 *Textbook of Neonatal Resuscitation (NRP), 7th Ed.* (American Academy of Pediatrics, 2016).
- 2 *Oxygen therapy for children.* (World Health Organization, 2016).
- 3 Bancalari, E. & Claure, N. Oxygenation Targets and Outcomes in Premature Infants. *JAMA* **309**, 2161 (2013).
- 4 Cummings, J. J., Polin, R. A. & Committee on Fetus and Newborn. Oxygen Targeting in Extremely Low Birth Weight Infants. *Pediatrics* **138**, e20161576 (2016).
- 5 Manja, V., Lakshminrusimha, S. & Cook, D. J. Oxygen Saturation Target Range for Extremely Preterm Infants: A Systematic Review and Meta-analysis. *JAMA Pediatrics* **169**, 332 (2015).
- 6 Polin, R. A. & Bateman, D. Oxygen-Saturation Targets in Preterm Infants. *New England Journal of Medicine* **368**, 2141–2142 (2013).
- 7 Walsh, M. Oxygen Delivery Through Nasal Cannulae to Preterm Infants: Can Practice Be Improved? *Pediatrics* **116**, 857–861 (2005).
- 8 Locke, R. G., Wolfson, M. R., Shaffer, T. H., Rubenstein, S. D. & Greenspan, J. S. Inadvertent administration of positive end-distending pressure during nasal cannula flow. *Pediatrics* **91**, 135–138 (1993).
- 9 Sreenan, C., Lemke, R. P., Hudson-Mason, A. & Osiovich, H. High-Flow Nasal Cannulae in the Management of Apnea of Prematurity: A Comparison With Conventional Nasal Continuous Positive Airway Pressure. *Pediatrics* **107**, 1081–1083 (2001).
- 10 Curless MS, Ruparelia CS, Thompson E, and Trexler PA, eds. 2018. Infection Prevention and Control: Reference Manual for Health Care Facilities with Limited Resources. Jhpiego: Baltimore, MD.
- 11 World Health Organization. *Technical specifications for oxygen concentrators.* (World Health Organization, 2016).

---

# Respiratory Support

---

## Bubble CPAP

# 1 Clinical Problem

**Bubble CPAP (bCPAP) devices provide both positive pressure & increased fractional concentration of oxygen ( $\text{FiO}_2$ ) to newborns with respiratory distress.**

Bubble CPAP (bCPAP) is particularly useful for premature babies with respiratory distress syndrome. **(1.1)**



**1.1** Chest indrawing in a neonatal patient, a common sign of respiratory distress

Very premature babies (<1.5kg and <32 weeks) benefit from early bCPAP. **(Alert 1.1)** Reference can be made to the **TRY algorithm** (see below). Depending on your facility and your national policy the lowest weight at which to commence bCPAP may differ. bCPAP should only be used when essential newborn care is in place, the equipment is functioning, oxygen is available, staff are adequately trained in bCPAP, and close monitoring can be assured.

?

## **ALERT 1.1: When do you initiate bCPAP vs low flow oxygen?**

Regarding the initiation of bCPAP versus low flow oxygen on the day of birth, protocol developers should consider the following functions and evidence. bCPAP functions to treat respiratory distress by improving both ventilation (controlled provision of continuous inspiratory pressure) and oxygenation [controlled provision of increased percentage of oxygen - termed the fraction of inspired oxygen ( $\text{FiO}_2$ )]. The positive pressure from bCPAP prevents lung tissue (alveolae) from collapsing on expiration thus improving ventilation, reducing the work of breathing and preventing potentially irreversible lung damage.<sup>1</sup> Additionally, bCPAP has been shown to promote production of endogenous surfactant,<sup>2</sup> improve apnoea of prematurity<sup>3,4</sup> and dramatically decrease progression to mechanical ventilation,<sup>5-9</sup> or death, in both high income<sup>10,11</sup> and low income<sup>12-15</sup> settings.

Thus, early bCPAP for preterm & small newborns, especially in settings where mechanical ventilation and surfactant are unavailable, is critical to prevent death. At a minimum, evidence points to preferential early initiation of bCPAP, rather than low flow oxygen, in preterm newborns under 1.5kg with any respiratory distress on the day of birth.

Bubble CPAP may also be used to treat neonatal patients with increased work of breathing, designated by nasal flaring, grunting, head nodding, severe recession, RR >60, or an oxygen requirement of 0.5 to 1 L/min with peripheral blood saturations of <90%, in premature or term infants.

### (Alert 1.2)

Increased work of breathing may be caused by:

- Neonatal pneumonia
- Severe transient tachypnoea of the newborn
- Persistent pulmonary hypertension of the newborn
- Apnoea of prematurity<sup>3,4</sup>
- Meconium aspiration syndrome
- Neonatal sepsis with severe respiratory distress

The **TRY algorithm** may be used by a nurse or clinician to decide who would benefit from bCPAP and, if necessary, whom to prioritise. The TRY algorithm signs and symptoms on which to act are straight forward and easily carried out. Premature babies benefit most from CPAP and are given priority. Babies with severe asphyxia leading to poor tone will not benefit. If CPAP machines are few in number, it is important to provide CPAP to those who will benefit most. There are always exceptions and in tertiary care units a paediatrician may decide to give CPAP to other infants. Deciding when to start CPAP for a premature baby may differ between national guidelines.

Contraindications to bCPAP include:

- Significant bleeding from mouth and nose
- Anatomical abnormalities of mouth and nose e.g., choanal atresia, cleft lip and palate
- Other obvious malformations incompatible with life
- Presence of a pneumothorax

Severely asphyxiated babies (with severe hypoxic ischaemic encephalopathy) do not benefit from bCPAP.



### ALERT 1.2 bCPAP & low flow oxygen context

Scale & delivery of neonatal care is critical. However, epidemiological data has shown that rapid scale up of neonatal care without sufficient attention to safety has long term negative consequences for neonatal morbidity<sup>16</sup> and is likely a contributor to the epidemic of preventable blindness due to retinopathy of prematurity (ROP) in these settings.<sup>17</sup>

Supplemental oxygen is life-saving. However, when given in supra-optimal doses, it has also been associated with ROP,<sup>18</sup> bronchopulmonary dysplasia,<sup>19</sup> periventricular leukomalacia and prolonged ventilation.<sup>20</sup> When using *any form* of oxygen therapy, it is important to closely monitor blood oxygen saturation (SpO<sub>2</sub>) levels in order to balance risks and benefits of supplemental oxygen. Exact blood oxygen saturation targets for premature newborns remain an area of controversy. However, most authorities agree that SpO<sub>2</sub> between 90-95% is reasonable to minimise complications associated with low and high oxygen levels.<sup>21-24</sup>

When choosing between low flow oxygen and bCPAP it is important to keep the following physiological considerations in mind. Newborns under 2.5kg receiving low flow oxygen exceeding 0.5 L/min are administered 40-100% effective FiO<sub>2</sub>,<sup>25-28</sup> which may increase morbidity. Delivery of low flow oxygen in preterm newborns under 1.5kg has the added complexity that positive pressure can be delivered even at flows as low as 1-2.5 L/min.<sup>29,30</sup> Unfortunately, as discussed above, at these rates of low-flow oxygen, preterm newborns would be exposed to elevated levels of effective FiO<sub>2</sub> which data show are likely to increase their morbidity.

In light of the above evidence and expert opinion, the recommendation was made by our consortium to consider bCPAP in appropriate settings when low flow oxygen greater than 0.5 - 1 L/min is required to maintain saturations >90%. Of note, this recommendation is in line with the WHO recommendation that a standard flow rate for neonates is 0.5 – 1L/min in WHO Oxygen Therapy for Children;<sup>31</sup> however, it is unaligned with the suggestion to consider 4L/min of oxygen as the transition threshold from nasal prongs to bCPAP.

**bCPAP outside the neonatal period is not addressed by NEST360° materials.**

### ASSESSING WHICH PATIENT TO PUT ON bCPAP

Always perform **ABC assessment** and **resuscitation** as needed **BEFORE** beginning **TRY bCPAP**

**T**

**TONE** is good

**R**

**RESPIRATORY DISTRESS:**  
O<sub>2</sub> saturations less than 90%  
on O<sub>2</sub> 1 L/min

**Y**

**YES** for **HR** greater than 100 bpm



**Baby is breathing**  
**HR greater than 100 bpm**  
**Weight more than 1 kg**

Tone is **POOR**  
Baby is floppy

**NO bCPAP**

Put on O<sub>2</sub> 1 L/min if saturation  
is less than 90% in room air

Tone is **GOOD**  
Baby is active

**WEIGHT IS BETWEEN 1-1.5 kg**  
**PREMATURE** less than 30 wks

**EARLY bCPAP**

**WEIGHT IS MORE THAN 1.5 kg**  
**RR** greater than 60 breaths per minute  
**O<sub>2</sub> Saturations** less than 90% in room air  
Signs of increased **work of breathing**

**START bCPAP**

## 2 Assessment

Respiratory distress can cause hypoxia contributing to both morbidity and mortality. Bubble CPAP devices (2.1) use a pump to provide a blend of air and oxygen at a continuous positive pressure. This pressure keeps airway spaces open and increases alveolar recruitment throughout respiration in a spontaneously breathing infant, which improves oxygenation and reduces work of breathing.



2.1 A typical bubble CPAP device with patient circuit.



2.2 Pressure is regulated by water depth

Traditional bCPAP devices are made up of the following components:

- **Pump:** pumps in air mixed with oxygen from an oxygen source.
- **Inspiratory tube:** connects the blended air and oxygen flow source to the patient.
- **Expiratory tube:** connects the patient to the pressure regulator.
- **Pressure regulator:** a water reservoir placed at the end of the expiratory circuit that provides pressure using water level.

bCPAP devices range in complexity from vitals measured (e.g., saturations/respiratory rates measured on the device) to outputs (e.g., humidified pressure vs pure pressure). **(Alert 2.1)**

Pressures used in bCPAP devices range from 5 to 10 cm of water. As bCPAP delivers a blend of air and oxygen, staff should also carefully monitor patients for oxygen saturation using a pulse oximeter. Neonatal patients should reach oxygen saturations of 90 – 95% by 15 minutes after birth. **(Alert 2.2)**



## ALERT 2.1: Use of humidification in bCPAP

Some bCPAP units use heated and humidified gas in the circuit although the exact benefits of humidification in non-invasive ventilation (i.e., bCPAP) in terms of survival, complications from therapy & morbidity are not well established. For a more thorough review of theoretical risk/benefits of heated humidified oxygen in bCPAP, see **Appendix 1**.

Potential benefits of heating and humidification could include:

- Increased comfort and adherence.
- Decreased upper airway mucosal injury.
- Decreased convective heat losses which may lead to hypothermia & challenging weight gain in infants.
- Decreased lung inflammation from mucus plugs which has unknown impact on morbidity & mortality of very low birthweight infants.

Potential drawbacks to heated humidification include:

- Hospital-acquired infection, especially in settings where clean water may not be readily available and humidifiers, which are typically meant for one-time use, are being cleaned and re-used between patients.<sup>32</sup>
- High financial cost of adding heated humidified gas.<sup>33</sup>
- High human resource cost in terms of repair and preparation of non-invasive ventilation units which may limit not only their use, but availability of this life saving technology within our setting.<sup>33</sup>

In summary, based mostly on expert opinion, it is likely that heated and humidified air is most important for the smallest newborns <1-1.25kg although this has never been explicitly studied. There is evidence from Malawi that unheated un-humidified bCPAP can be used successfully to decrease mortality of infants without excessive reports of upper airway complications, but physiological implications in terms of morbidity and mortality (hypothermia & weight gain) were not explicitly studied. Of note, survival of infants >1.5kg on un-heated un-humidified air bCPAP in this study<sup>12</sup> were similar to survival of infants >1.5kg in Rwanda on heated and humidified bCPAP.<sup>34</sup>

At this time, based on expert opinion and available literature, it does not appear that the benefits of humidification outweigh the potential risks/drawbacks for infants >1kg. Further study of the degree of humidity provided by compressed air in various settings as well as implications of humidification in low resource settings on iatrogenic infections, morbidity, and mortality of neonates is needed.



## ALERT 2.2: SpO<sub>2</sub> & 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)<sup>35</sup>
- 2 Target peripheral oxygen concentrations (SpO<sub>2</sub>) 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 ROP.<sup>21-24</sup>

# 3 Management

Management of bCPAP covers how to use the bCPAP device 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 Collect: (3.1)

- bCPAP machine
- Power cable
- Inspiratory tubing
- Expiratory tubing
- CPAP prongs
- Connectors
- Oxygen tubing
- Oxygen source



3.1 (a) Collect bCPAP supplies



3.1 (b) Collect ancillary equipment

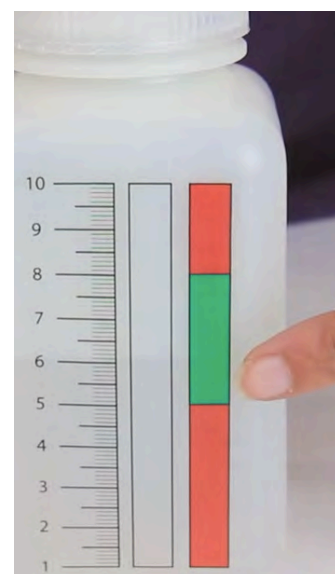
### 2 Position the bCPAP device at a secure location near the patient being considered for bCPAP treatment. Plug the power cable into the back of the machine (3.2) and plug into a socket or extension.



3.2 Plug the power cable into the device.



3.3 Pull bottle strap out and begin to remove bottle.



3.4 Fill bottle with clean water to desired settings (6cm)

- 3 Pull the bottle strap gently away from the bottle and remove the bottle. **(3.3)** Unscrew the lid and fill with clean water to desired initial settings. **(3.4)** Most patients will start with pressure levels of 6 cm of water. Rescrew the bottle lid to the bottle and place back in bottle holder.
- 4 Connect the inspiratory tubing to the Patient Port (indicated by the baby icon) **(3.5)** and the expiratory tubing to the Bottle Port. **(3.6)**



**3.5** Connect inspiratory tubing to patient port



**3.6.** Connect & brace long expiratory tubing in bottle bracket

- 5 Connect the CPAP prongs between the inspiratory and expiratory tubing. **(3.7)**
- 6 Turn on the bCPAP device. **(3.8)**



**3.7** Connect bCPAP prongs between inspiratory and expiratory tubing

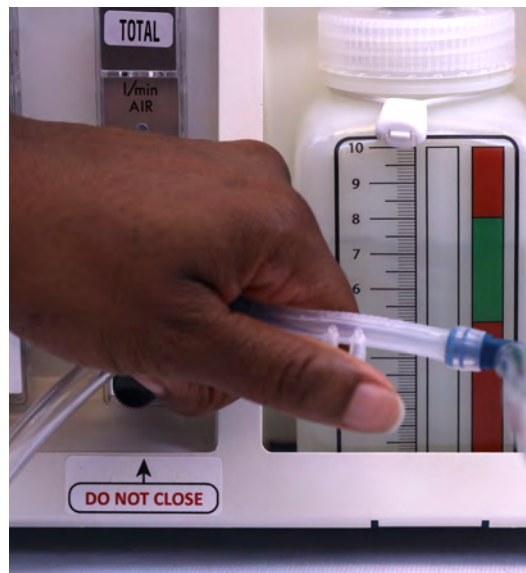


**3.8** Turn on bCPAP

- 7 Open the oxygen flowmeter. Using oxygen tubing, connect the oxygen source to the bCPAP device. **(3.9)**
- 8 Test the bubbling of the bCPAP device by occluding the CPAP prongs with your fingers. **(3.10)** If the water within the water bottle bubbles, the bCPAP device is ready for use.



**3.9** Connect Tubing to the oxygen port



**3.10** Occlude bCPAP prongs to test bubbling

## PREPARING A PATIENT

- 1 Place patient on oxygen and keep the baby warm whilst preparing for bCPAP.
- 2 Always explain the purpose, risks, and benefits of a procedure to guardians BEFORE performing the procedure.
- 3 Follow handwashing protocol.
- 4 Collect:
  - Hat or length of stockinette (if hat is not available)
  - Orogastic tube (OGT)
  - Gloves
  - Syringe
  - Tape
  - Suction catheter
  - Correctly sized bCPAP prongs
- 5 If a hat is not available, make a hat from a length of stockinette. **(3.11)**



**3.11** If needed, make a hat from stockinette or similar.

- 6 Wash hands and put on gloves. Using suctioning guidelines, suction the patient's nose and mouth using the suction catheter if clinically indicated. **(3.12)**



**3.12** Suction using a suction catheter if clinically indicated

- 7 Insert an OGT: **(Alert 3.1)**
- a Place the patient's head in a neutral position, measure from the middle of the mouth to the ear and then to halfway between the xiphisternum and umbilicus. Mark this distance with a small amount of tape.
  - b Gently insert the OGT in the mouth to this length.
  - c Tape the OGT to the chin to keep in place. Use appropriate tape for delicate newborn skin.
  - d Check placement of the OGT.<sup>36</sup>
    - Using a syringe aspirate gastric contents. Test with litmus paper. The litmus paper's colour change should reflect an acidic pH ( $\leq 6$ ); if it does not, the OGT is incorrectly placed and should be re-sited. NOTE: Litmus paper is manufactured in different colours. Acidic pH may be indicated by different colour changes depending on manufacturer.
    - If no gastric contents are aspirated, perform a whoosh test: push 2ml of air down the OGT whilst listening over the abdomen with a stethoscope. If no gurgling sound is heard the OGT is incorrectly placed and should be re-sited.
    - If no gastric contents are aspirated and a whoosh test is not viable, an alternative method is to place the OGT end into water. If continuous bubbling occurs, the OGT is incorrectly placed and should be re-sited.
- 8 Select bCPAP prong size from 000 to 5 based on nostril size. bCPAP prongs should completely fill the patient's nostrils. If prongs do not fill the nostril completely, the pressure delivered to the patient will be decreased. If nostrils turn a white colour the prongs are too tight and should be exchanged for the next size down.

## STARTING A PATIENT

- 1 Collect: **(3.13)**

- Appropriately sized bCPAP prongs
  - Hat
  - 2-mL syringe filled with normal saline
  - Hat clips OR
  - 2 rubber bands & 4 safety pins
- 2 Turn on the bCPAP device and connect oxygen source. Place hat on patient.
  - 3 Determine initial settings for the patient. Most patients will start with a pressure level of 6 cm water, total flow of 6 L/min and oxygen concentration (FiO<sub>2</sub>) of 50%. Determine oxygen flow using FiO<sub>2</sub> and total flow as shown on the oxygen blending table printed on top of device. **(3.14)**



**3.13** Collection of materials

| FiO <sub>2</sub> Level | Total Flow Rate (L/min)                    |     |     |     |     |
|------------------------|--------------------------------------------|-----|-----|-----|-----|
|                        | 5                                          | 6   | 7   | 8   | 9   |
|                        | Suggested O <sub>2</sub> Flow Rate (L/min) |     |     |     |     |
| 20% O <sub>2</sub>     | 0                                          | 0   | 0   | 0   | 0   |
| 30% O <sub>2</sub>     | 1                                          | 1.5 | 2   | 2   | 2.5 |
| 40% O <sub>2</sub>     | 2                                          | 2.5 | 3   | 3.5 | 4   |
| 50% O <sub>2</sub>     | 3                                          | 3.5 | 4   | 4.5 | 5   |
| 60% O <sub>2</sub>     | 3.5                                        | 4   | 4.5 | 5   | 5.5 |
| 70% O <sub>2</sub>     | 3.5                                        | 4.5 | 5   | 6   | 6.5 |
| 80% O <sub>2</sub>     | 4                                          | 5   | 5.5 | 6.5 | 7   |
| 90% O <sub>2</sub>     | 4.5                                        | 5.5 | 6   | 7   | 8   |

**3.14** Set typical initial total flow and FiO<sub>2</sub> settings & determine oxygen flow

- 4 Set total flow. Set oxygen flow on both oxygen source and bCPAP oxygen flowmeter.
- 5 Connect correctly sized bCPAP prongs to the inspiratory and expiratory tubing. Retest the bubbling by pinching the bCPAP prongs shut.
- 6 If the water within the pressure regulating bottle bubbles:
  - Using syringe filled with saline, place a drop of saline within each nostril.
  - Gently insert the prongs into the nostrils with the writing on the prongs facing towards the caregiver.
  - bCPAP prongs should be inserted until the line on the bCPAP prongs is **just** visible. This will leave 1 mm of space between the prongs and the nasal septum to aid nasal patency. **(3.15)**
- 7 Secure inspiratory and expiratory tubing to the patient using hat clips. **(3.16)** If hat clips are unavailable, secure using rubber bands & safety pins:
  - Insert two safety pins on each side of the head in the brim of the hat. Pins should open away from the baby's face and should go only through the folded brim of the hat. **Pins should never touch the patient's skin.**
  - Hold the inspiratory tubing in place between the two safety pins. Wrap the rubber bands around the safety pins on either side of the tubing to secure. Repeat for the expiratory tubing on the other side of the patient's face. **(3.17)**
  - Recheck that the prongs are still within the nose and inserted to the correct distance from the nasal septum.
  - Sometimes a small folded cloth placed under the baby's shoulders prevents the neck from bending and improves air/oxygen flow.



**3.15** Insert bCPAP prongs until prong line is just visible (1mm space).



**3.16** Secure inspiratory and expiratory tubing using clips



**3.17 (a)** Pin placement



**3.17 (b)** Securing of the tubes using elastics.

- 8 Check that the water within the pressure regulating bottle bubbles. If it does not bubble, check that the prongs completely fill the patient's nostrils. If they do not, replace with appropriately sized prongs.
- 9 Monitor the patient 15 minutes after initiating bCPAP treatment and then 4 hourly for:
  - Vital signs, including respiratory rate, heart rate, oxygen saturation and temperature
  - Work of breathing
  - Nasal blockages
  - Abdominal distension
- 10 Act in accordance to clinical findings.

## CARING FOR A PATIENT

Monitoring the patient should be completed 4 hourly, but may be required more frequently depending on clinical condition. Monitoring should include:

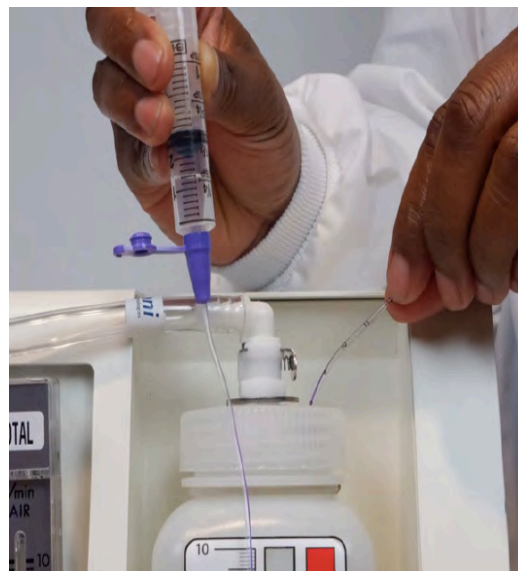
- Vital signs, including respiratory rate, heart rate, oxygen saturation, and temperature
- Work of breathing
- Nasal blockages
- Abdominal distension
- Nasal septum trauma or breakdown

At every monitoring point:

- 1 Provide a drop of saline to each nostril. **(3.18)**
- 2 Check prongs, tubing & hat:
  - Prongs should not be against nasal septum and check for skin compromise
  - Tubing should not be kinked or misplaced
  - Hat should not be loose; if it is loose, replace with new hat
- 3 Check water level: if water level is below decided treatment level, add water into bottle cap hole using a syringe or OG tube. **(3.19)** Water should be changed daily.



**3.18** Provide saline drops in nostrils via syringe.



**3.19** Add water to pressure regulator using OG tube

Prior to increasing bCPAP always ensure bCPAP is functioning well and all parts are in place. One mnemonic to help with this is **DOPE**:

- **D**: Displacement of prongs
- **O**: Obstruction of prongs or tubing
- **P**: Patient problem (e.g., pneumothorax)
- **E**: Equipment failure (e.g., power cut, tubing leak, see complications section)

Increases in treatment are made as clinically necessary in accordance to the **Increasing bCPAP Treatment** algorithm.

## INCREASING BCPAP

### INCREASING bCPAP TREATMENT

Increase by pressure and fractional concentration of oxygen ( $\text{FiO}_2$ )

#### Criteria for increasing bCPAP treatment:

The bCPAP device is functioning well, but any one of the following is present:

1. **Respiratory rate** greater than 60 bpm
2. **O<sub>2</sub> Saturations** less than 90%
3. Persistent increased **work of breathing**

**bCPAP water level: 6 cm**  
**Oxygen: 3 L/min**  
**Blended flow: 6 L/min**  
 **$\text{FiO}_2$ : 50%**

O<sub>2</sub> saturations  
greater than 90%?

Yes

No

**Increase  $\text{FiO}_2$  to 70%**  
**Oxygen: +1 L/min**

**After 4 hours:**  
O<sub>2</sub> saturations  
greater than 90%?

Yes

No

**Increase  $\text{FiO}_2$  &  
maintain pressure**

$\text{FiO}_2$ : 80%  
Oxygen: 4.5 L/min  
bCPAP water level: 6 cm  
Blended flow: 6 L/min

Substantial indrawings  
or work of breathing?

No

**BABY IS RESPONDING  
TO TREATMENT.**  
Continue management.

Yes

**Increase pressure &  
maintain  $\text{FiO}_2$**

$\text{FiO}_2$ : 70%  
Oxygen: 5 L/min  
bCPAP water level: 7 cm  
Blended flow: 7 L/min

O<sub>2</sub> Saturations greater than 90%?

No

**Maintain Total Flow & increase:**

Oxygen: +0.5 L/min  
bCPAP water level: +1 cm  
 $\text{FiO}_2$ : +10%

**Reassess for complications or  
alternative diagnosis.**

**CALL FOR ASSISTANCE!**

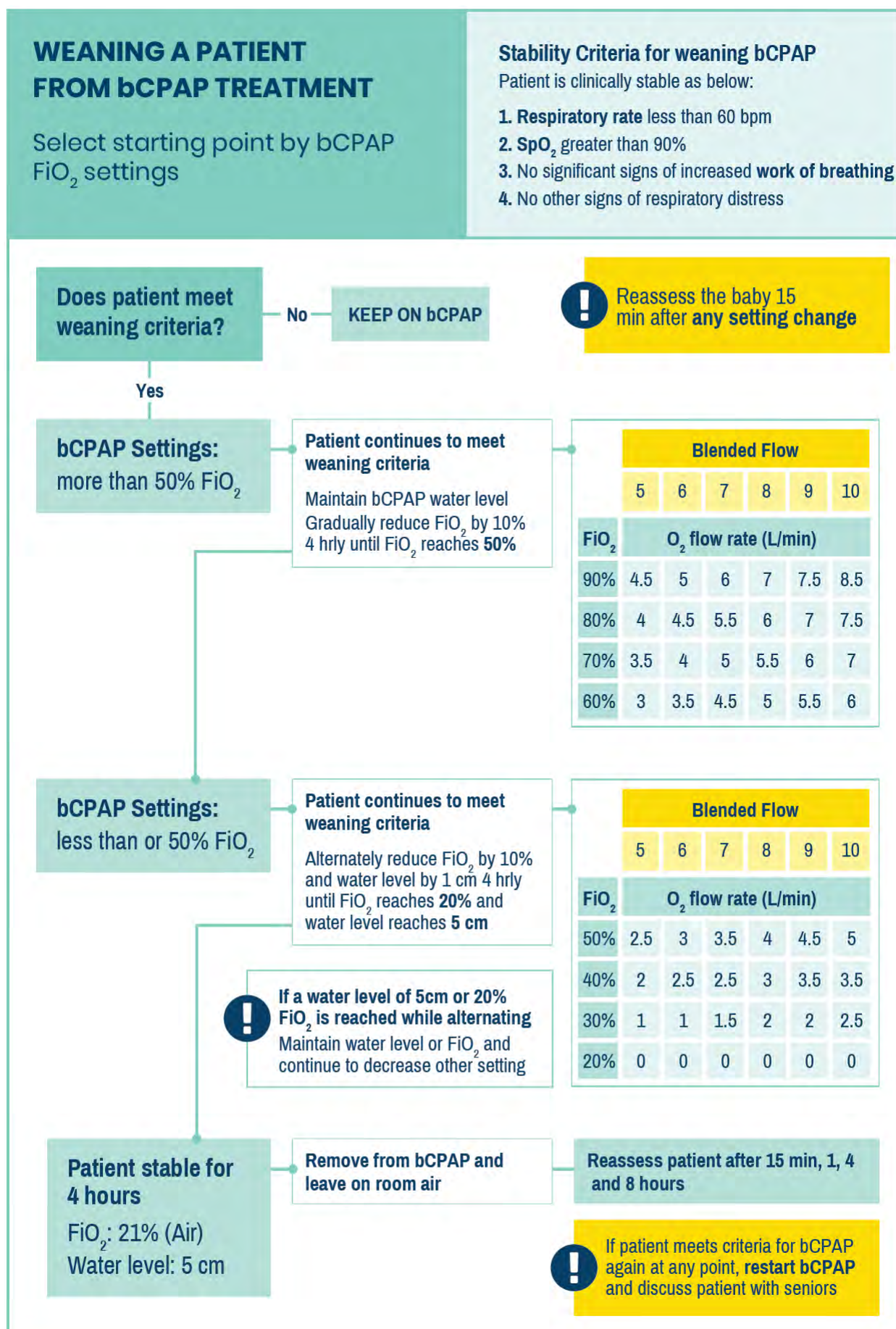
bCPAP water pressure  
should not be above 8 cm

**Always check connections before increasing treatment**  
Is the water bubbling? Does the baby need suctioning?

Reassess the baby after 15 min after any setting change

## REMOVING A PATIENT

Refer to the following **Weaning a Patient from bCPAP Treatment** flow chart:



## 4 Infection Prevention

Infection prevention, especially when using humidification or re-processing respiratory circuits intended for single use, is **CRITICAL** to preventing equipment related infections in newborns. If devices and equipment are not disinfected or re-processed 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 bCPAP or handling any tubing that will be used on a patient.
- 2 Ensure that all patient-related tubing (including prongs, inspiratory, and expiratory tubing) is new or has been cleaned thoroughly and dried as per re-use guidelines. **(Alert 4.1)** Any patient-related tubing must be cleaned before it is used to place another patient on bCPAP. Nasal prongs are especially difficult to clean thoroughly. Tubing should be hung to dry after disinfection and should not touch the floor or other unsanitary surfaces whilst drying. Any item falling on the floor is contaminated and must be cleaned thoroughly again.
- 3 All patient-related 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.



#### ALERT 4.1: Re-processing single-use devices

Respiratory circuits and humidifiers associated with bCPAP 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 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<sup>37</sup>](#) for more detailed guidance on the re-processing of single use devices.

### DISINFECTION AFTER USE

- 1 Turn off bCPAP and dispose of water within pressure regulating water bottle.
- 2 Dispose of hat and follow protocols for cleaning tubing if reusing prongs, inspiratory and expiratory tubing. If patient consumables are not cleaned thoroughly before using, infection can be transmitted. Care should be taken particularly for consumables that are marked as single-use but are practically reused.
- 3 Clean the outside of the bCPAP device using a swab soaked in alcohol or diluted chlorine. Total and oxygen flowmeter regulator controls should be disinfected after each use using a cotton swab or gauze soaked in 70% 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.

## CLINICAL COMPLICATIONS

- **Nasal blockage:** the bCPAP prongs and nostrils can become blocked with mucus which may result in increased respiratory distress and impaired oxygen delivery resulting in hypoxia.
- **Necrotic nasal septum:** incorrectly sized or applied bCPAP prongs may result in pressure on the nasal septum with resultant necrosis (tissue breakdown).
- **Gastric distension:** delivery of continuous airway pressure can cause gastric distension and potential feed intolerance. The OGT should be closed for 30–60 min after feeding but otherwise the OGT should be kept open on free drainage as this may relieve distension.
- **Pneumothorax:** delivery of bCPAP occasionally causes a pneumothorax. If a patient suddenly deteriorates whilst on bCPAP with increased respiratory distress and worsening hypoxia assess for a pneumothorax.
- **Decreased cardiac output:** with excessive bCPAP levels, venous return may be reduced resulting in decreased cardiac output.

## DEVICE COMPLICATIONS

- **Pressure leakages:** if the water in the bottle is not bubbling, it is likely that the patient is not getting therapeutic pressures. This may be due to the patient's mouth being open or bCPAP prongs not fully fitting the patient's nostrils. It could also be caused by kinking of the tube or a loose tube connection. **Bubble CPAP: Troubleshooting & Repair | If the water in the bottle is not bubbling** to identify and manage potential causes for no bubbling.
- **Power failure:** bCPAP should ideally always be utilising outlets that have a source of back-up power. If the power supply fails and patients are NOT on outlets with back-up power they should be moved to outlets where back up power is available. If no back up power is available the baby should receive oxygen from an oxygen cylinder until they can be safely returned to bCPAP.

---

## 6 Care & Maintenance

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

### POWER SOURCE

Mains power.

### WARD LOCATION

The bubble CPAP device should be secured in an easily accessible and visible location near an oxygen source where nursing staff can regulate flows and manage patients easily, but where it is not at risk of falling. All consumables required to place a patient on bCPAP should be near the device and readily available to start treatment. bCPAP devices vibrate during use; ensure that the vibration is not causing excess sound (e.g., if placed on a table with metal instruments that will vibrate with the bCPAP device).

### USER PREVENTIVE MAINTENANCE

Minimal preventive maintenance is required for bCPAP devices. The bCPAP device should be turned on weekly to a total flow of 10 L/min and allowed to run while connected to an oxygen source at 2 L/min for at least 15 minutes. This is important to ensure device functioning and minimise infection risk within internal respiratory circuits.

---

## 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 **(7.1)** and connected to the socket.
- Check that the power at the socket is turned on.
- If the device still does not turn on, contact your maintenance department.

### 2 If the silver balls in the oxygen or total flowmeters are not going up

- Tap the front of the flowmeter firmly with your knuckle or the handle of a screwdriver (or similar).
- If the flowmeter silver balls still do not go up, contact your maintenance department to request cleaning of the flowmeter and to check that all internal tubing is still connected.

### 3 If the total flowmeter does not go up to 10L/min

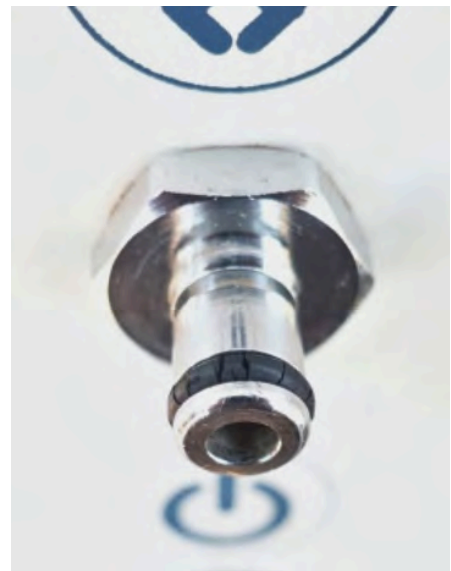
- Contact your maintenance department to request an internal filter change.

### 4 If the water in the bottle is not bubbling

- Check that the bCPAP prongs fully fill the nostrils and that the patient's mouth is not open. If the prongs do not fully fill the nostrils, replace the prongs with a larger size.
- If the prongs are well-fitted, remove from the patient's nose and occlude the prongs with your finger. If the water is still not bubbling check the seal at the patient port. If the seal is deteriorating or cracked **(7.2)**, contact your maintenance department to replace or troubleshoot further.



7.1 Power cable should not be pulling out of power socket.



7.2 Deteriorating seal.

# Assessment Questions

- 1 Label the image below.



- 2 What is the maximum water pressure that should be used with neonatal patients?  
**8 cm water.**
- 3 Where should the initial oxygen flow be set for a bCPAP device?  
**On the oxygen source and on the bCPAP Oxygen Flowmeter.**

---

# Appendix 1

## Heated & Humidified Air in Non-Invasive Ventilation

When breathing, air is physiologically heated and humidified as it passes through our upper airways into the lungs. Artificial heating and humidification are essential in invasive ventilation (i.e., when using ventilators) which bypasses the upper airways. However, the risks and benefits of heating and humidifying air supplied through non-invasive ventilator techniques such as Highflow Nasal Cannula (HFNC) and bCPAP are not well established and currently there is not consensus about whether or not it is a necessary element of all non-invasive ventilation systems.<sup>38,39</sup>

Benefits of heated and humidified gas in non-invasive ventilation may include increased adherence and comfort.<sup>38</sup> In neonates specifically, there is a physiological argument that removal of heated and humidified gas may lead to increased convective heat losses and therefore increased metabolic demand as well as increased insensible fluid losses. One needs to consider if these effects may or may not have significant effects on the infant's ability to maintain their temperature and grow adequately during the first weeks of life impacting mortality. In the long term, the effect of removing humidification on morbidity of infants (specifically in terms of development of bronchopulmonary dysplasia) is also unknown.<sup>40</sup> Lastly, heated humidified bCPAP may lead to lower incidence of mucosal injury which, in one study, was linked to increased rates of sepsis in extremely low birthweight infants<sup>41</sup>; however, early data from Malawi demonstrated few mucosal injuries when using un-heated un-humidified bCPAP.<sup>12</sup>

Risks of humidification include a theoretical risk of infection especially in settings where clean water may not be readily available and humidifiers, which are typically meant for one time use, are being cleaned and re-used between patients.<sup>32</sup> In addition, humidification incurs a high financial cost as well as human resource costs in terms of repair and preparation of non-invasive ventilation units which may limit not only their use, but availability of this life saving technology within low resource settings.<sup>33</sup>

There is reason to believe that when supplying ambient air through the upper airway there is in fact, no need for heated humidification.<sup>33</sup> This may be doubly true in low resource bCPAP units such as the Pumani which, rather than using compressed air sources (i.e., cylinders) are in fact driving flow through the circuit using compressed ambient air.<sup>42</sup> It is worth noting that although some lower cost bCPAP models do offer passive humidification, expert opinion and experience suggests that perhaps the level of humidification achieved via this method is not significant (data unpublished). Of note, although the studies differ significantly, reported survival rates for infants >1.5kg in Rwanda on a heated and humidified bCPAP circuit<sup>34</sup> were similar to those reported in Malawi on an un-heated, un-humidified circuit.<sup>12</sup>

In conclusion, despite recent WHO recommendations that bCPAP units should contain humidification.<sup>31</sup> In light of primary data which shows (1) the unknown necessity, (2) the risks and benefits of heated and humidified gas in non-invasive ventilation, and (3) the life-saving implications bCPAP has for neonates, our consortium maintains there is a lack of evidence to resolve the question of humidification at this time. Further study of the degree of humidity provided by compressed air in various settings as well as implications of humidification in low resource settings on iatrogenic infections, morbidity and mortality of neonates is needed. It is important that when considering implementation of bCPAP, one considers not only physiological implications of this feature in the bCPAP units, but also how this feature impacts supply chain, human resource costs, financial costs, training, infection control, maintenance, and availability of units in country.

---

# References

- 1 Subramaniam, P., Ho, J. J. & Davis, P. G. Prophylactic nasal continuous positive airway pressure for preventing morbidity and mortality in very preterm infants. *Cochrane Database of Systematic Reviews* (2016) doi:10.1002/14651858.CD001243.pub3.
- 2 Mulrooney, N. *et al.* Surfactant and Physiologic Responses of Preterm Lambs to Continuous Positive Airway Pressure. *American Journal of Respiratory and Critical Care Medicine* **171**, 488–493 (2005).
- 3 Miller, M. J., Carlo, W. A. & Martin, R. J. Continuous positive airway pressure selectively reduces obstructive apnea in preterm infants. *J. Pediatr.* **106**, 91–94 (1985).
- 4 Kattwinkel, J., Nearman, H. S., Fanaroff, A. A., Katona, P. G. & Klaus, M. H. Apnea of prematurity. Comparative therapeutic effects of cutaneous stimulation and nasal continuous positive airway pressure. *J. Pediatr.* **86**, 588–592 (1975).
- 5 Gittermann, M. K., Fusch, C., Gittermann, A. R., Regazzoni, B. M. & Moessinger, A. C. Early nasal continuous positive airway pressure treatment reduces the need for intubation in very low birth weight infants. *Eur. J. Pediatr.* **156**, 384–388 (1997).
- 6 Jónsson, B., Katz-Salamon, M., Faxelius, G., Broberger, U. & Lagercrantz, H. Neonatal care of very-low-birthweight infants in special-care units and neonatal intensive-care units in Stockholm. Early nasal continuous positive airway pressure versus mechanical ventilation: gains and losses. *Acta Paediatr Suppl* **419**, 4–10 (1997).
- 7 te Pas, A. B., Spaans, V. M., Rijken, M., Morley, C. J. & Walther, F. J. Early nasal continuous positive airway pressure and low threshold for intubation in very preterm infants. *Acta Paediatr.* **97**, 1049–1054 (2008).
- 8 Narendran, V. *et al.* Early bubble CPAP and outcomes in ELBW preterm infants. *J Perinatol* **23**, 195–199 (2003).
- 9 Hascoet, J.-M., Espagne, S. & Hamon, I. CPAP and the preterm infant: Lessons from the COIN trial and other studies. *Early Human Development* **84**, 791–793 (2008).
- 10 Ho, J. J., Subramaniam, P. & Davis, P. G. Continuous distending pressure for respiratory distress in preterm infants. *Cochrane Database of Systematic Reviews* (2015) doi:10.1002/14651858.CD002271.pub2.
- 11 Sekar, K. C. & Corff, K. E. To tube or not to tube babies with respiratory distress syndrome. *Journal of Perinatology* **29**, S68–S72 (2009).
- 12 Kawaza, K. *et al.* Efficacy of a Low-Cost Bubble CPAP System in Treatment of Respiratory Distress in a Neonatal Ward in Malawi. *PLoS ONE* **9**, e86327 (2014).
- 13 Koyamaibole, L. An Evaluation of Bubble-CPAP in a Neonatal Unit in a Developing Country: Effective Respiratory Support That Can Be Applied By Nurses. *Journal of Tropical Pediatrics* **52**, 249–253 (2005).
- 14 Martin, S., Duke, T. & Davis, P. Efficacy and safety of bubble CPAP in neonatal care in low and middle income countries: a systematic review. *Archives of Disease in Childhood – Fetal and Neonatal Edition* **99**, F495–F504 (2014).
- 15 Okello, F. *et al.* Reducing preterm mortality in eastern Uganda: the impact of introducing low-cost bubble CPAP on neonates <1500 g. *BMC Pediatrics* **19**, (2019).
- 16 Lawn, J. E., Blencowe, H., Darmstadt, G. L. & Bhutta, Z. A. Beyond newborn survival: the world you are born into determines your risk of disability-free survival. *Pediatric Research* **74**, 1–3 (2013).
- 17 Gilbert, C. *et al.* Epidemiology of ROP update – Africa is the new frontier. *Seminars in Perinatology* (2019) doi:10.1053/j.semperi.2019.05.002.

- 18 Flynn, J. T. *et al.* A cohort study of transcutaneous oxygen tension and the incidence and severity of retinopathy of prematurity. *N. Engl. J. Med.* **326**, 1050–1054 (1992).
- 19 SUPPORT Study Group of the Eunice Kennedy Shriver NICHD Neonatal Research Network *et al.* Target ranges of oxygen saturation in extremely preterm infants. *N. Engl. J. Med.* **362**, 1959–1969 (2010).
- 20 Kayton, A., Timoney, P., Vargo, L. & Perez, J. A. A Review of Oxygen Physiology and Appropriate Management of Oxygen Levels in Premature Neonates: *Advances in Neonatal Care* **18**, 98–104 (2018).
- 21 Cummings, J. J., Polin, R. A. & Committee on Fetus and Newborn. Oxygen Targeting in Extremely Low Birth Weight Infants. *Pediatrics* **138**, e20161576 (2016).
- 22 Bancalari, E. & Claure, N. Oxygenation Targets and Outcomes in Premature Infants. *JAMA* **309**, 2161 (2013).
- 23 Manja, V., Lakshminrusimha, S. & Cook, D. J. Oxygen Saturation Target Range for Extremely Preterm Infants: A Systematic Review and Meta-analysis. *JAMA Pediatrics* **169**, 332 (2015).
- 24 Polin, R. A. & Bateman, D. Oxygen-Saturation Targets in Preterm Infants. *New England Journal of Medicine* **368**, 2141–2142 (2013).
- 25 Fan, L. L. & Voyles, J. B. Determination of inspired oxygen delivered by nasal cannula in infants with chronic lung disease. *The Journal of Pediatrics* **103**, 923–925 (1983).
- 26 Benaron, D. A. Maximizing the Stability of Oxygen Delivered Via Nasal Cannula. *Archives of Pediatrics & Adolescent Medicine* **148**, 294 (1994).
- 27 The STOP-ROP Multicenter Study Group. Supplemental Therapeutic Oxygen for Prethreshold Retinopathy of Prematurity (STOP-ROP), A Randomized, Controlled Trial. I: Primary Outcomes. *Pediatrics* **105**, 295–310 (2000).
- 28 Walsh, M. Oxygen Delivery Through Nasal Cannulae to Preterm Infants: Can Practice Be Improved? *Pediatrics* **116**, 857–861 (2005).
- 29 Locke, R. G., Wolfson, M. R., Shaffer, T. H., Rubenstein, S. D. & Greenspan, J. S. Inadvertent administration of positive end-distending pressure during nasal cannula flow. *Pediatrics* **91**, 135–138 (1993).
- 30 Sreenan, C., Lemke, R. P., Hudson-Mason, A. & Osiovich, H. High-Flow Nasal Cannulae in the Management of Apnea of Prematurity: A Comparison With Conventional Nasal Continuous Positive Airway Pressure. *Pediatrics* **107**, 1081–1083 (2001).
- 31 *Oxygen therapy for children.* (World Health Organization, 2016).
- 32 Dreimanis, D., Beckingham, W., Collignon, P. & Graham, M. Review of neonatal unit continuous positive airways pressure (CPAP)(with humidification). *Healthcare Infection* **11**, 22–23 (2006).
- 33 Branson, R. D. & Gentile, M. A. Is humidification always necessary during noninvasive ventilation in the hospital? *Respiratory Care* **55**, 209–216 (2010).
- 34 Nahimana, E. *et al.* Bubble CPAP to support preterm infants in rural Rwanda: a retrospective cohort study. *BMC Pediatrics* **15**, (2015).
- 35 *Textbook of Neonatal Resuscitation (NRP), 7th Ed.* (American Academy of Pediatrics, 2016).
- 36 *Pocket book of hospital care for children: guidelines for the management of common childhood illnesses.* (World Health Organization, 2013).
- 37 Curless MS, Ruparelia CS, Thompson E, and Trexler PA, eds. 2018. Infection Prevention and Control: Reference Manual for Health Care Facilities with Limited Resources. Jhpiego: Baltimore, MD.
- 38 Restrepo, R. D. & Walsh, B. K. Humidification during invasive and noninvasive mechanical ventilation: 2012. *Respiratory Care* **57**, 782–788 (2012).
- 39 Roberts, C. T. *et al.* The effects of non-invasive respiratory support on oropharyngeal temperature and humidity: a neonatal manikin study. *Archives of Disease in Childhood – Fetal and Neonatal Edition* **101**, F248–F252 (2016).
- 40 Shaffer, T. H., Alapati, D., Greenspan, J. S. & Wolfson, M. R. Neonatal non-invasive respiratory support: Physiological implications. *Pediatric Pulmonology* **47**, 837–847 (2012).

- 41 Kopelman, A. E. & Holbert, D. Use of Oxygen Cannulas in Extremely Low Birthweight Infants is Associated with Mucosal Trauma and Bleeding, and Possibly with Coagulase-negative Staphylococcal Sepsis. *Journal of Perinatology* **23**, 94–97 (2003).
- 42 Brown, J. *et al.* A High-Value, Low-Cost Bubble Continuous Positive Airway Pressure System for Low-Resource Settings: Technical Assessment and Initial Case Reports. *PLoS ONE* **8**, e53622 (2013).

---

# Point-of-Care Diagnostics

---

## Glucometer

# 1 Clinical Problem

**Assessment of blood glucose with a glucometer should be conducted as part of routine assessment for all infants on admission.**

Glucometers should also be used during continuing management for all sick or at-risk patients. Hypoglycaemia may present as:<sup>1</sup>

- Jitteriness
- Irritability
- Hypotonia
- Lethargy
- Reduced level of consciousness
- Failure to feed or poor feeding
- Seizures
- Hypothermia
- Apnoea or irregular breathing

Hypoglycaemia may also be asymptomatic or the signs may be very non-specific and identified incidentally as part of routine blood glucose testing.<sup>1</sup> It is important to identify hypoglycaemia as it may lead to permanent brain damage. Prematurity, intrauterine growth retardation, birth asphyxia, babies born to diabetic mothers, and sick babies are all especially prone to develop hypoglycaemia.

# 2 Assessment

**Hypoglycaemia occurs in 10% of healthy neonates but can also directly contribute to both morbidity and mortality.<sup>2,3</sup> It is the most common medical emergency to occur in neonatal patients.**

Glucometers **(2.1)** provide a rapid measurement of approximate whole blood glucose level<sup>1</sup> to direct treatment for patients with mild to severe hypoglycaemia. Where available, point of care tests should be confirmed by laboratory analysis when hypoglycaemia is persistent, recurrent, or there is concern about accuracy of the point of care device.

Glucometers use test strips **(2.2)** with a glucose oxidase electrode. These strips generate a current proportional to the glucose in the blood that reacts with the glucose oxidase, which is then measured and analysed to determine an estimated blood glucose level.



2.1 Glucometers.



2.2 Glucometer test strips.

There are multiple types of glucometers, including portable and benchtop. Glucose strips that change colour according to a visual scale are also available for measuring glucose levels. **These are not recommended due to their higher inaccuracy and subjective nature of measurement.** Not all glucometers are accurately able to measure hypoglycaemia in neonatal patients;<sup>4,5</sup> all devices in use should be thoroughly validated for use both in neonatal patients and as an assessment of hypoglycaemia.

Glucose levels in all neonatal patients should not fall below **2.5 mmol/L** (45 mg/dL).

## 3 Management

Management of a glucometer covers how to use the device in a variety of settings, including set up for a patient, patient preparation & conducting & concluding the assessment.

### SETTING UP FOR A PATIENT

- 1 Collect: **(3.1)**
  - Glucometer
  - Glucometer strips
  - Control solutions
- 2 Turn on the glucometer. This may be completed by pressing the power button of the glucometer or inserting a glucometer strip into the glucometer strip port.



3.1 Collect glucometer, test strip & control solutions.

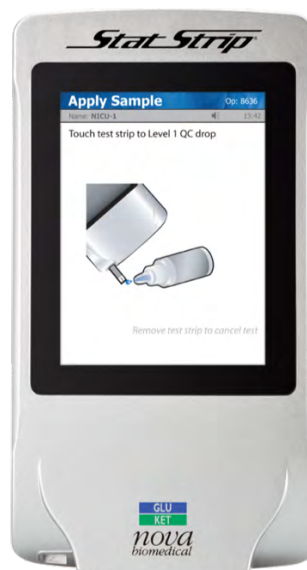


3.2 Insert strip.

- 3 Fully insert a test strip into the meter. (3.2) The strip should click into place.
- 4 A **Quality Control** test should be conducted daily. If this has not been completed, perform a test using the control solutions provided with the glucometer (3.3), or a solution of known glucose content. The solution should be placed on the strip as with a normal sample. (3.4) The results should appear within seconds as a **Pass**. (3.5)



3.3 Collect control solutions.



3.4 Allow the strip to absorb a drop of the control solution.



3.5 The control solution should test as a **Pass**.

## PREPARING A PATIENT

- 1 Assess patient for clinical conditions associated with hypoglycaemia.
- 2 Always explain the purpose, risks and benefits of a procedure to guardians BEFORE performing the procedure.
- 3 Follow handwashing protocol and put on gloves.

- 4 Collect:
  - Gloves
  - 70% Alcohol
  - Cotton swab
- 5 Clean the skin on the outer edge of the patient's heel using cotton wool soaked in alcohol. **(3.6)** Allow the alcohol to dry before testing. **Blood glucose samples should never be taken from the finger of a neonate. Avoid areas of skin which are poorly perfused, oedematous, inflamed or infected.**



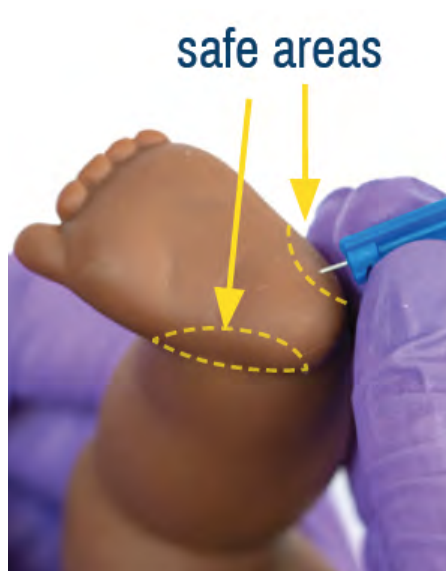
**3.6** Clean outer edge of the patient's heel using cotton/gauze soaked in alcohol.

## ASSESSING A PATIENT

- 1 Collect: **(3.7)**
  - New lancet
  - Glucometer
  - Glucometer strip
  - Cotton swabs
  - Alcohol (swabs/solution)
  - Gloves
  - A small tray to carry the items above
- 2 Follow handwashing procedures & put on gloves.
- 3 Insert glucometer strip into glucometer and ensure it is turned on.
- 4 Using the lancet, prick the disinfected outer edge of the heel. **(3.8)** A blood drop should form. If this does not occur, massage the heel to generate the blood drop. The patient may cry during blood collection as use of the lancet can be painful.
- 5 Wipe the first drop from the patient's skin and generate an additional blood drop. Collect the second blood drop on the tip of the glucometer strip. **(3.9)** The glucometer should automatically absorb the blood drop.



3.7 Collect assessment materials.

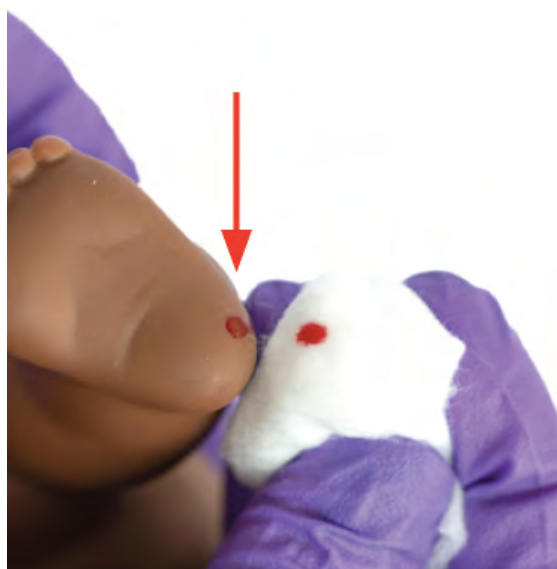


3.8 Prick disinfected outer edge of heel using lancet.



3.9 Collect blood drop on glucometer strip.

- 6 Using a dry cotton swab, apply pressure to the heel to stop the bleeding. (3.10)
- 7 Blood glucose level will be displayed as a number on the glucometer screen. (3.11) Read and record the glucose levels. If the measurement is not in accord with the clinical condition of the patient, repeat the test.



3.10 Apply pressure to stop bleeding.



3.11 Read & record glucose levels.

- 8 Compare glucose levels to normal standards.<sup>6</sup>
  - If levels fall **below 2.5 mmol/L** (45mg/dL) but the baby is **alert**, can breastfeed, be fed by cup and spoon or has a nasogastric tube, give extra feed and recheck in 2 hours.
  - If levels fall **below 2.5 mmol/L** (45mg/dL) but the baby is **unable to feed**, immediately administer 2 mL/kilogram 10% dextrose IV and then start an infusion of 10% dextrose.
  - If levels fall **below 1.2 mmol/L** (21.6mg/dL) in **any baby**, immediately administer 2 mL/kilogram 10% dextrose IV and then start an infusion of 10% dextrose.

Whenever hypoglycaemia is found and treated, the blood glucose should be rechecked 30 minutes after intervening.



### ALERT 3.1: Variance in international standards for hypoglycaemia management

American Academy of Pediatrics, Pediatric Endocrine Society and WHO are all in agreement that glucose levels below 2.5mmol/L (45mg/dL) signify hypoglycaemia in newborns. However, they differ on the specific actions that should be taken and how aggressively to manage glucose levels below 45mg/dL, (2.5 mmol/L). For a full discussion of management of hypoglycaemia in newborns, these documents should be referenced and local practices put into place.<sup>7-9</sup>

## CONCLUDING ASSESSMENT

Remove the glucose strip from the glucometer and dispose of strip in hazardous waste container. Dispose of the used lancet in sharps container. Remove gloves, dispose in hazardous waste container, and wash hands.

# 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 alcohol before and after assessing a patient using a glucometer or handling any materials that will be used on a patient (e.g., a lancet). **Gloves should be worn throughout the process of taking a blood glucose measurement and disposed of immediately after concluding the measurement.**
- 2 Always thoroughly clean the patient's skin before taking a measurement using a glucometer. Inadequate cleaning of the skin may result in an infection. Taking a sample from a site with a skin infection also poses the risk of infection dissemination.
- 3 Ensure that all patient-related consumables are new before use. Materials used in blood glucose measurements **should never be reused.**
- 4 All patient-related consumables should be stored in a clean, dry location. Glucometer measurement strips should be stored in an airtight container and according to hospital policy.
- 5 Follow universal precautions of handling sharps.



## ALERT 4.1 Equipment Disinfection

Disinfection of equipment should always comply with manufacturer guidelines. General guidance on environmental cleaning and disinfection of equipment was taken from the Infection Prevention and Control: Reference Manual for Health Care Facilities with Limited Resources, Jhpiego, Module 6<sup>8</sup> 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.<sup>9</sup>

When utilizing re-processed devices meant for single-use (like temperature probes), careful attention must always be paid to assure that devices are continuing to function properly.

## DISINFECTION AFTER USE

- 1 Remove the glucose strip from the glucometer and dispose of strip in hazardous waste container. Dispose of used lancet in sharps container. Remove gloves, dispose in hazardous waste container, and wash hands.
- 2 Wipe down the glucometer with 70% alcohol. **(4.1)** Be careful not to submerge or drip alcohol onto the glucometer, particularly in its glucometer strip reading slot.



4.1 Wipe down the glucometer with 70% 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.

## CLINICAL COMPLICATIONS

- **Bruising:** inappropriate or repeated attempts to collect blood for glucose testing may result in bruising to the heel.
- **Bleeding:** if pressure is not applied post blood collection bleeding may persist for a short period of time. Continued bleeding may indicate an underlying bleeding disorder.
- **Artery, nerve or bone damage:** do not use the back or the inner part of the heel for blood collection. This may cause artery, nerve, or bone damage.
- **Pain:** the lancet prick can cause pain, employ appropriate soothing measures.
- **Infection:** rarely infection may occur at the site if infection precautions are not adequate.

## DEVICE COMPLICATIONS

- **Falsely high readings:** dextrose gel or substances on the skin can affect readings. If you record a very high reading in a patient that is otherwise showing symptoms of hypoglycaemia, consider recleaning the patient's skin and retaking the measurement.
- **Expired glucose strips:** outdated or improperly stored glucose strips can produce inaccurate readings. Make sure the lid is kept tightly on the strip container as humidity damages the strips. When possible, unexpired glucometer strips should not be used.

---

# 6 Care & Maintenance

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

## POWER SOURCE

A glucometer 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

The glucometer and associated glucometer testing strips should be stored in a clean, dry and secure area. As glucometers are fairly small, care should be taken to ensure that they remain on the ward and accessible for use when required. If the glucometer has a docking or charging station, it should be kept on the dock or charging station when not in use. **(6.2)**



6.1 Low battery warning.



6.2 Glucometer on its charging port.

## USER PREVENTIVE MAINTENANCE

Glucometers require little preventive maintenance beyond recharging or replacing batteries. A **Quality Control** test using the control solutions provided with the glucometer (6.3), or a solution of known glucose content should be conducted monthly or when changing glucometer strip containers to ensure consistent results. The solution should be placed on the strip as with a normal sample. (6.4) The results should appear within seconds as a **Pass**. (6.5)



6.3 Collect control solutions.



6.4 Allow the strip to absorb a drop of the control solution.



6.5 The control solution should test as a **Pass**.

---

# 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 glucometer is not turning on:

- ☐ Some models of glucometer require a strip to be inserted and will automatically turn on once this is completed. Try inserting a glucometer strip.
- ☐ If the glucometer still does not turn on, try charging or replacing the batteries. If the glucometer still does not turn on, contact your maintenance department.

## 2 The glucometer is providing results consistently incompatible with patient conditions:

- ☐ Check the expiration date of the glucometer strips. If the strips are expired, try using non-expired strips.
- ☐ If the results are still inconsistent, complete a quality control test as described in **Glucometer: Care & Maintenance | Preventive Maintenance**. If the results are still inconsistent, contact your maintenance department.

---

# Assessment Questions

- 1 How often should quality control tests be performed on glucometers?

Daily, monthly & when a new container of glucometer strips is opened

- 2 On the image of the foot below, mark the area of the foot that is most safely used to collect blood for a glucometer reading.



---

# References

- 1 Thompson-Branch, A. & Havranek, T. Neonatal Hypoglycemia. *Pediatr Rev* **38**, 147–157 (2017).
- 2 Samayam, P. Study of Asymptomatic Hypoglycemia in Full Term Exclusively Breastfed Neonates in First 48 Hours of Life. *Journal of Clinical and Diagnostic Research*. **9**, 4 (2015).
- 3 Heck, L. J. & Erenberg, A. Serum glucose levels in term neonates during the first 48 hours of life. *The Journal of Pediatrics* **110**, 119–122 (1987).
- 4 Ho, H. T. Evaluation of 'point of care' devices in the measurement of low blood glucose in neonatal practice. *Archives of Disease in Childhood - Fetal and Neonatal Edition* **89**, F356–F359 (2004).
- 5 Beardsall, K. Measurement of glucose levels in the newborn. *Early Human Development* **86**, 263–267 (2010).
- 6 Committee on Fetus and Newborn. Postnatal Glucose Homeostasis in Late-Preterm and Term Infants. *PEDIATRICS* **127**, 575–579 (2011).
- 7 Committee on Fetus and Newborn. Postnatal Glucose Homeostasis in Late-Preterm and Term Infants. *PEDIATRICS* **127**, 575–579 (2011).
- 8 Thornton, P. S. *et al.* Recommendations from the Pediatric Endocrine Society for Evaluation and Management of Persistent Hypoglycemia in Neonates, Infants, and Children. *The Journal of Pediatrics* **167**, 238–245 (2015).
- 9 Williams, A. F. Hypoglycaemia of the newborn: Review of the literature. *World Health Organization* (1997).

---

# Thermal Management

---

## Radiant Warmer

# 1 Clinical Problem

**Temperature less than 36°C at birth has been recognised as an independent risk factor for death in preterm infants.<sup>1,2</sup>**

Radiant warmers may be used on any neonatal patient admitted to the nursery ward, but especially for:

- Initial assessment of a sick or premature baby
- Hypothermia
- Undertaking invasive procedures
- Resuscitation
- When stabilising a sick baby

## OBSTETRIC & LABOUR NOTE

**In stable newborns priority should always be given to skin-to-skin and KMC over artificial warming devices.** Unstable babies and any requiring resuscitation need an area post-delivery to prevent hypothermia. Using pre-warmed towels, neonatal patients should immediately be dried, with one towel that is then discarded and replaced by another dry one, wrapped and placed under a radiant warmer following delivery. Newborn babies can drop their body temperature very quickly, even within minutes. They must be kept warm from the moment of birth, during their time in the labour ward and when transferred to the nursery. **Even small drops in temperature increase the likelihood of mortality.<sup>2-4</sup>**

Extremely premature babies can be placed in a clean plastic bag immediately after birth, without prior drying and ensuring the head is kept free from the plastic.<sup>4</sup> **(1.1)** The head is covered with a hat. This assists prevention of heat loss. A baby in a plastic bag must be monitored very frequently to prevent overheating.



**1.1** A neonatal patient may be wrapped in plastic, with head free, to prevent heat loss.

Regardless of location, it is preferential to start patients on Kangaroo Mother Care if it is clinically appropriate and the patient is stable.

## 2 Assessment

However warm a room may feel to an adult, a neonate can lose heat. This heat loss in neonatal patients is rapid, with hypothermia directly contributing to mortality.<sup>2-4</sup> Radiant warmers (2.1) use overhead heating elements to provide radiating heat ensuring maintenance of normothermia.

Newborn babies lose heat through four main mechanisms.<sup>5</sup>

- **Evaporation:** water loss through the skin.
- **Radiation:** heat radiating from the warmer patient towards cooler surfaces (e.g., windows or walls).
- **Conduction:** direct heat travel from warmer surface of the skin to the cooler mat or cot on which the patient rests.
- **Convection:** air currents move heat away from the skin/body.

Radiant warmers provide radiating heat to minimise metabolic requirements for heat production, decreasing the risks of hypoglycaemia and respiratory distress associated with hypothermia. Radiant warmers provide an area where resuscitations, procedures, and short-term observation can take place while keeping the baby warm. Warmers may vary in complexity, including only heating functionality or heating functionality with resuscitation and oxygen equipment. All warmers include a temperature probe that provides information on the patient's temperature. (2.2)



2.1 A typical radiant warmer.

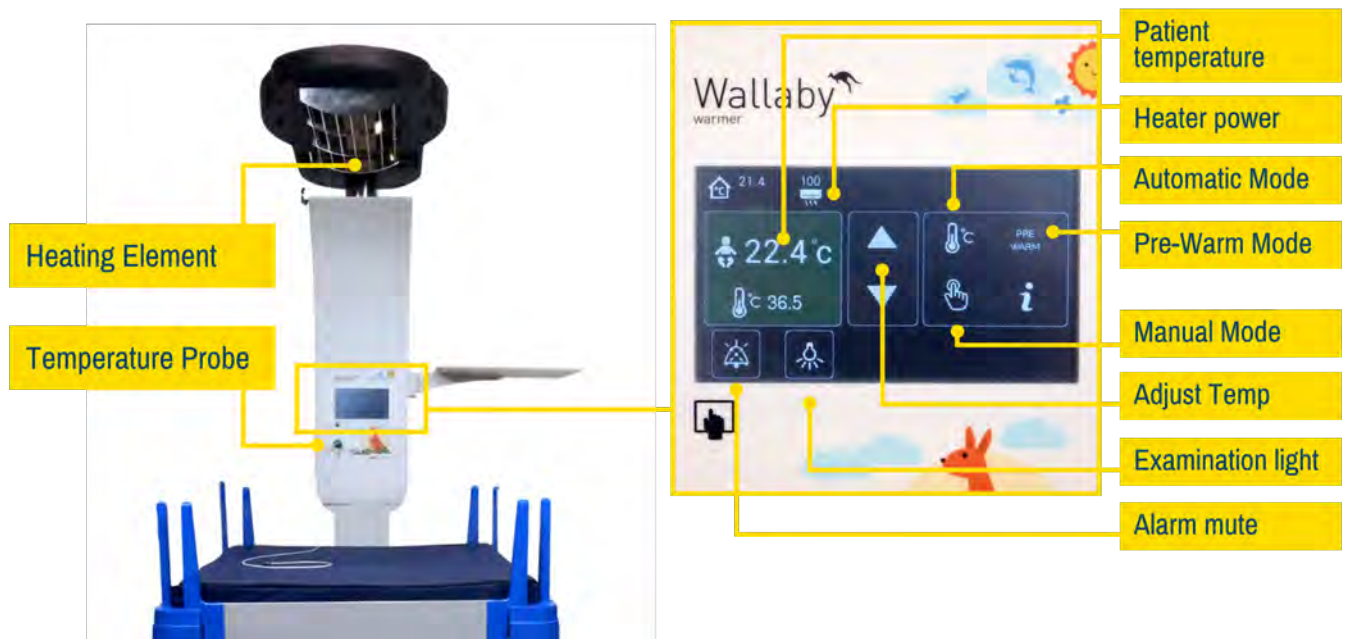


2.2 A typical temperature probe.

Radiant warmers heat in various modes, the names of which may vary based on device: (2.3)

- **Prewarm:** provides constant low heat for a short amount of time (typically 10 minutes or less) to prepare the cot underneath the warmer to receive a patient.

- **Automatic:** also called servo or baby mode; uses a temperature probe on the baby to automatically adjust heat provided to maintain the patient's temperature within an acceptable range.
- **Manual:** provides a constant, unadjusting heat that is set by the user. Patients should never be left unattended if being treated in manual mode.



2.3 Major components & modes of a radiant warmer.

Normothermic axillary temperature in neonates ranges from 36.5°C to 37.5°C.<sup>4,5</sup> **Every effort must be made to keep a baby's temperature within the normal range as temperature below 36°C is an independent risk factor for death in newborns.**<sup>1,2</sup>

## 3 Management

Management covers how to use the radiant warmer, 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 power cable into the radiant warmer. **(3.1)** Plug power cable into a wall socket & surge protector if available and switch on the power. **(3.2)**
- 2 Select manual setting at 25% or **Prewarm** setting (if available on model). **(3.3)**



**3.1** Plug in the radiant warmer.



**3.2** Switch on the power.

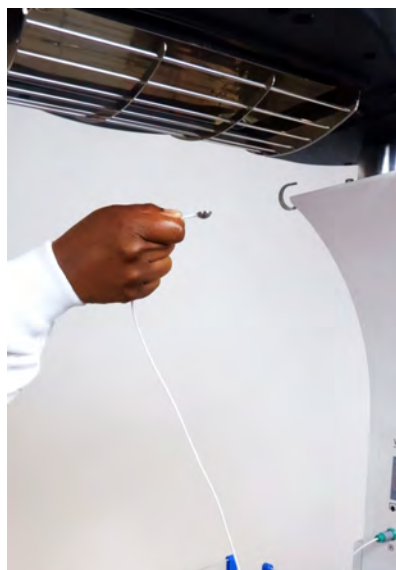


**3.3** Select Pre-Warm setting to warm bedding.

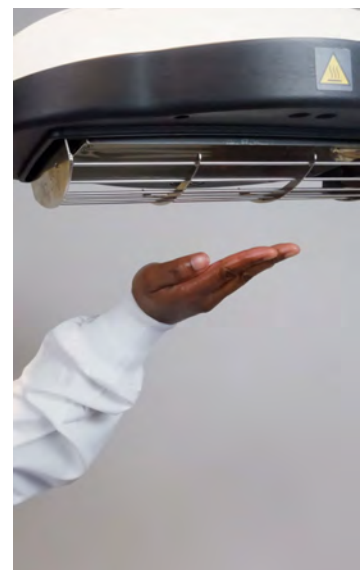
- 3** Plug temperature probe into the infant temperature probe port. **(3.4)** Hold temperature probe in hand and move hand directly under overhead heating elements to check for heat. **(3.5)** You should be able to feel heat emitting from the heating elements. **(3.6)** Allow bedding to grow warm while waiting for the baby to arrive in the nursery, be transferred to the radiant warmer, or be delivered in the labour ward.



**3.4** Plug in the temperature probe.



**3.5** Pass the temperature probe underneath the heating elements.



**3.6** Feel heat emitted from elements.

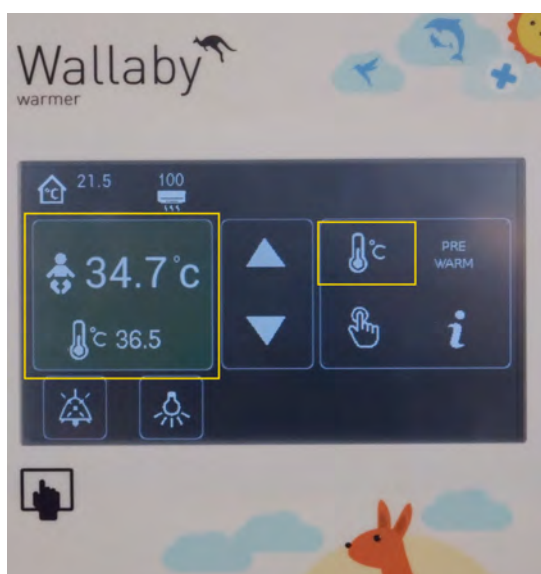
## PREPARING A PATIENT

- 1** Collect:
  - Tape or elastic bandage
  - Gauze
  - 70% alcohol
- 2** Always explain the purpose, risks, and benefits of a procedure to guardians BEFORE performing the procedure.

- 3 Follow handwashing protocol.
- 4 Ensure patient is dry from any birth fluids or bodily secretions and is wearing a hat to prevent excess heat loss from the head.

## STARTING A PATIENT

- 1 Ensure radiant heater has been prewarmed. If the radiant warmer has not been prewarmed, then take steps to do so. Prewarming is essential in order to prevent infant from losing heat to the mattress when initially placed on the warmer.
- 2 Change the radiant warmer from **Pre-Warm** to select **Servo/Automatic** mode. **(3.7)**
- 3 Position infant in middle of radiant warmer cot, maintaining additional treatment tubing (e.g., CPAP tubing, IV lines) in place. **(3.8)**
- 4 Use gauze and 70% alcohol to clean temperature probe.
- 5 Place temperature probe directly above infant's liver and secure with tape or elastic bandage. **(3.9)** If a child with myelomeningocele needs to be cared for prone, then place the probe over the infant's flank. The probe should be secured firmly enough that it will not fall off the patient, but not so firmly that it is pressing into the infant's skin.



**3.7** Switch to servo mode.



**3.8** Place the patient in the centre of the cot.

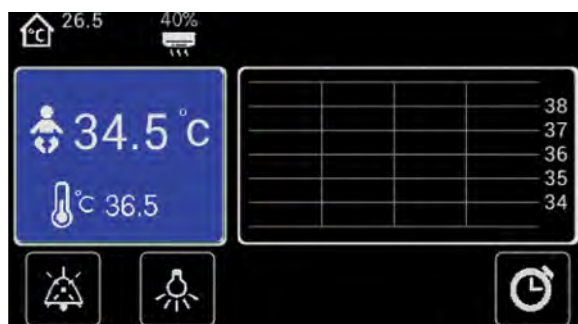


**3.9** Place & secure temperature probe.

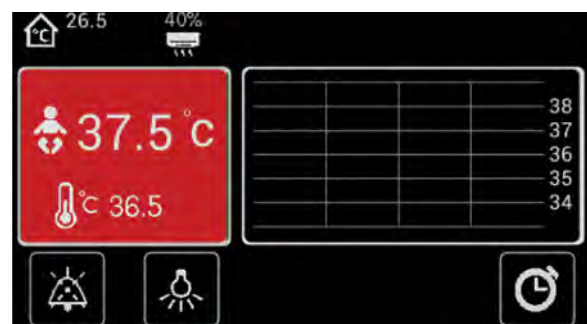
- 6 If used in servo mode, the **goal temperature** for the baby is usually set to a default 36.5°C. The user may change the goal temperature depending on patient's clinical status.
- 7 Ideally, each radiant warmer should be used for one baby with a temperature probe dedicated for that patient. Sharing of a radiant warmer and temperature probe poses a risk for temperature regulation and infection control. If multiple patients are sharing one warmer, regular temperature monitoring must be conducted using a temperature probe or thermometer. If the radiant heater is used in manual mode, the baby must be constantly attended as there is a real danger of overheating.

## CARING FOR A PATIENT

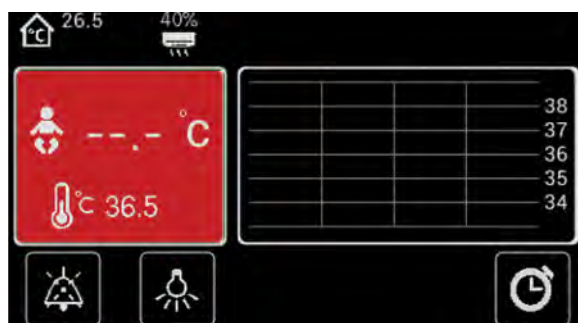
- 1 Monitor the patient's temperature 5 minutes after starting on radiant warmer, and then 4 hourly (if in **servo** mode) or every 30 minutes (if in **manual** mode).
- 2 Pay close attention to any alarms:
  - **Temperature:** the infant temperature probe has recorded temperatures below **(3.10)** or above **(3.11)** the safe range for the patient. Assess if the patient is too hot or cold and change the radiant warmer settings accordingly. Check probe is not dislodged from the baby.
  - **Probe:** the temperature probe is not secured in the radiant warmer appropriately or the probe has malfunctioned. **(3.12)** Make sure the probe is plugged in; if the alarm continues, replace the probe or contact your maintenance department.
  - **Power:** the mains power has failed. **(3.13)** Turn off the power button on the radiant warmer control and move the patient to a working warmer.
  - **System:** the radiant warmer has recorded a problem with its system. **(3.14)** This may result in the radiant warmer no longer providing heat or no longer monitoring the patient. Move the patient to a working warmer and contact your maintenance department.



3.10 Low Patient Temperature alarm.



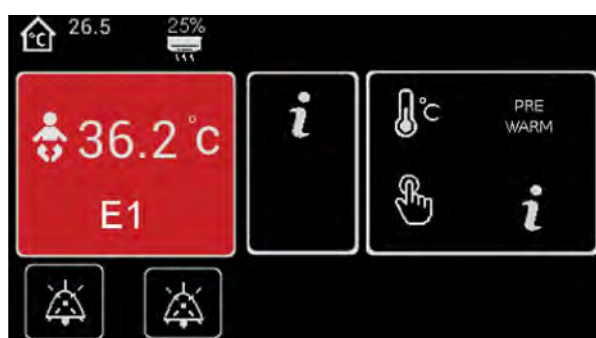
3.11 High Patient Temperature alarm.



3.12 Probe Failure alarm.



3.13 Power Failure alarm.



3.14 System Failure alarm.

## REMOVING A PATIENT

- 1 Collect:
  - Gauze
  - 70% alcohol
- 2 Gently remove tape/bandage holding temperature probe from patient. **(3.15)**



**3.15** Peel off tape holding temperature probe in place.

- 3 Disinfect probe site on patient and temperature probe with gauze and 70% alcohol.
- 4 Turn off warmer using switch and unplug.
- 5 Check the patient's temperature after 30 minutes off the warmer, to ensure normal body temperature is maintained.
- 6 Disinfect the cot before reuse.

---

## 4 Infection Prevention

**Routine and adequate cleaning of medical devices is critical to prevent hospital-acquired infections in newborn care units.**

### GENERAL INFECTION PREVENTION

- 1 Clean hands with soap and water or 70% alcohol before and after placing a patient in a radiant warmer or handling any consumables that will be used on a patient (e.g., temperature probe).

- 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 on the radiant warmer.
- 3 All patient-related consumables should be stored in a clean, dry location. Any cables should be loosely wrapped and secured, preventing sharp bends or kinks, which will decrease the lifetime of the cables. Do not pinch or bend the cables.
- 4 As mentioned in **Radiant Warmer: Management**, each radiant warmer should be used for one baby with a temperature probe dedicated for that patient. Sharing of a radiant warmer and temperature probe poses a high risk for infection transmission between patients. If the patient probe and surfaces are not cleaned thoroughly before use, infection can also be transmitted.

## DISINFECTION AFTER USE

- 1 Turn off and unplug the radiant warmer, if not using with another patient. Allow to cool.
- 2 After every use, use gauze and 70% alcohol or diluted chlorine (**Alert 4.1**) to thoroughly wipe:
  - Temperature probe, including cable and plug head
  - Control panel
  - Power button
  - Mattress – cleaning both sides
  - Cot walls
- 3 Housing of the radiant warmer should be cleaned according to ward guidelines for disinfecting surfaces.



### ALERT 4.1

Disinfection of equipment should always comply with manufacturer guidelines. General guidance on environmental cleaning and disinfection of equipment was taken from the [Infection Prevention and Control: Reference Manual for Health Care Facilities with Limited Resources](#), Jhpiego, Module 6<sup>6</sup> 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.<sup>7</sup>

When utilising re-processed devices meant for single-use (like temperature probes), careful attention must always be paid to assure that devices are continuing to function properly.

## 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

- **Hypothermia & cold stress:** if the device is not prepared correctly, is malfunctioning, or the baby is left exposed for a long period of time, there is a risk of hypothermia. This is associated with a significant increase in mortality and morbidity including respiratory distress syndrome, metabolic derangements, interventricular haemorrhage, and late onset sepsis.<sup>4</sup> Hypothermia additionally increases the risk of necrotising enterocolitis in preterm infants.<sup>2,4</sup> If a baby is cold, rewarming must be careful and gradual.
- **Hyperthermia & heat stress:** hyperthermia can occur in patients whilst on manual mode who are not monitored regularly or on servo mode if the temperature probe falls off as they may become overheated. Risks of hyperthermia include increased fluid loss with development of hypernatraemic dehydration, convulsions, increased metabolism, tachypnoea, tachycardia, and recurrent apnoea.<sup>8-12</sup> **(Alert 5.1)**
- **Pressure sores:** pressure sores may develop if the patient is incorrectly positioned, is lying on additional tubing/equipment, or the temperature probe is not positioned correctly.
- **Falls:** the cot sides of the radiant warmer must be in place to prevent the baby falling off the mattress on to the floor.
- **Infection:** if the temperature probe or infant warmer are not cleaned thoroughly before use, infection can be transmitted. Care should be taken particularly for consumables that are marked as single-use but are reused in practice (such as temperature probes).



### ALERT 5.1 Contextualising Hyperthermia

There are two ways that an infant might have an elevated core temperature: (1) infection (2) environmental.

- 1 **Infection:** In the case that an elevated temperature is generated by infection, there is no temperature which is considered “dangerous” and would require additional alarms. Fever, regulated by the hypothalamus, is the body’s normal response to infection or inflammation which is induced by cytokine activation.
- 2 **Environmental overheating:**
  - **Device overheating:** A device overheating an infant can lead to a number of potentially dangerous outcomes that may result in serious harm. Environmental overheating is not a body’s normal response to an illness (as seen in fever) but rather a mismatch between environmental heat and the ability of the infant’s body to dissipate heat. Environmental overheating may result in serious heat related illness including damage to the central nervous system.<sup>8,9</sup> Compared to older individuals, babies are at particularly high risk of environmental overheating since they have higher heat production (metabolic rates), higher surface area to mass ratios (i.e., higher absorption of heat from environment), less ability to dissipate heat and no ability to independently access fluids.<sup>10-12</sup>
  - **Maternal heat transference:** Immediately following delivery hyperthermia can be caused by maternal fever during labour and delivery as foetal temperature is up to 1°C higher than maternal temperature.<sup>13</sup>

Note on special circumstances: CNS injury, in which it is critical to avoid hyperthermia in the first 72 hours following birth, may affect the newborn’s temperature. However, CNS damage will typically result in temperature instability rather than hyperthermia.<sup>13</sup>

## DEVICE COMPLICATIONS

- **Hyperthermia due to probe mismanagement:** if the device is set to automatically adjust its temperature based on the patient’s temperature (servo mode) and the patient temperature probe falls off the patient or is not well secured **(5.1)**, the radiant warmer may

overheat in an attempt to compensate for what it observes as a low body temperature. This puts the patient at risk for a body temperature > 40°C and clinical harm



5.1 An unsecured temperature probe may cause the radiant warmer to overheat.

- **Alarms:** radiant warmers have in-built alarms that should sound if the patient's temperature is above or below a set normothermic range. If this range is not appropriately set, alarms may sound at incorrect situations.
- **Fire:** if linen is placed on the radiant heater head, heat and dust may build up and pose a fire hazard. Never store linen on top of the device or close to the heating elements. Although treatment devices (e.g., phototherapy units, oxygen concentrators) can be used with a radiant warmer, care should be taken to ensure that the direct line of heat to the patient from the radiant warmer heating elements is not obstructed.

## 6 Care & Maintenance

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

### POWER SOURCE

Radiant warmers are powered with mains/socket power. Radiant warmers are typically the largest consumers of power in a nursery and should be plugged into their own socket and surge protector if available. **(6.1 & 6.2)** Radiant warmers typically draw too much power to be used with small-scale solar systems. In most cases, the cost (both financially and energetically) to run radiant warmers during a power cut prevents them from being used with backup power.



**6.1** Radiant warmers should be plugged into their own socket.



**6.2** Radiant warmers should be plugged into a surge protector if possible.

## WARD LOCATION

Radiant warmers should be placed against a wall with the power cable/stand facing the wall and control panel facing the middle of the nursery room. **(6.3)** Warmers should be away from any windows to avoid air currents disrupting heat radiation. Windows are preferably kept closed.



**6.3** Appropriate placement with the power cable port facing the wall and displace LCD facing away from the wall.

## USER PREVENTIVE MAINTENANCE

Preventive maintenance should be conducted weekly and should include:

### 1 Test the heating elements and temperature probe:

- Plug in the machine. Connect the temperature probe. Turn the power switch to ON. Leave the machine on for 1 minute.

- Hold the temperature probe in the palm of your hand and hold your hand near the overhead heating elements. Slowly move it from the part of the heating element closest to the stand, moving towards the outside end of the heating element. You should feel your hand progressively heat as you move it, and see the temperature reading on the machine steadily increase.
  - If you feel any sections of the heating elements are not providing heat, contact your maintenance department.
- 2 Test the power loss alarm:** while the radiant warmer is plugged in and turned on, turn off the power at the wall socket. An alarm should sound. If it does not sound, contact your maintenance department.

## 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 radiant warmer does not turn on

- Check that the power cable is firmly plugged in to the back of the device. Check that the power switch on the back of the device is turned on.
- If the power switch is turned on and the power cable is firmly plugged in but the device is still not turning on, try replacing the power cable.
- Should the radiant warmer still not turn on, contact your maintenance department.

### 2 The radiant warmer is turning on, but is not heating

- Check the radiant warmer settings to ensure that heating is turned on: If in manual, the heating settings may be set to 0%. **(7.1a)** Make sure that the heater output is set to a number above 0%. **(7.1b)**
- If the heating settings are turned on & the radiant warmer is still not heating, contact your maintenance department.



**7.1a** Manual settings set to 0% heat output.



**7.1b** Manual settings set to 25% heat output.

### 3 The radiant warmer is turning on, but the temperature probe is not reading the patient's temperature

- Hold the temperature probe in the palm of the hand and watch temperature reading on control panel to see if the temperature changes to a reasonable body temperature.
- If the temperature does not change or there is a "Probe alarm" displayed, replace the probe with a spare or contact your maintenance department.

## Assessment Questions

- 1 You have started to manage a patient's temperature using a radiant warmer. When you are making your monitoring rounds, you note that the warmer display shows the alarm in **1a**. What does this alarm indicate?

The patient has a high temperature.

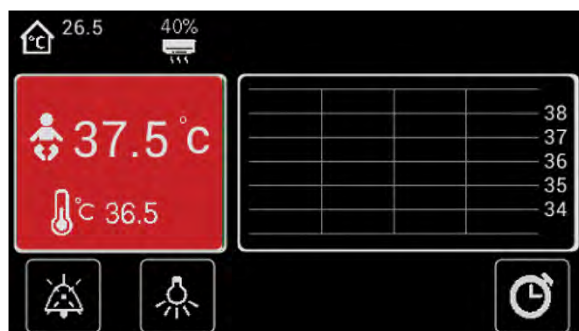
You walk over to check the patient. Whilst there, you see the patient as in **1b**.

- a What is wrong with this patient's monitoring?

The patient temperature probe is not secured on the patient's core.

- b Will it have an effect on the patient's temperature management? If so, what?

It will have an effect; the temperature probe is reading the temperature of the mattress, which is colder than that of the patient. If the radiant warmer is in servo/automatic mode, it may overheat the patient.



1a



1b

- 2 A baby is under the radiant heater which is in manual mode. What is the most important, potential complication?

The baby may become hypo- or hyperthermic if the heater output is not watched and increased or decreased as necessary.

- 3 How often will you monitor the baby?

Monitor the patient's temperature 5 minutes after starting on radiant warmer, and then 4 hourly (if in servo mode) or every 30 minutes (if in manual mode).

---

# References

- 1 Mullany, L. C. *et al.* Hypothermia and associated risk factors among newborns of southern Nepal. *BMC Pediatrics* **8**, 13 (2010).
- 2 Laptook, A. R. *et al.* Admission Temperature and Associated Mortality and Morbidity among Moderately and Extremely Preterm Infants. *The Journal of Pediatrics* **192**, 53–59.e2 (2018).
- 3 Miller, S. S., Lee, H. C. & Gould, J. B. Hypothermia in very low birth weight infants: distribution, risk factors and outcomes. *Journal of Perinatology* **31**, S49–S56 (2011).
- 4 Perlman, J. M. *et al.* Part 7: Neonatal Resuscitation: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations (Reprint). *PEDIATRICS* **136**, S120–S166 (2015).
- 5 *Essential elements of obstetric care at first referral level.* (World Health Organization, 1991).
- 6 Curless MS, Ruparelia CS, Thompson E, and Trexler PA, eds. 2018. Infection Prevention and Control: Reference Manual for Health Care Facilities with Limited Resources. Jhpiego: Baltimore, MD.
- 7 Sharma, G. Infection Prevention and Control at Neonatal Intensive Care Units. 134.
- 8 Bouchama, A. & Knochel, J. P. Heat stroke. *N. Engl. J. Med.* **346**, 1978–1988 (2002).
- 9 Bynum, G. D. *et al.* Induced hyperthermia in sedated humans and the concept of critical thermal maximum. *Am. J. Physiol.* **235**, R228–236 (1978).
- 10 Bytowski, J. R. & Squire, D. L. Heat illness in children. *Curr Sports Med Rep* **2**, 320–324 (2003).
- 11 Naughton, G. A. & Carlson, J. S. Reducing the risk of heat-related decrements to physical activity in young people. *J Sci Med Sport* **11**, 58–65 (2008).
- 12 Falk, B. Effects of thermal stress during rest and exercise in the paediatric population. *Sports Med* **25**, 221–240 (1998).
- 13 Ringer, S. A. Core Concepts: Thermoregulation in the Newborn, Part II: Prevention of Aberrant Body Temperature. *NeoReviews* **14**, e221 (2013).

---

# Jaundice Management

---

## Phototherapy

# 1 Clinical Problem

**Infants have a large volume of bilirubin in the bloodstream because they have a high red cell mass (haemoglobin) and rapid breakdown of red blood cells in the first days of life. A newborn's immature liver is often unable to rapidly remove bilirubin, leading to an excess of unconjugated bilirubin and thus jaundice.**

Phototherapy should be commenced for neonates with:

- Any visible jaundice on the day of birth
- Jaundice extending below the umbilicus
- Bilirubin level indicating need for treatment

Phototherapy should also be considered for neonates with jaundice and the following complications:

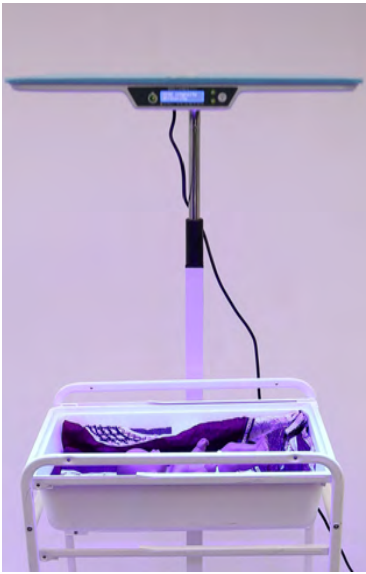
- Prematurity
- Sepsis
- Significant bruising or cephalohaematoma
- Maternal-infant blood incompatibility (e.g., ABO or Rhesus incompatibility)
- G6PD deficiency

Initiation of phototherapy is very rarely required after 14 days of life in term infants and 21 days in preterm infants.<sup>1</sup> Jaundice due to breast feeding may last for a long time (but the baby is well). Prolonged jaundice (>14 days) warrants further investigation and discussion for possible referral to a tertiary centre.

# 2 Assessment

**Phototherapy uses blue light transmitted on the patient's skin within the wavelengths of 425 to 475 nm<sup>2</sup> to break down unconjugated bilirubin to a water-soluble, non-toxic form that can be easily excreted.<sup>3</sup>**

Phototherapy lights may be integrated into units with overhead **(2.1)**, over- and under-body **(2.2)**, or flexible blanket lights. **(2.3)** Most phototherapy units can be used in tandem with other devices (e.g., radiant warmers, incubators, and oxygen therapy). This clinical module will provide guidelines for the use of overhead phototherapy lights.



2.1 Overhead phototherapy unit.



2.2 Over & under the body phototherapy unit.



2.3 Flexible phototherapy blanket.

Phototherapy lights are most effective when providing blue light within 425 to 475 nm via LEDs. Other types of bulbs providing blue light within 425 to 475 nm (e.g., halogen or fluorescent) are less effective for treating jaundice, have a shorter lifetime, and are not as sustainable for long term use. Halogen and fluorescent bulbs are less efficient than LEDs and may also be a source of heat, introducing a potential risk for hyperthermia.<sup>45</sup> Other types of phototherapy are also used, but are typically not recommended:

- **UV lights:** not recommended for neonatal therapy due to increased melanoma risk associated with childhood UV exposure.
- **Natural sunlight:** traditionally used in lieu of phototherapy devices; natural sunlight is not ideal due to increased challenges with temperature control of the patient and UV radiation risks.
- **Filtered sunlight:** there is emerging evidence that devices that filter sunlight, while requiring close monitoring in order to prevent temperature instability, can be used in babies > 2.2kg in tropical climates to treat neonatal jaundice.<sup>6-9</sup>

There are different methods to determine need for phototherapy, all of which rely on measuring or estimating the bilirubin levels in the blood. Bilirubin levels can be measured in all babies using a blood test and transcutaneous devices<sup>10,11</sup> or estimated through visual assessment with reference to the Kramer's scale. (2.4)

## Kramer's Scale

|   |              |                         |
|---|--------------|-------------------------|
| 1 | 4 - 6mg/dL   | 70 - 100 $\mu$ mol/dL   |
| 2 | 8 - 10mg/dL  | 130 - 170 $\mu$ mol/dL  |
| 3 | 12 - 14mg/dL | 200 - 240 $\mu$ mol/dL  |
| 4 | 15 - 18mg/dL | 250 - 310 $\mu$ mol/dL  |
| 5 | 15 - 20mg/dL | 250 - >340 $\mu$ mol/dL |



2.4 Kramer Scale visual assessment areas.

In the absence of timely availability of serum bilirubin measurements, which are the gold standard, phototherapy should be started for any visible jaundice on day one of life (make sure to press nose, look in mouth and check conjunctiva), or at a Kramer's level of 3 for jaundice on day 2 of life and later (when jaundice is visible below the umbilicus). See **Alert 2.1** for detailed information about the Kramer's scale. Assessment should be made in natural or white light to ensure results are accurate. Both transcutaneous bilirubin<sup>12</sup> and the Kramer's scale are less precise in determining serum levels after phototherapy has begun. Some units may plot bilirubin levels using nomograms as well. Ensure a reference is used which is consistent with unit policy.

If serum bilirubin or transcutaneous bilirubin is available, **Table 2.1** provides reference levels for when to start phototherapy or consider an exchange transfusion.<sup>13,14</sup>

**TABLE 2.1 JAUNDICE & PHOTOTHERAPY VS TRANSFUSION**

| Treatment                                                                                                                                                                                                                                | Day of Life   | Healthy Term Baby                            | Premature <35wks, LBW or sick baby |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|----------------------------------------------|------------------------------------|
| <b>Phototherapy</b><br>Jaundice of these levels is treated with phototherapy                                                                                                                                                             | Day 1         | Treat any visible jaundice with phototherapy |                                    |
|                                                                                                                                                                                                                                          | Day 2         | 15mg/dl<br>260mmol/l                         | 10mg/dl<br>170mmol/l               |
|                                                                                                                                                                                                                                          | Day 3         | 18 mg/dl<br>310 mmol/l                       | 15mg/dl<br>260mmol/l               |
|                                                                                                                                                                                                                                          | Day 4 onwards | 20mg/dl<br>340mmol/l                         | 17mg/dl<br>290mmol/l               |
|  <b>Exchange Transfusion</b><br>Jaundice of these levels or above is dangerous and the baby requires urgent referral for possible exchange transfusion | Day 1         | 15mg/dl<br>260mmol/l                         | 10mg/dl<br>220mmol/l               |
|                                                                                                                                                                                                                                          | Day 2         | 25mg/dl<br>425mmol/l                         | 15mg/dl<br>260mmol/l               |
|                                                                                                                                                                                                                                          | Day 3         | 25mg/dl<br>425mmol/l                         | 20mg/dl<br>340mmol/l               |
|                                                                                                                                                                                                                                          | Day 4 onwards | 25mg/dl<br>425mmol/l                         | 20mg/l<br>340mmol/l                |

If a baby needs a possible exchange transfusion, intensive phototherapy should be given while waiting to be transferred.



**ALERT 2.1 Physical exam estimation of serum bilirubin**

Measurement of serum bilirubin is the best assessment of neonatal jaundice. However, when timely serum bilirubin measurements are unavailable, Kramer's is the only studied physical exam proxy for estimating serum bilirubin levels in neonates.

The Kramer's scale has shown observer to observer variance, especially at high bilirubin levels.<sup>15-17</sup> However, when ruling out jaundice of bilirubin levels >12 mg/dL (215 mmol/L), studies have shown that the Kramer's scale can be used pre-phototherapy in term infants if limited to zones 1,2.<sup>16,17</sup>

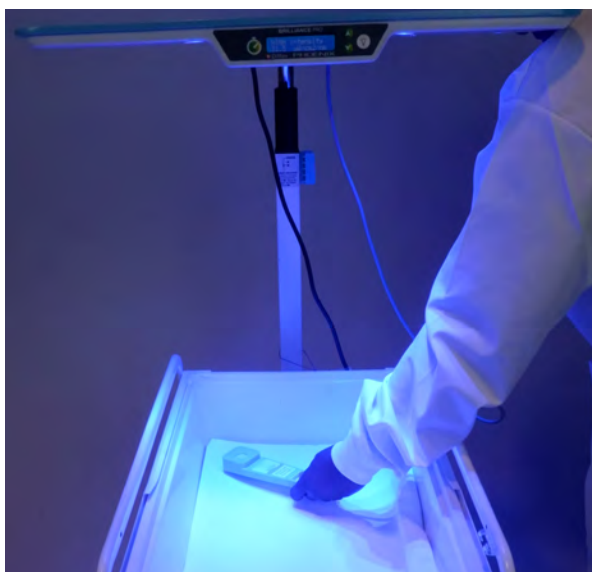
Usual optimal spectral irradiance for conventional phototherapy is 25–30  $\mu\text{W}/\text{cm}^2$  as measured by a phototherapy light meter. Higher optimal spectral irradiances of 30–35  $\mu\text{W}/\text{cm}^2$  may be used for intensive phototherapy for at risk infants.<sup>18</sup> Most jaundiced patients require treatment for 24 to 48 hours, and typically do not require treatment for any longer than 7 days. If jaundice persists, further investigation into the cause of the jaundice should be conducted.

## 3 Management

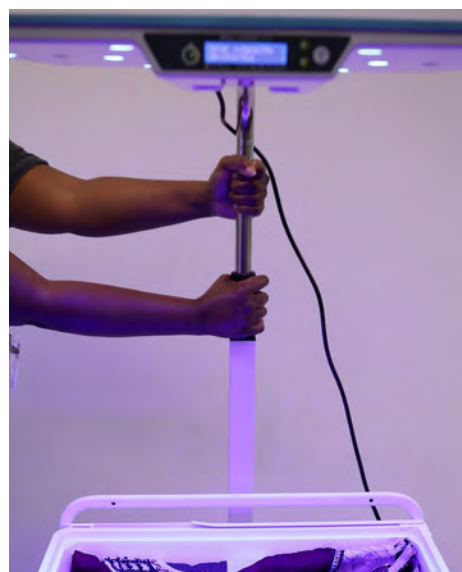
Management of an overhead phototherapy unit covers how to use the device in a variety of settings, including set up for a patient, patient preparation & commencement, care whilst on the device & removal of the patient from the device.

### SETTING UP FOR A PATIENT

- 1 Collect:
  - Phototherapy device
  - Power cable
  - Phototherapy light meter (if available)
- 2 Plug in phototherapy device. Turn on and check for **blue light** from the overhead light elements. NOTE: Some phototherapy lights may have white examination lights. In most models, if light emitting from this type of device is white, it is **not therapeutic**.
- 3 Turn on light meter if available. Place light meter on the mattress where the patient needing phototherapy will be located. **(3.1)**



3.1 Ideal lightmeter reading location.



3.2 Adjust height if necessary.

- 4 The phototherapy unit is typically set at a point where the overhead lights are approximately 20 – 30 cm above a typical cot. Check that irradiance provided at this height is within therapeutic ranges and adjust the height if necessary. **(3.2)**
  - If irradiance is too low, lower the height of the phototherapy light until therapeutic ranges are reached without obstructing care.
  - If irradiance is too high, raise the height of the phototherapy light until therapeutic ranges are reached.

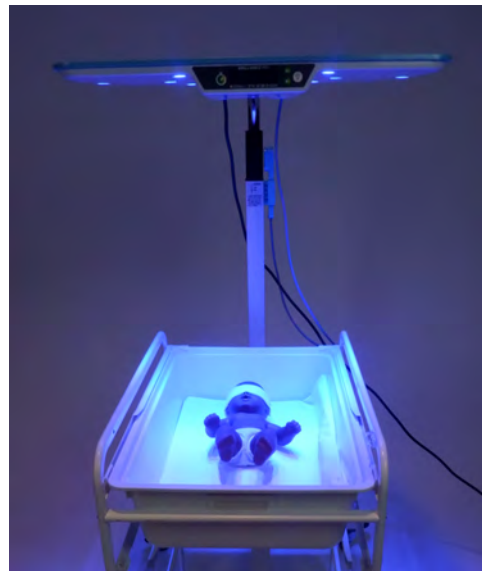
Light should cover the entire surface on which the patient will be treated.

## PREPARING A PATIENT

- 1 Always explain the purpose, risks and benefits of a procedure to guardians BEFORE performing the procedure.
- 2 Follow handwashing protocol.
- 3 Collect:
  - Eye mask or gauze and tape
- 4 Remove all clothes. The diaper should cover the minimum necessary to keep the baby clean.
- 5 Place eye mask so that it fully covers the patient's eyes. **(3.3)** The mask should be tight enough that it will remain in place should the patient be active, but not so tight that it is visibly uncomfortable or cutting into the patient's skin. If a ready-made eye mask is not available, use gauze to cover the eyes and tape to secure in place. Avoid putting tape on the eyebrows and hair.



**3.3** Fully cover the eyes.



**3.4** Place the patient in centre of prepared cot with phototherapy light on.

## STARTING A PATIENT

- 1 Place patient directly under phototherapy lights that are switched on in a prepared cot, warming crib or incubator. **(3.4)** Always document the date and time that phototherapy was started.

## CARING FOR A PATIENT

- 1 Babies should receive as continuous phototherapy treatment as possible.
- 2 Monitor according to clinical condition, or in accordance to local policy:
  - **Vital signs:** including respiratory rate, heart rate, peripheral blood oxygen saturation, blood sugar and temperature, or any additional danger signs.
  - **Skin rotation:** the baby should be turned 4 hourly to expose more skin to phototherapy lights.
  - **Daily bilirubin levels:** at least 4 hourly if rising rapidly and if available. Document all bilirubin results with date and time. If serum bilirubin measurement is not available, provide daily reference to the level observed on the Kramer scale.
  - **Signs of dehydration:** jaundiced babies must be well hydrated; extra breastfeeds encourage bowel motions and promote bilirubin excretion. Check that urine is being passed frequently.
  - **Daily weight**
- 3 At every monitoring point (4 hourly), check that:
  - The eye mask fully covers the patient's eyes and is still secure. **(Alert 3.1)**
  - The baby is feeding well and weight is not decreasing. If the baby is not feeding well, consider providing additional expressed breast milk via a nasogastric tube (NGT) or cup, or if very ill an IV fluid therapy containing dextrose.
  - There are no abnormal movements.
  - Any underlying conditions are being treated.
  - Serum bilirubin levels or jaundice areas are not increasing. **Blue lights must be switched off to accurately assess visible jaundice.** Some phototherapy lights may have white examination lights that can be used to better assess the patient.
- 4 If serum bilirubin levels or jaundice areas are increasing:
  - Check the irradiance at the patient's bed-level using a lightmeter. If the irradiance is lower than recommended, **increase the irradiance** provided by changing the machine settings to a higher level (e.g., brilliance mode) if available, or lowering the height of the phototherapy lights.
  - Ensure maximum skin exposed to light and continue regular feeds. Consider starting IV fluids if bilirubin levels or jaundice is rapidly increasing.
- 5 Always document the date and time that phototherapy settings were changed.



### ALERT 3.1

When feeding and not under the blue light, remove the patient's eye mask and check for any signs of infection. The baby can be removed from the phototherapy unit and fed in mother's arms. This will facilitate mother-child bonding. Keep mother and baby together as much as possible whilst still allowing effective treatment time.

## REMOVING A PATIENT

- 1 If referring to the Kramer's scale, stop phototherapy when jaundice is limited to area 1 in premature infants and areas 1 & 2 in term infants. **(Alert 3.2)** When serum bilirubin or transcutaneous bilirubin measurement is available, stop phototherapy when the measurement is less than 50mmol/L or 3mg/dl below the level requiring treatment.
- 2 Turn off the phototherapy light. Gently remove the eye covering from the patient and dispose of the covering. **(3.5)**



3.5 Gently remove and dispose of eye covering.

- 3 Continue to monitor the baby for jaundice over the next 24-48 hours in case the bilirubin level rises again.



### ALERT 3.2 Discontinuation of phototherapy when serum bilirubin measurements unavailable

In the absence of timely serum bilirubin measurement, there is no evidence-based method for determining when to remove a patient from phototherapy. WHO Europe guideline suggests a “minimum of 12 hours phototherapy” which is too short for most preterm infants or deeply jaundiced term infants. *WHO Pocket Book for Children* does not provide guidance on how to stop phototherapy in the absence of utilising serum bilirubin.<sup>1,19,20</sup>

Thus, based on expert opinion, although there are no studies addressing the accuracy of the Kramer's scale after starting phototherapy, it was determined best to give some physical exam guidance based on the Kramer's scale for when to discontinue phototherapy. Additionally, in the absence of bilirubin levels, cleared conjunctiva are often used as indicating that jaundice has resolved sufficiently to stop treatment. This has not been formally evaluated.

Alternately, if choosing to discontinue phototherapy using length of therapy, based on expert opinion we would recommend a minimum of 24 hours of phototherapy for term infants and longer for preterm infants.

## 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 re-processed 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 under phototherapy or handling any materials that will be used on a patient (e.g., eye covers).
- 2 Ensure that all patient-related equipment (including eye coverings) are new or have been cleaned thoroughly before use. Any patient-related materials, including cot linen, must be cleaned before they are placed on a patient under a phototherapy device.
- 3 All patient-related equipment should be stored in a clean, dry location. Any cables should be loosely wrapped and secured, preventing sharp bends or kinks, which will decrease the lifetime of the cables. Do not pinch or bend the cables.
- 4 Only one baby should be under each phototherapy unit. Sharing of a phototherapy light in one cot poses a high risk for infection transmission between patients. Some phototherapy units may be able to provide therapeutic light to multiple patients in several cots at once; though this inevitably means that the cots are close to each other and increases the likelihood of infection transmission. The light should always be tested for efficacy using a light meter near the location in which the patient will be placed.

### DISINFECTION AFTER USE

- 1 Turn off phototherapy light and unplug. Disinfect handle of phototherapy light meter and LCD controls using alcohol. **(4.1)**
- 2 Housing of the phototherapy unit (including the casing on the LEDs or lightbulbs) should be cleaned thoroughly according to ward guidelines for disinfecting surfaces.



#### ALERT 4.1 Equipment Disinfection

Disinfection of equipment should always comply with manufacturer guidelines. General guidance on environmental cleaning and disinfection of equipment was taken from the Infection Prevention and Control: Reference Manual for Health Care Facilities with Limited Resources, Jhpiego, Module 6<sup>21</sup> 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.<sup>22</sup>

When utilizing re-processed devices meant for single-use (like temperature probes), careful attention must always be paid to assure that devices are continuing to function properly.



4.1 Clean the housing of the phototherapy unit according to ward guidelines.

## 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

- **Dehydration:** neonatal patients under phototherapy with lights other than LEDs may require more fluid than maintenance volumes. It is important to ensure the patient is feeding well and to monitor for signs of dehydration (not passing urine, weight loss  $\geq 5\%$ , prolonged skin turgor). Additional feeds or intravenous fluids may be required. Dehydration may be worsened by diarrhoea which is a recognised complication of jaundice.<sup>23</sup>
- **Hypothermia:** temperature should be carefully monitored as patients are nearly naked under phototherapy. Phototherapy devices **are not intended as heating devices**. LED bulbs used in most modern devices are very efficient so generate minimal heat; a warming device may be required to avoid hypothermia.
- **Retinal damage:** consistent exposure of the eyes to strong light has been shown to cause retinal damage in adults. Although this has not been tested in neonates, care should be taken to keep the eyes covered at all times during treatment. **(5.1)**
- **Eye infections:** check for redness, swelling or discharge. The skin under the eye pads should be cleaned daily with warm sterile water to prevent infection.
- **Bronze baby syndrome:** some babies develop a greyish colour to their skin (difficult to see in pigmented babies), urine, and plasma during phototherapy. This is attributed to increased accumulation of bilirubin photoisomers, degradation products, or copper-

porphyrin conjugates. The true cause remains uncertain. It is self-limiting, resolves after phototherapy is stopped, and has no long-term sequelae.<sup>24–26</sup>



5.1 Uncovered eyes during phototherapy can lead to retinal damage.

- **Acute bilirubin encephalopathy (Kernicterus):** extremely high levels of bilirubin can cross the blood brain barrier causing kernicterus. This may manifest as hypertonia and seizures. If the jaundice is not promptly and appropriately treated with adequate phototherapy light, permanent brain damage may occur e.g., development of deafness, choreoathetoid movements, and cerebral palsy. In addition to phototherapy, exchange transfusions are required for serious jaundice.<sup>23</sup>

## DEVICE COMPLICATIONS

- **Inadequate light:** after a set period of use (about 20,000 hours of use, depending on manufacturer recommendations), phototherapy devices may lose their ability to provide therapeutic light. It is important to test the capacity of the phototherapy regularly to ensure that the phototherapy light is still providing a therapeutic range (25 – 35  $\mu\text{W}/\text{cm}^2$ ).

# 6 Care & Maintenance

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

## POWER SOURCE

Phototherapy units may be powered via mains or grid power with a rechargeable battery, depending on model.

## WARD LOCATION

Phototherapy devices are usually rolling units with brakeable caster wheels. Devices may be rolled from patient bed to patient bed as needed.

## USER PREVENTIVE MAINTENANCE

Test the light for therapeutic light levels once a week using the phototherapy light meter, following the steps in **Phototherapy: Management | Setting Up for a Patient**.

# 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 phototherapy light does not turn on.

- ☐ Check that the power cable is securely attached to the phototherapy device **(7.1)** and that the switch and power outlet are turned on.
- ☐ If the phototherapy unit still does not turn on, contact your maintenance department.



7.1 If the light does not turn on, check that the power cable is securely attached.



7.2 If bulbs are not working, ask for replacement bulbs.

### 2 The phototherapy light turns on, but only some of the lights are functional. (7.2)

- ☐ Contact your maintenance department and ask for replacement bulbs.

- Some phototherapy units have different switches for the white examination lights and the blue phototherapy lights. Each set of lights must be switched on separately. Examination lights **do not treat jaundice**. Blue phototherapy lights are therapeutic and must be replaced in order for treatment to be effective.

---

# Assessment Questions

- 1 Which of the following is the most therapeutically effective and efficient method of providing phototherapy? Please circle an option below.  
(A) blue LEDs within 425 – 475 nm    (B) blue halogen bulbs    (C) UV fluorescent bulbs
- 2 Under what conditions would you lower the height of the phototherapy unit?  
The patient's jaundice requires increased intensity and the phototherapy unit in use does not have a higher intensity setting.
- 3 Your patient's temperature is being managed on a radiant warmer during their first day of life. While monitoring the patient, you note that they shows signs of jaundice. What will you do?  
Keep the patient in the radiant warmer. Angle an overhead phototherapy unit to provide treatment at the same time, measuring the provided therapeutic irradiance at the point of the radiant warmer cot using a lightmeter.

---

# References

- 1 *Pocket book of hospital care for children: guidelines for the management of common childhood illnesses.* (World Health Organization, 2013).
- 2 Granati, B. *et al.* Efficacy and safety of the 'integral' phototherapy for neonatal hyperbilirubinemia. Results of a follow-up at 6 years of age. *Clin Pediatr (Phila)* **23**, 483–486 (1984).
- 3 Maisels, M. J. Phototherapy for Neonatal Jaundice. *N Engl J Med* **358**, 2522–2525 (2008).
- 4 Kumar, P., Chawla, D. & Deorari, A. Light-emitting diode phototherapy for unconjugated hyperbilirubinaemia in neonates. *Cochrane Database Syst Rev* CD007969 (2011) doi:10.1002/14651858.CD007969.pub2.
- 5 Morris, B. H. *et al.* Efficacy of phototherapy devices and outcomes among extremely low birth weight infants: multi-center observational study. *J Perinatol* **33**, 126–133 (2013).
- 6 Slusher, T. M. *et al.* Filtered sunlight versus intensive electric powered phototherapy in moderate-to-severe neonatal hyperbilirubinaemia: a randomised controlled non-inferiority trial. *The Lancet Global Health* **6**, e1122–e1131 (2018).
- 7 Slusher, T. M. *et al.* Safety and efficacy of filtered sunlight in treatment of jaundice in African neonates. *Pediatrics* **133**, e1568–1574 (2014).
- 8 Slusher, T. M. *et al.* A Randomized Trial of Phototherapy with Filtered Sunlight in African Neonates. *New England Journal of Medicine* **373**, 1115–1124 (2015).
- 9 Vreman, H. J. *et al.* Evaluation of Window-Tinting Films for Sunlight Phototherapy. *Journal of Tropical Pediatrics* **59**, 496–501 (2013).
- 10 Nagar, G., Vandermeer, B., Campbell, S. & Kumar, M. Reliability of Transcutaneous Bilirubin Devices in Preterm Infants: A Systematic Review. *PEDIATRICS* **132**, 871–881 (2013).
- 11 Hassan Shabuj, M., Hossain, J. & Dey, S. Accuracy of transcutaneous bilirubinometry in the preterm infants: a comprehensive meta-analysis. *J. Matern. Fetal. Neonatal. Med.* **32**, 734–741 (2019).
- 12 Nagar, G., Vandermeer, B., Campbell, S. & Kumar, M. Effect of Phototherapy on the Reliability of Transcutaneous Bilirubin Devices in Term and Near-Term Infants: A Systematic Review and Meta-Analysis. *Neonatology* **109**, 203–212 (2016).
- 13 Appendices A–F [Nomograms depicting jaundice management at various gestational periods]. in *Queensland Clinical Guidelines: Neonatal Jaundice*. 34–39 (Queensland Health, 2019).
- 14 WHO recommendations on newborn health: guidelines approved by the WHO Guidelines Review Committee. Geneva: World Health Organization; 2017 (WHO/MCA/17.07). Licence: CC BY-NC-SA 3.0 IGO.
- 15 Madlon-Kay, D. J. Home health nurse clinical assessment of neonatal jaundice: comparison of 3 methods. *Arch Pediatr Adolesc Med* **155**, 583–586 (2001).
- 16 Moyer, V. A., Ahn, C. & Sneed, S. Accuracy of Clinical Judgment in Neonatal Jaundice. *ARCH PEDIATR ADOLESC MED* **154**, 4 (2000).
- 17 Szabo, P. *et al.* Detection of hyperbilirubinaemia in jaundiced full-term neonates by eye or by bilirubinometer? *European Journal of Pediatrics* **163**, 722–727 (2004).
- 18 American Academy of Pediatrics Subcommittee on Hyperbilirubinemia. Management of hyperbilirubinemia in the newborn infant 35 or more weeks of gestation. *Pediatrics* **114**, 297–316 (2004).
- 19 Moyer, V. A., Ahn, C. & Sneed, S. Accuracy of Clinical Judgment in Neonatal Jaundice. *ARCH PEDIATR ADOLESC MED* **154**, 4 (2000).

- 20 *Neonatology: Effective Perinatal Care*. (World Health Organization Regional Office of Europe, 2010).
- 21 Curless MS, Ruparelia CS, Thompson E, and Trexler PA, eds. 2018. *Infection Prevention and Control: Reference Manual for Health Care Facilities with Limited Resources*. Jhpiego: Baltimore, MD.
- 22 Sharma, G. *Infection Prevention and Control at Neonatal Intensive Care Units*. 134.
- 23 Kliegman, R. *Nelson textbook of pediatrics*. (Elsevier Inc, 2020).
- 24 McDonagh, A. F. Bilirubin, copper-porphyrins, and the bronze-baby syndrome. *J. Pediatr.* **158**, 160–164 (2011).
- 25 Ottinger, D. Bronze baby syndrome. *Neonatal Netw* **32**, 200–202 (2013).
- 26 Rubaltelli, F. F., Da Riò, R., D'Amore, E. S. & Jori, G. The bronze baby syndrome: evidence of increased tissue concentration of copper porphyrins. *Acta Paediatr.* **85**, 381–384 (1996).

**THIS IS ONE SERIES OF NEST-ED & NEST  
360° MATERIALS AVAILABLE.**

To view more materials, visit the **NEST360° Resources** website.

NEST360°