These materials are intended to strengthen locally developed neonatal clinical and biomedical engineering trainings in pre- and in-service settings and are not intended to be comprehensive clinical guidelines or targeted towards intensive care of the newborn.
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Clinical Education Module: Bubble CPAP

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### ABBREVIATIONS

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<tr>
<td>ABC</td>
<td>Airway, Breathing, Circulation</td>
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<tr>
<td>bCPAP</td>
<td>Bubble continuous positive airway pressure</td>
</tr>
<tr>
<td>FiO₂</td>
<td>Fractional Concentration of Oxygen</td>
</tr>
<tr>
<td>HFNC</td>
<td>High flow nasal cannula</td>
</tr>
<tr>
<td>NEST360</td>
<td>Newborn Essential Solutions and Technologies</td>
</tr>
<tr>
<td>O₂</td>
<td>Oxygen</td>
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<td>OGT</td>
<td>Orogastric tube</td>
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<td>ROP</td>
<td>Retinopathy of Prematurity</td>
</tr>
<tr>
<td>SpO₂</td>
<td>Peripheral blood oxygen saturation</td>
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<td>WHO</td>
<td>World Health Organization</td>
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### NOMENCLATURE

<table>
<thead>
<tr>
<th>Nomenclature</th>
<th>Definition</th>
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<tr>
<td>bCPAP prongs</td>
<td>bCPAP patient interface</td>
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<tr>
<td>Hospital Acquired Infection</td>
<td>Iatrogenic infection, nosocomial infection</td>
</tr>
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<td>Nasal prongs</td>
<td>Oxygen catheter, oxygen cannula, oxygen prongs</td>
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<td>Positive Pressure</td>
<td>Positive end expiratory pressure, positive airway pressure</td>
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Introduction

This Clinical Module has been prepared to help healthcare staff and students understand when and how to use equipment essential to newborn care. This material may be used by teaching institutions to supplement current newborn care curricula or by hospitals, clinical departments and individuals to update their knowledge and to better facilitate the effective and safe use of newborn care equipment.

Whilst reading this series on a digital device, download and open the document in Adobe Acrobat. On the toolbar click View, Navigation Panes, and then click Bookmarks. Use the Bookmarks pane to navigate between sections of the document.

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

1 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.

2 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).

3 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.

4 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.

5 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.

6 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.

7 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.
8 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 to facilitate 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 Subject

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

Bubble CPAP (bCPAP) devices provide both positive pressure & increased fractional concentration of oxygen (FiO$_2$) to newborns with respiratory distress. Bubble CPAP (bCPAP) is particularly useful for premature babies with respiratory distress syndrome (Figure 1.1).

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

Very premature babies (<1.5 kg and <32 weeks) benefit from prophylactic 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 Benefits of early CPAP

Early CPAP is recommended for preterm (<32 weeks) and small (<1.5 kg) newborns.

This is because, CPAP prevents and treats respiratory distress by improving both ventilation (controlled provision of continuous inspiratory pressure) and oxygenation (controlled provision of increased percentage of oxygen termed as the fraction of inspired oxygen (FiO$_2$)).

The positive pressure from CPAP prevents lung tissue (alveolae) from collapsing on expiration thus improving ventilation, reducing the work of breathing and preventing potentially irreversible lung damage. Additionally, CPAP has been shown to promote production of endogenous surfactant, improve apnoea of prematurity and dramatically decrease progression to mechanical ventilation, or death, in both high- and low-income settings.

Bubble CPAP may also be used to treat neonatal patients with increased work of breathing, defined by nasal flaring, grunting, head nodding, severe recession, RR >60, or peripheral blood saturations of <90%, in premature or term infants. Common causes of increased work of breathing are:

- Neonatal pneumonia
- Severe transient tachypnoea of the newborn
• Persistent pulmonary hypertension of the newborn
• Apnoea of prematurity\(^3,4\)
• 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 (Figure 1.2). The TRY algorithm signs and symptoms are straight forward and easy to act on. Premature babies benefit most from CPAP and are given priority. Babies with severe asphyxia may 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) are unlikely to benefit from bCPAP

2 Assessment

Respiratory distress can cause hypoxia contributing to both morbidity and mortality. Bubble CPAP devices 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. All CPAP devices have an inspiratory tube delivering a mixture of oxygen and air, an expiratory tube to generate positive end expiratory pressure and an interface to connect the device to the baby (Figure 2.1).
Traditional bubble CPAP devices are made up of the following components:

- **Pump**: pumps in air mixed with oxygen from an oxygen source.
- **Inspiratory tube**: connects the blend of air and oxygen 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 (Figure 2.2).

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 and 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 and challenging weight gain in infants.
- Decreased lung inflammation from mucus plugs which has unknown impact on morbidity and 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.16
- High financial cost of adding heated humidified gas.17
- 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.17

In summary, based mostly on expert opinion, it is likely that heated and humidified air is most important for the smallest newborns < 1–1.25 kg although this has never been explicitly studied. There is evidence from Malawi that un-heated 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 and weight gain) were not explicitly studied. Of note, survival of infants > 1.5 kg on un-heated un-humidified air bCPAP in this study were similar to survival of infants > 1.5 kg in Rwanda on heated and humidified bCPAP.12, 18

At this time, based on available literature and experience, there is no definitive evidence as to whether or not the risks of humidification of bCPAP outweigh the benefits generally, but more especially in settings which may be re-processing respiratory circuits.

We recommend that each facility weigh the factors discussed above in addition to supply chain, cost, availability and ability to reliably disinfect respiratory bCPAP respiratory circuits INCLUDING humidification units prior to deciding of which equipment is most appropriate for the facility and level of neonatal care.

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 SpO₂ and safe oxygen delivery

When making this recommendation the following resources were considered:

- 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)19
- Target peripheral oxygen concentrations (SpO₂) for newborns vary depending on age and clinical condition. However, most authorities agree that saturations between 90 - 95% minimises the complications associated with both low and high oxygen levels including death, neurodevelopmental impairment and ROP.20–23
3 Management

Management of bCPAP covers how to use the bCPAP device in a variety of settings, including setting up for a patient, patient preparation and commencement, care whilst on the device and removal of the patient from the device.

**SETTING UP DEVICE FOR A PATIENT**

1. Collect the following *(Figure 3.1)*:
   - bCPAP machine
   - Power cable
   - Inspiratory tubing
   - Expiratory tubing
   - Appropriately sized CPAP prongs
   - Connectors
   - Oxygen tubing
   - Oxygen source

**Figure 3.1** Collect bCPAP supplies.

2. Position the bCPAP device at a secure and suitable location near the patient being considered for CPAP. Plug the power cable into the back of the machine and plug into a socket or extension.

3. Fill the water bottle with clean water to desired initial settings *(Figure 3.2)*. Most patients will start with pressure levels of 6 cm of water.

**Figure 3.2** Fill bottle with clean water to desired settings (6 cm).

4. Connect the inspiratory tubing and the expiratory tubing to the appropriate ports.

5. Connect the CPAP prongs between the inspiratory and expiratory tubing *(Figure 3.3)*.
Figure 3.3 Connect CPAP prongs to tubing.

6 Ensuring the device is turned on, open the oxygen flowmeter. If required using oxygen tubing, connect the oxygen source to the bCPAP device.

7 Test the bubbling of the bCPAP device by occluding the CPAP prongs with gloved fingers. If the water within the bottle bubbles, the bCPAP device is ready for use.

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
   - Orogastric 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 (Figure 3.4).

Figure 3.4 Creating a hat from a stockinette.

6 Wash hands and put on gloves. Following suctioning guidelines, clear the patient’s nose and mouth with a suction catheter or penguin sucker if clinically indicated (Figure 3.5).
7 Insert an OGT. This is usually inserted prior to applying CPAP. It may be necessary to start with CPAP in a very distressed baby.
   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 the placement of the OGT:\n      o Using a syringe to aspirate gastric contents. Test aspirate with litmus paper. The litmus paper’s colour change should reflect an acidic pH (<=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. This test may be unreliable in a premature baby.
      o 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.
      o 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 based on nostril size. bCPAP prongs should snugly fit the patient’s nostrils. If prongs do not fill the nostrils, 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 (Figure 3.6):
   • Appropriately sized bCPAP prongs
   • Hat
   • Interface connectors: e.g., hat clips OR 2 rubber bands and 4 safety pins, or velcro strip, chin strip
   • 2 mL syringe filled with normal saline
   • A small tray to carry the items above
2 Follow handwashing procedures and put on gloves.
3 Ensure the bCPAP device is turned on and connected to an oxygen source. Place hat on patient.
4 Determine initial settings for the patient. Most patients will start with a pressure level of 6 cm water and oxygen concentration (FiO₂) of 50%. Set blended flow. To do this refer to the device blending table. This may show the amount of oxygen and air to set on separate flow metres. Or it may show the oxygen flow and total flow.
5 Connect correctly sized bCPAP prongs to the inspiratory and expiratory tubing. Ensure bubbling by pinching the bCPAP prongs shut.
6 Using the syringe filled with saline, put a drop of saline in each nostril.
7 Gently insert the prongs into the nostrils leaving 1 mm of space between the prongs and the nasal septum to prevent nasal trauma. (Figure 3.7).

Figure 3.6 Collect all items (pictured left; hat clips, pictured right; velcro strips).

8 Secure inspiratory and expiratory tubing to the hat on the patient (Figure 3.7). If hat clips are unavailable, make secure by using rubber bands and safety pins (Figure 3.8):

- 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 (Figure 3.9).
- 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.

Figure 3.7 Leave 1 mm of space between prongs and nasal septum. Secure inspiratory and expiratory tubing using hat clips.
9 Check that the water within the pressure regulating bottle bubbles. If it does not bubble, ensure:
   - That all tubes are connected properly and not kinked
   - That the patient is well positioned and the airway is clear
   - That the prongs snuggly fill the patient’s nostrils

10 Step Monitor the patient 15 minutes after initiating bCPAP treatment and then 3-4 hourly for:
   - Vital signs including respiratory rate, heart rate, oxygen saturation and temperature
   - Work of breathing
   - Nasal blockages
   - Abdominal distension

11 Act in accordance to clinical findings.

### CARING FOR A PATIENT

1 Monitoring the patient should be completed and documented every 3-4 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

2 At every monitoring point:
   - Provide a drop of saline to each nostril (Figure 3.10).
   - Check prongs, tubing and 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 a new hat
   - Check water level: if water level is below decided treatment level, add water.
Figure 3.10 Provide a drop of saline to each nostril.

3 Prior to increasing bCPAP always ensure the bCPAP device 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)

4 Different types of CPAP devices have their own blending tables and validated methods of increasing and decreasing FiO₂ and water pressures. The principles behind these are similar. Users should refer to the relevant manual for their device. Suggested increasing and weaning algorithms are below (Figures 3.11, 3.12).
**Figure 3.11 Increasing CPAP treatment algorithm.**

- **TIME**
  - START
  - 15 – 20 min
  - 15 – 20 min
  - 15 – 20 min

- **OXYGENATION**
  - FiO2 50%
  - Is SpO2 >90% yes
    - Increase FiO2 to 60%
    - Is SpO2 >90% yes
      - Increase FiO2 to 70%
      - Is SpO2 >90% yes
      - Increase FiO2 to 80%
      - Is SpO2 >90% no
        - Increase FiO2 to 90%
        - Increase water level to 7 cm
        - Call for assistance
        - Reassess for complications and alternative diagnosis
    - No
      - Is there substantial lower chest wall indrawing & work of breathing yes
      - Increase water level to 7 cm
      - Call for assistance
      - Reassess for complications and alternative diagnosis

- **WORK OF BREATHING**
  - Water level 6 cm
  - Water level 6 cm
  - Continue current FiO2 and water level
  - Assess work of breathing every hour.
  - If significant work of breathing is present despite SpO2 being 90–95%, increase water level by 1 cm up to a maximum of 8 cm
  - Monitor HR, RR, SpO2 & temperature every hour until stable then 3-4 hourly and at 15 minutes after change of settings. Maintain SpO2 90–95%
  - Ensure airway is patent
  - Instill normal saline drops every 3-4 hours
  - Document on chart

**Water level should never exceed 8 cm**

A senior consultant may increase CPAP as they deem necessary. Depending on the bCPAP device in use, maintain a total flow rate of 6-10 L/min and use an oxygen blending table to determine amount of oxygen to set.
DECREASING & WEANING CPAP TREATMENT

Does the baby meet weaning criteria?

- No
  - Keep on current CPAP settings and treatment

- Yes
  - Decrease CPAP treatment
    - Reduce FiO₂ by 10% every 3-4 hours until FiO₂ is 30%
    - Maintain water level
    - If baby does not meet weaning criteria at any point, maintain at current settings and treatment
    - Maintain FiO₂ of 30%
    - Reduce water level by 1 cm every 3-4 hours until water level is 5 cm
    - If baby does not meet weaning criteria at any point, maintain at current settings and treatment
    - If baby is stable for 3-4 hours with minimal CPAP settings of 30% FiO₂ and water level of 5 cm, stop CPAP
    - Put on 1 L/min oxygen via nasal prongs

- Stop CPAP treatment
  - Disconnect baby from CPAP device
  - Put on 1 L/min oxygen via nasal prongs
  - Assess baby at 15 mins, 1 hourly then 3-4 hourly for 12 hours. If baby meets criteria to restart CPAP at any point, restart CPAP and consult
  - Follow guidelines for weaning off oxygen before removing oxygen

Keep baby warm, implement a feeding plan, observe IPC and involve mother in care

Weaning Criteria
The patient has been clinically stable for 24 hours on current CPAP settings with:
- RR is less than 60 bpm
- SpO₂ 90 – 95%
- No significant signs of increased work of breathing
- No other signs of respiratory distress

Figure 3.12 Decreasing and weaning CPAP treatment algorithm.
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 promptly or adequately between patients, they may pose a significant infection risk.

**CLINICAL INFECTION PREVENTION**

1. Clean hands with soap and water or alcohol before and after caring for a patient using a bCPAP device or handling any materials that will be used on a patient (e.g., an oral gastric tube). **Gloves should be worn throughout the process of initiating the baby on CPAP and disposed of immediately.**

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 and according to hospital policy (Alert 4.1). Tubing should be stored in loose rolls, preventing sharp bends or kinks which will decrease the lifetime of the tubing.

4. Follow universal precautions of handling sharps.

**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 use, infection can be transmitted. Care should be taken particularly for consumables that are marked as single-use but are in practice re-used.

3. Disinfect the outside of the bCPAP device using a swab soaked in alcohol or diluted chlorine. Each flowmeter regulator control should be disinfected after use with a cotton swab or gauze soaked in 70% alcohol.

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

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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.
Preventive maintenance is an important part of improving and maintaining the lifespan and viability of the syringe pump (Alert 6.1).

**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 in the tubing or a loose tube connection. Trouble shoot to identify and manage potential causes of pressure leaks.
- **Power failure**: If the bCPAP device requires power it should ideally always be connected to 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 or battery.

**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 maximum 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.

All bCPAP devices have a users’ manual. These should be accessible online. If not available for download online, contact the manufacturer to request access to a copy.

The device is not turning on:

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

If the silver balls in the flowmeter are not moving:

- 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.

If the total flowmeter does not go up to the maximum level:

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

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 all seals and connections. If a seal is worn out or cracked, contact your maintenance department to replace or troubleshoot further (Figure 7.2). Tighten all loose connections.

All bCPAP devices have a users’ manual. These should be accessible online. If not available for download online, contact the manufacturer to request access to a copy.
8 Assessment Questions

1 What is the maximum water pressure that should be used with neonatal patients?
   **Answer:** 8 cm water

2 When do you monitor a newborn on bCPAP?
   **Answer:** 15 minutes after every bCPAP setting change and at least 3-4 hourly

3 What are the 2 criteria for starting prophylactic bCPAP?
   **Answer:**
   - Weight less than 1500 gm **and/or**
   - Gestational age less than 32 weeks

4 A 30-week baby is on bCPAP FiO\(_2\) 80%. On assessment the O\(_2\) saturations are 88% and there is evidence of severe indrawings. What are your next steps?
   **Answer:**
   - Increase FiO\(_2\) to 90%
   - Increase water level to 7cm
   - Call for help
   - Reassess for complications or alternative diagnosis

5 What are the criteria for decreasing and weaning bCPAP treatment?
   **Answer:**
   - Stable for 24 hours with:
     - Respiratory rate less than 60 bpm
     - SpO\(_2\) between 90 – 95%
     - No significant signs of increased work of breathing
     - No other signs of respiratory distress
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.26,27

Benefits of heated and humidified gas in non-invasive ventilation may include increased adherence and comfort.26 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.28 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 infants29 however, early data from Malawi demonstrated few mucosal injuries when using un-heated un-humidified bCPAP.12

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.16 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.17

There is reason to believe that when supplying ambient air through the upper airway there is in fact, no need for heated humidification.17 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.30 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 >1.5 kg in Rwanda on a heated and humidified bCPAP circuit18 were similar to those reported in Malawi on an un-heated, un-humidified circuit.12

In conclusion, despite recent WHO recommendations that bCPAP units should contain humidification,31 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


**IMAGE CITATIONS**

Clinical Education Module: Bubble CPAP

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In addition, all forms, instructions, checklists, guidelines, and examples are intended as resources to be used and adapted to meet national and local health care settings’ needs and requirements.
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MATERIALS SUMMARY

This series has been designed with the intent of supporting the clinical use and biomedical repair of technologies in newborn care units.

These clinical modules provide educational support for technologies used in newborn care. These materials are intended to strengthen locally developed neonatal and biomedical 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.

These clinical modules were developed through a combination of international standard review, international expert feedback and multinational expert consensus opinion.