NEST-ED

Technical Modules

February 2021

Newborn Essential Solutions and Technologies-Education (NEST-ED) Technical 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 technical guidelines or device-specific manuals.

FACILITATING THE CLINICAL USE AND TECHNICAL REPAIR OF TECHNOLOGIES FOR NEWBORN CARE IN LOW-RESOURCE SETTINGS

DISCLAIMER

Newborn Essential Solutions and Technologies-Education
Technical Modules: Bubble CPAP

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Suggested citation. Liaghati-Mobarhan, S., Molyneux E., Werdenberg J. & Langton J., NEST360. *Newborn Essential Solutions and Technologies-Education – Technical Modules: Respiratory Support - Bubble CPAP.* (February 2021). License: CC BY-SA 4.0.

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

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

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PREFACE

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

Newborn Essential Solutions and Technologies-Education (**NEST-ED**) Technical Modules provide educational support for each of the technologies included in the NEST360º 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 technical guidelines or to replace the use of device-specific user and service manuals or textbooks. They are to be used to facilitate the implementation of comprehensive newborn care, including bubble CPAP, in a resource limited setting.

The NEST-ED Technical Modules were developed through a combination of international standard review, international expert feedback, and multinational NEST360º expert consensus opinion. NEST-ED Modules form the backbone of all lectures, power points, job aids, and other supportive education materials supplied by NEST360º.

THIS IS ONE MODULE IN A SERIES OF NEST-ED CLINICAL & TECHNICAL MODULES AVAILABLE.

To view the full series, visit the NEST360° Resources website.

ABBREVIATIONS

bCPAP	Bubble continuous positive airway pressure
BMET	Biomedical Equipment Technician
dL	Decilitre
ESD	Electrostatic Discharge
FiO_2	Increased Fractional Concentration of Oxygen
Fr	French size
HAI	Hospital acquired infections
HCWs	Healthcare workers
KMC	Kangaroo mother care
LBW	Low birth weight
LCD	Liquid Crystal Display
LED	Light-Emitting Diode
mm Hg	Millimeters of mercury
NEST-ED	Newborn Essential Solutions & Technologies-Education
NEST360°	Newborn Essential Solutions & Technologies
nm	Nanometer
O_2	Oxygen
OGT	Orogastric tube
PCB	Printed Circuit Board
ppm	Parts per million
ROP	Retinopathy of Prematurity
PSA	Pressure Swing Adsorption
PSU	Power Supply Unit
ROP	Retinopathy of Prematurity
SpO_2	Peripheral blood oxygen saturation
UPS	Uninterruptible power supply
WASH	Water, sanitation and hygiene

NOMENCLATURE

Allen keys	Hex keys
bCPAP prongs	bCPAP patient interface
Christmas tree adapter	Barbed oxygen fitting, nipple and nut adapter
Control PCB	Main PCB
Cot	Bassinet, infant crib
Flat head screwdriver	Slot head screwdriver
Flow splitter	Oxygen splitter, flow meter stand
Glucometer	Glucose meter
Hospital Acquired Infection	Iatrogenic infection, nosocomial infection
Multimeter	Digital multimeter, Avometer
Nasal prongs	Oxygen catheter, oxygen cannula, oxygen prongs
Positive Pressure	Positive end expiratory pressure, positive airway pressure
Radiant warmer	Resuscitaire, resuscitation table
Star screwdriver	Torx screwdriver
Suction pump	Suction machine

Introduction

The NEST-ED Technical Modules have been prepared to help technical staff and students understand the basics of when and how to use equipment essential to newborn care. More importantly, the Technical Modules support staff in troubleshooting common issues, as well as prepare staff to repair equipment when it breaks down or malfunctions. 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. Modules should be used alongside device user and service manuals to provide additional context as needed.

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.

The NEST-ED Technical Modules are intended as a flexible resource that hospitals and partners can adapt to their specific needs. The Technical Modules consist of generic content that can be applied to any model within a device category, coupled with model specific device images that can be exchanged for alternative images depending on the devices available at your facility. Individuals who are interested in gaining access to the editable NEST-ED Technical Modules should contact the **NEST Training Materials Coordinator** (Anniina Lockwood, al90@rice.edu) or the **NEST Biomedical Tech Training Director** (Sara Liaghati-Mobarhan, slmobarhan@rice.edu).

CLINICAL PROBLEM

This section provides useful information on the clinical application of a device that would bear relevance to the biomedical team, not only to aid in their troubleshooting, but also for user training.

ASSESSMENT

This section explains how the device works, and what kinds of patients it is useful for. This section also includes comprehensive diagrams of internal and external views of the devices, including consumables that may be used with the device. This section also contains detailed descriptions of key device components (including alarms) and includes a diagram of typical device flow (including components and how they interact with each other, electrical current and fluid movement through the device if relevant).

MANAGEMENT

This section focuses on **clinical** management and provides step by step directions on how to set the device up for a patient, followed by instructions on starting the patient on the device and monitoring a patient whilst on the device. This section also describes how to remove the equipment from the patient when it is no longer needed. Although a biomedical engineer or a technician will not be responsible for providing care, understanding these steps will be useful in training and when assessing the device.

INFECTION PREVENTION

This section lays out the basic infection prevention measures that should always be taken when handling equipment, followed by directions for disinfecting the equipment both during and after use. This section also describes the crucial Infection Prevention and Control steps that are particularly relevant to biomedical engineers and technicians.

COMPLICATIONS

This section explains some of the common but serious clinical complications that relate to and can arise from the use of the equipment (e.g., complications that will be seen or directly apply to the patient). Biomedical engineers' and technicians' understanding of potential complications for the patient is crucial to ensure patient safety. This section also describes common device complications (e.g., complications that will be seen or directly apply to the device).

CARE & MAINTENANCE

This section describes where to place equipment for use, how to safely handle devices and their consumables, whether calibration is recommended, and how to decommission the equipment. Biomedical engineers and technicians are responsible for second-line care and maintenance to ensure the equipment lasts to their potential lifetime; as such, this section also lists the necessary daily, weekly, monthly and annual preventive maintenance steps required to keep the device in good working condition. First-line care and maintenance is the responsibility of the user and is described in the **NEST-ED Clinical Modules**.

TROUBLESHOOTING & REPAIR

This section describes steps that should be taken when a device malfunctions and first-line troubleshooting efforts have failed to address the issue. This section describes tools and spare parts that might be required to prepare for repairs and to troubleshoot failures, and provides a list of components commonly provided with the device to ensure that all components return to the ward post-repair. Finally, this section also explains steps for testing, repairing, and replacing specific parts of the device.

REFERENCES & ALERTS

References & 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 Technical Modules and (2) implementer review of content for incorporation in local trainings.

? ALERT 0.0 Subject

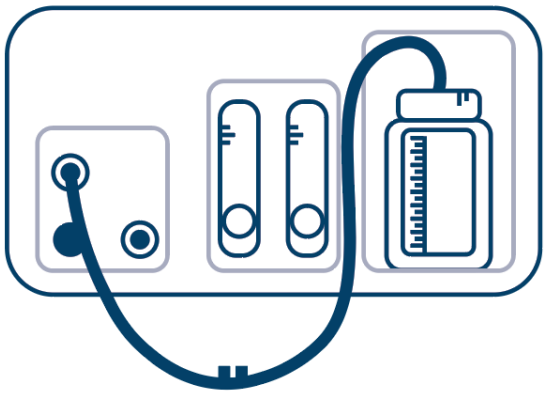
QUERY ALERT BOXES appear where there may be controversy or disagreement. In these cases, alert boxes provide background to the recommendations that are made in the body of the document. Relevant documents are cited and brief explanation of reasoning for current module content provided.

! 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.

Respiratory Support

Bubble CPAP



1 Clinical Problem

Bubble CPAP (bCPAP) devices are used within the newborn care ward to provide positive pressure to increase fractional concentration of oxygen (FiO_2) and decrease work of breathing in newborns with respiratory distress.

Although continuous positive airway pressure devices may be used to treat adult symptoms of respiratory distress (or trouble breathing), bCPAP treatment is used mainly in neonatal or paediatric patients.[1] bCPAP is used to address physiological symptoms of respiratory distress in patients who are able to spontaneously breathe, but has minimal impact on patients with neurological (or, brain-related) damage leading to respiratory distress (e.g., birth asphyxia). **bCPAP should only be used when essential newborn care is in place, equipment is functioning, oxygen is available, staff are adequately trained in bCPAP and close monitoring can be assured.**

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

? Alert 1.1 bCPAP & low flow oxygen context

Scale and delivery of neonatal care is critical. However, data has shown that rapid scale up of neonatal care without sufficient attention to safety has long term negative consequences for neonatal morbidity[2] and is likely a contributor to the epidemic of preventable blindness due to retinopathy of prematurity (ROP) in these settings.[3]

Supplemental oxygen is life-saving. However, when given in doses that are too high, it has also been associated with various complications (ROP,[4] bronchopulmonary dysplasia,[5] periventricular leukomalacia and prolonged ventilation[6]). When using any form of oxygen therapy, it is important to closely monitor blood oxygen saturation (SpO2) 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 SpO2 between 90-95% is reasonable to minimise complications associated with low and high oxygen levels.[7–10]

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

2 Assessment

Infants born prematurely have underdeveloped lungs which are unable to produce sufficient surfactant for effective respiration. Without treatment, the baby becomes exhausted with the work of breathing, and progressive alveolar collapse leads to low blood oxygen levels.

Surfactant is a substance produced by the lungs that reduces surface tension on the alveoli and prevents alveolar collapse. Structurally immature lungs (as in premature or young neonatal patients) have decreased compliance and tend towards collapse. Without adequate surfactant, the alveoli collapse more readily and remain collapsed, even during inhalation, which prevents gas exchange. The baby's work of breathing increases with attempts to reinflate the collapsed alveoli.

bCPAP devices **(2.1)** provide continuous positive pressure generated by bubbling a blend of air and oxygen through a constant depth of water. Tightly fitting nasal prongs or a mask connect the patient to this source of pressure to increase the baseline pressure in the lungs. This decreases work of breathing for the patient and improves oxygenation.

2.1 Typical bubble CPAP devices.

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)** Form factor varies by model, although most models follow a standard pressure circuit design. Normal therapeutic 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 2.1: 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.

Potential benefits of heating and humidification could include increased comfort, decreased upper airway mucosal injury and decreased convective heat losses which may lead to hypothermia (directly related to mortality).Potential drawbacks to heated humidification may include hospital-acquired infection and high financial and human resource cost. Hospital-acquired infection is particularly influential, 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.[11] Adding heated humidified gas may increase the unit cost of the bCPAP unit.[12] High human resource cost may impact both repair and preparation costs of non-invasive ventilation units which may limit not only their use, but availability of this life saving technology within resource-limited settings.[12]

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[13] were similar to survival of infants >1.5kg in Rwanda on heated and humidified bCPAP.[14]

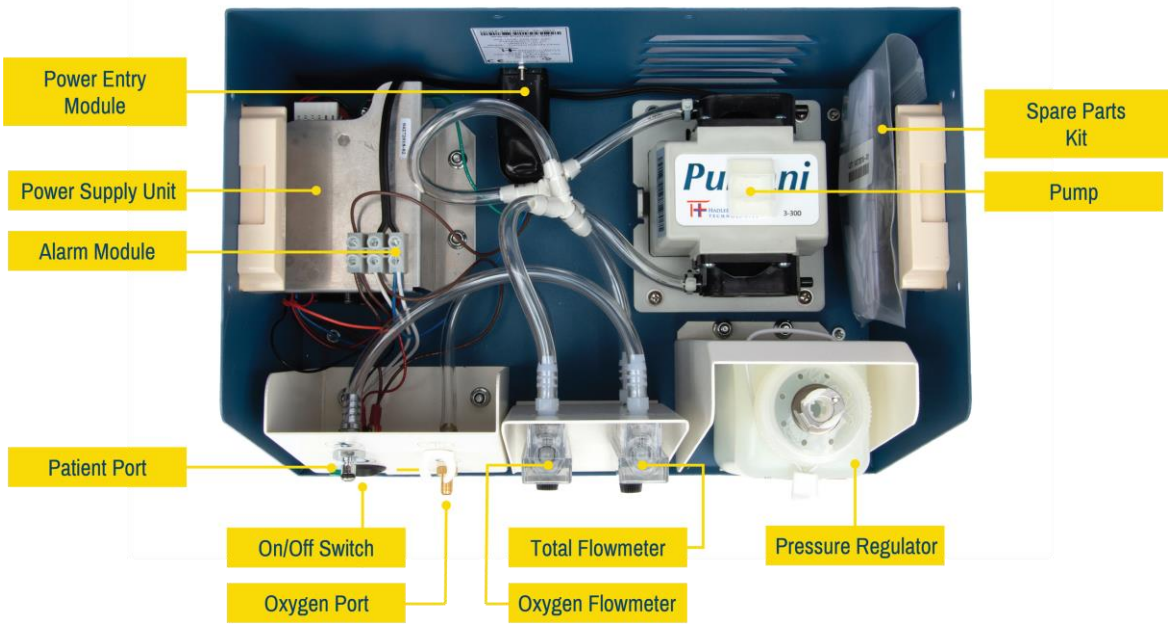
At this time, based on expert opinion and available literature, it does not appear that the benefits of humidification outweigh the potential risks/drawbacks for infants >1kg.

HOW IT WORKS

A bCPAP device uses an internal **pump** to bring in and compress ambient air through an **intake filte**r. Simultaneously, an oxygen source is connected (or integrated into the device). Oxygen from the oxygen source is blended with the ambient air to provide a user-specified concentration of inspired oxygen (FiO_2) which is fed through the **inspiratory tubing** to the patient. In traditional CPAP circuits, gentle pressure is then created by placing the distal end of the **expiratory tubing** in water, placing the **patient interface** (tightly fitting nasal prongs or a mask) in the centre of the circuit between the blended flow and the **pressure regulator**. Pressure levels vary depending on the length of tubing immersed. Basic or improvised bCPAP models may not rely on electricity or a pump to generate flow, but use the flow created by the oxygen source.

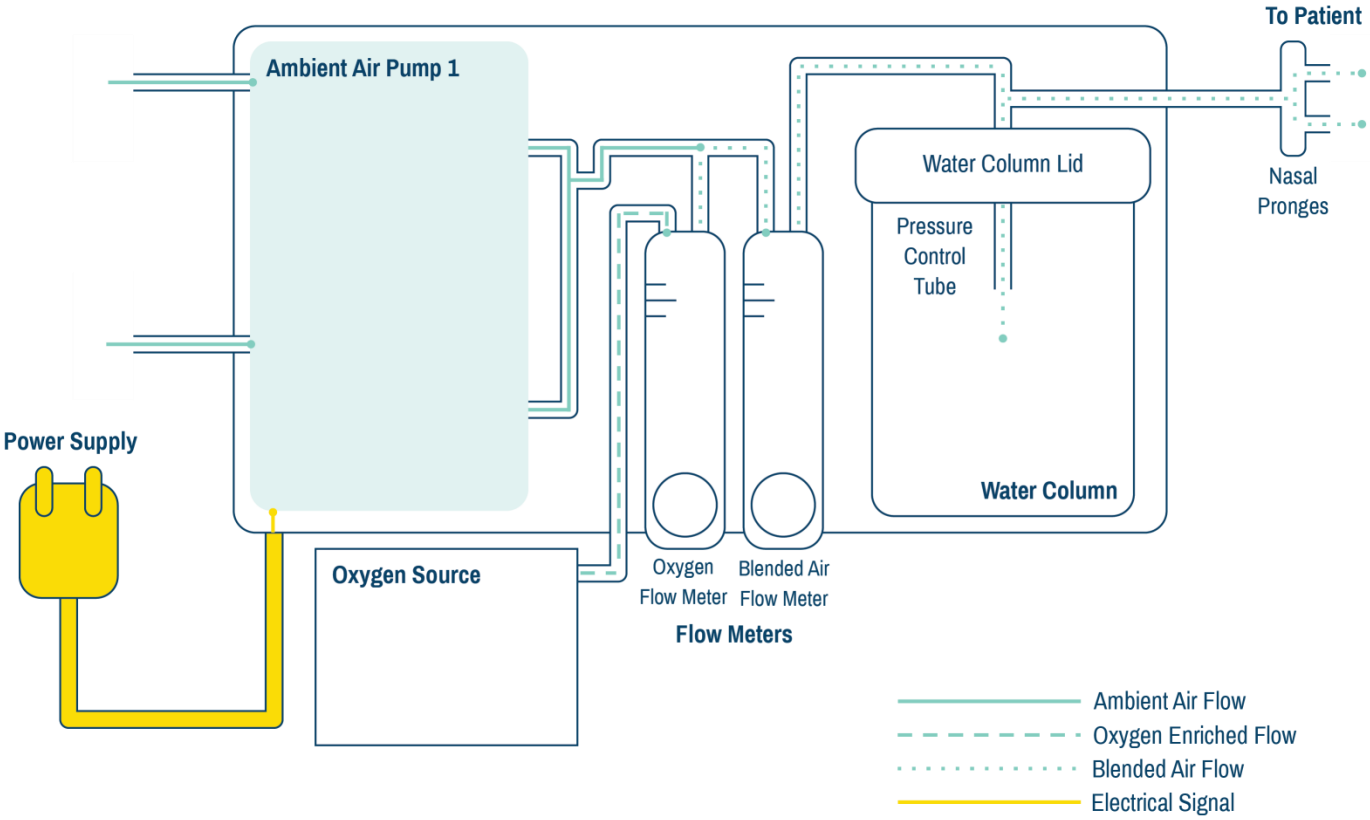
Standard external and internal device components are annotated below in **Figures 2.2** and **2.3**. Components should be similar regardless of model. However, specific locations, visual setup and component type vary by brand and device model. Refer to service and user manuals to identify components if model in use is different from the displayed version.

2.2 External components of a bCPAP device.



2.3 Internal components of a bCPAP device.

TYPICAL DEVICE FLOW



MAIN COMPONENTS

The following device components should be similar regardless of model. However, specific locations, visual setup and component type may vary by brand and device model. Refer to model service and user manuals if different from the displayed model for more device-specific information.

Power entry module

Located at the back of the machine and houses the entry point for the power cable from the mains power outlet.

Power supply unit (PSU)

Located internally within the unit, the PSU converts AC mains power (110 or 220 V) to lower voltage regulated DC power. The basic components within a power supply are a transformer, rectifier, voltage regulator and filters. The bCPAP power supply unit powers the internal pump and may connect to a Power Failure Alarm to activate in the event of a power outage.

Pump

Located internally within the unit, the pump brings in ambient air to blend with oxygen from an external or integrated oxygen source. The pump type depends on the model of bCPAP in use but is commonly an inductive diaphragm pump with two diaphragms connected to each other by an intermediate shaft with magnets at its opposite ends. Two inductive coils are wrapped around the intermediate shaft and are alternately energised to produce an induced magnetic field.

The action of the inductors pulls or releases the shaft to pull or push the diaphragms. On each induction cycle, one diaphragm will be pulled while the other will be pushed in reciprocating fashion. As one diaphragm admits air, the other diaphragm expels air from the system.

Pump intake filter

Filters gross particles from ambient air before the air is processed through the pump system.

Pressure regulator

A water reservoir placed at the end of the expiratory circuit that provides pressure using water level. Pressure levels vary depending on the length of tubing immersed.

Oxygen source

Oxygen sources may be external to the bCPAP or internally integrated. Any oxygen sources may be used with independent bCPAPs (e.g., oxygen concentrators, cylinders or piped oxygen) although care should be taken to ensure that the pressure of the oxygen source is within manufacturer specifications.

Oxygen flowmeter

Regulates the continuous volume flow rate of oxygen from an external or integrated source.

Total flowmeter

Regulates the continuous volume flow rate of blended air. The total flowmeter allows the user to regulate the delivered FiO_2.

Inspiratory tubing

In a standard bCPAP circuit, the inspiratory tubing connects from the device to the patient, carrying flow from the device to the patient via tubing and tightly sealed nasal prongs. Gaskets or sealing rings are typically placed on the patient port of the device or within the patient circuit tubing to ensure a tight seal, which is essential for effective treatment.

Expiratory tubing

In a classic bCPAP circuit, the expiratory tubing connects from the patient to the device at the pressure regulator.

Patient interface

In a classic bCPAP circuit, the patient interface is typically wide, soft plastic nasal prongs or a tightly fitting mask.

3 Management

Management covers how to use the bCPAP device, including set up and preparing for a patient, patient commencement, care whilst on the device and removal of the patient from the device. These instructions are helpful for a biomedical engineer or technician both in user training and in assessing the appropriate functionality of the device.

SETTING UP FOR A PATIENT

1 Collect: (**3.1)**

- bCPAP machine
- Power cable
- Inspiratory & expiratory tubing
- CPAP prongs

- Connectors
- Oxygen tubing
- Oxygen source

3.1 (a) Collect bCPAP supplies.

3.1 (b) Oxygen sources that can be considered for use with a bCPAP.

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 tap water to desired initial settings. **(3.4)** Most patients will start with pressure levels of 6 cm of water. Re-screw the bottle lid to the bottle and place back in bottle holder.

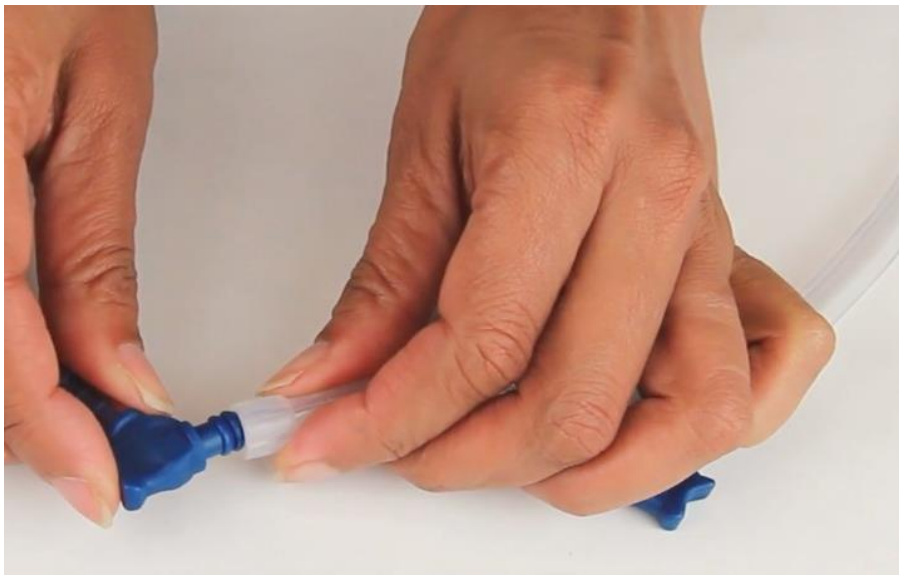
4 Connect the inspiratory tubing to the Patient Port (indicated by the baby icon) **(3.5)** and the expiratory tubing to the Bottle Port. **(3.6)**

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)**



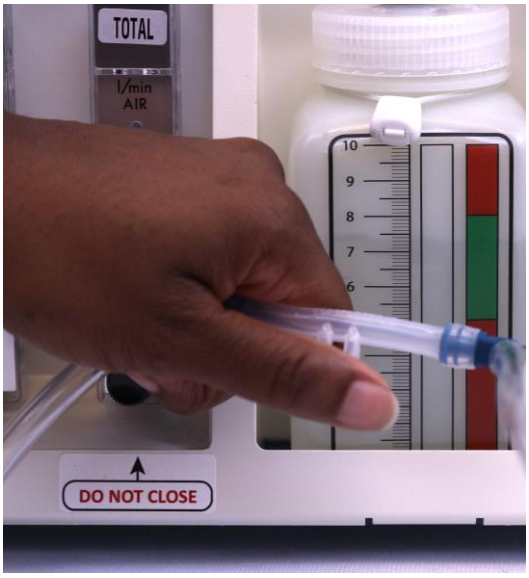
3.7 Connect bCPAP prongs between inspiratory and expiratory tubing.

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.

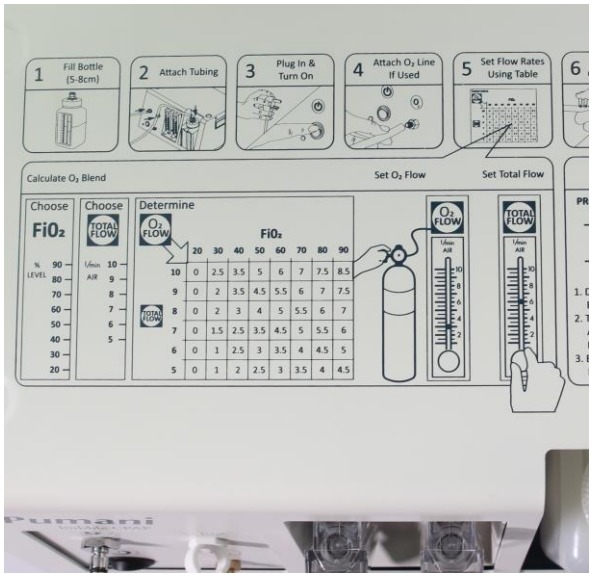
PREPARING A PATIENT

1. Clinical or nursing staff should place the patient on oxygen and keep the baby warm whilst preparing for bCPAP. Staff should suction if clinically indicated and insert an orogastric feeding tube if clinically applicable to prevent obstruction of the pressure delivery.
2. Staff should 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. Staff should collect: **(3.11)**
    - Appropriately sized bCPAP prongs
    - Hat
    - 2-mL syringe filled with normal saline
    - Hat clips OR
    - 2 rubber bands & 4 safety pins
2. Clinical and nursing staff should turn on the bCPAP device and connect oxygen source, place hat on patient and determine and set initial settings for pressure, total flow and oxygen concentration (FiO2) for the patient. Staff can determine oxygen flow using FiO_2 and total flow as shown on the oxygen blending table printed on top of device. **(3.12)**

3.11 Collection of materials.



3.12 Set initial total flow and FiO_2 settings & determine needed oxygen flow.

3 Connect correctly sized bCPAP prongs to the inspiratory and expiratory tubing. Retest the bubbling by pinching the bCPAP prongs shut.

4 If the water within the pressure regulating bottle bubbles, staff should place a drop of saline within each nostril and gently insert the prongs into the nostrils until the line on the bCPAP prongs is **just** visible, leaving 1 mm of space between the prongs and the nasal septum to protect the nasal septum. **(3.13)**

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

3.14 Secure inspiratory and expiratory tubing using clips.

5 Inspiratory and expiratory tubing should be secured to the patient to prevent displacement of the patient circuit. **(3.14)** If hat clips are provided with the bCPAP device, they may be used for this purpose. If they are unavailable, clinical staff may also secure using rubber bands & safety pins:

- Insert two safety pins into the brim of the hat on each side of the head. 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. **(3.15)** 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. **(3.16)**

Healthcare staff should be encouraged to recheck the prongs are securely placed within the nose and inserted to the correct distance. Sometimes a small folded cloth placed under the baby's shoulders may help keep the neck in a neutral position and improve air flow.

3.15 Pin placement.

3.16 Patient circuit secured using elastics.

CARING FOR A PATIENT

1. Clinical or nursing staff should monitor vital signs (including respiratory rate, heart rate, oxygen saturation, and temperature), work of breathing, nasal blockages, abdominal distension and nasal septum trauma or breakdown 4 hourly or more frequently. Staff should also provide nasal saline drops at each monitoring point. Increases in treatment should be made progressively and the patient should be reassessed 15 minutes after any setting change. Pressures should be kept within 5 to 8 cm H_2O unless otherwise advised by a consultant.
2. At every monitoring point, staff should also confirm that prongs, tubing, hat and water are appropriate for effective care and that 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, see complications section)

If the bCPAP device is not bubbling, troubleshoot the device and patient circuit.

REMOVING A PATIENT

The patient should be weaned gradually from bCPAP to room air.

4 Infection Prevention

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

CLINICAL 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.

DISINFECTION AFTER USE

1. Turn off bCPAP and dispose of water within pressure regulating water bottle.
2. Discard 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 marked as single-use but practically reused.
3. Clean bCPAP device housing using a swab soaked in alcohol. Total and oxygen flowmeter regulator controls should be disinfected after each use using a cotton swab or gauze soaked in 70% alcohol.

BMET INFECTION PREVENTION

1. Any piece of equipment used in providing patient care must be handled carefully, as it may be contaminated and have the potential to spread infection.
2. Clean and disinfect bCPAP housing and components whilst wearing PPE as appropriate (e.g., rubber gloves, apron, face protection, etc.) **before any repairs or maintenance are made.**

3 Avoid any contact between used piece of equipment and skin, mucosa or clothing.

4 Post-maintenance, decontaminate all tools and surfaces used with 70% alcohol or according to manufacturer guidelines. Do not use equipment until it has fully dried following decontamination.

Alert 4.1 Disinfecting Equipment

Disinfection of equipment should always comply with manufacturer guidelines. WHO recommends 0.5% dilution of chlorine (0.5% or > 100ppm available sodium hypochlorite) as the standard disinfectant for materials and surfaces contaminated by blood or body fluids.[15] For metal and rubber surfaces which may be corroded by chlorine, 70% alcohol is also commonly utilised for low level disinfection.

Other appropriate low-level disinfectants include quaternary ammonium, improved hydrogen peroxide and Iodophor germicidal detergent.[16] Phenolic germicidal detergent is also identified 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.[17]

See dedicated NEST360° module on Infection Prevention and Control for further details on risks, benefits and utilisation of chemical disinfectants. For comprehensive guidance on infection prevention and control we recommend utilising Reference Manual for Health Care Facilities with Limited Resources Infection Prevention and Control (Caston-Gaa & Ruparelia, 2018).

5 Complications

Equipment in newborn care units are highly specialised. Without proper knowledge and skills, this equipment can be potentially dangerous for the infants, families and care providers.

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).
- **Pneumothorax**: pneumothorax is air outside the lung but inside the chest cavity. Delivery of bCPAP may occasionally cause a pneumothorax which presents as sudden deterioration and increased respiratory distress.

DEVICE COMPLICATIONS

- **Pressure leakages:** if the water in the bottle is not bubbling, it is likely that the patient is not getting therapeutic pressures. Clinical and nursing staff should assess the patient for

common clinical issues that may cause this (e.g., the patient's mouth being open, non-CPAP-related tubing affecting the seal on the nostrils). Technical staff should assess the device for tubing kinks or leakage.

- **Power failure:** bCPAP should ideally always use outlets that have a source of backup 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

Biomedical engineers and technicians are responsible for second-line care and maintenance to ensure equipment lasts to their potential lifetime.

POWER SOURCE

bCPAP devices are usually powered via mains power. Some units may have an optional charging battery that can be used in the event of a blackout. In the event of a power failure, the patient should be immediately removed from the device as prongs in the nose without flow could lead to respiratory failure. Basic or improvised bCPAP models may not rely on electricity to generate flow, but use the flow created by the oxygen source.

WARD LOCATION

The bCPAP 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).

DEVICE CALIBRATION

Manufacturers do not typically recommend calibration for any bCPAP components.

DECOMMISSIONING

Assuming appropriate use and consistent maintenance, a bCPAP device may last up to 3 years or more. The internal pump assembly is intended to last the lifetime of the device and should not require replacement. Should the pump break down, the device should be considered for decommissioning and replacement. Internal tubing, flowmeters and housing may be considered for repurposing for other devices although care should be taken to ensure that the specifications of the parts (e.g., the internal diameter and length of the tubing, the capacity of the flowmeters) align with the device needing repair.

PREVENTIVE MAINTENANCE

After Each Use

- [ ] Turn off and unplug the bCPAP device. Use gauze and 70% alcohol or diluted chlorine to thoroughly wipe the Total and Oxygen flowmeter regulator controls. Between patients, disinfect the housing, patient circuit tubing and pressure regulating bottle.

  See Bubble CPAP: Disinfection After Use and Alert 4.1 for more information.

- [ ] Visually inspect bCPAP device components.

Weekly

- [ ] Turn on the bCPAP device to a total flow of 10 L/min (or max total flow, if gradated higher on the Total Flowmeter) and allow to run while connected to an oxygen source at 2 L/min for at least 15 minutes to clear the bCPAP device of any ambient humidity-related buildup.
- [ ] Document preventive maintenance actions taken.

Monthly

- [ ] Perform **Weekly** preventive maintenance steps.
- [ ] While the bCPAP device is plugged in and turned on:
  - **Test the Total Flow capacity:** verify that the Total Flowmeter reaches 10 L/min (or max total flow, if gradated higher on the Total Flowmeter) when not connected to an oxygen source.
  - **Test the bubbling functionality:** fill the pressure regulating bottle to 6 cm of water. Connect the patient circuit tubing and prongs. Occlude the prongs or kink the tubing to block flow. The pressure regulating bottle should bubble.
  - **Test the Power Failure alarm:** turn off the power at the wall socket. An alarm should sound (if model-applicable).
- [ ] Document preventive maintenance actions taken.

Quarterly

- [ ] Perform **Monthly** preventive maintenance steps.
- [ ] Measure grounding integrity and earth and casing leakage current.
- [ ] Document preventive maintenance actions taken.

Annually

- [ ] Perform **Quarterly** preventive maintenance steps.
- [ ] Confirm supply of spare pump filters, regulator bottles, patient circuits, fuses and power cables are adequate to support estimated replacement for next year.
- [ ] Document preventive maintenance actions taken.

7 Troubleshooting & Repair

Biomedical engineers & technicians are responsible for providing rapid maintenance, troubleshooting & repair support for users.

PREPARE FOR REPAIR

ACCESSIBLE TOOLS	SPARE PARTS	DEVICE CHECKLIST
Digital multimeter Phillips, star & flat head screw drivers Needle nose pliers Soapy water Wire strippers	Power supply unit Power cable Pump filter Flowmeter assembly Sealing O-rings or gaskets Crimp or zip ties	☐ bCPAP device ☐ Power cable (if detachable) ☐ Pressure regulating bottle ☐ Patient circuit tubing (inspiratory & expiratory)

TROUBLESHOOTING FAILURES

The bCPAP does not turn on.

Probable Cause: Faulty power supply

Components to Check:
Power cable continuity
Power switch physical integrity & continuity
Power entry module fuse(s) physical integrity & continuity
Power supply unit continuity & voltage

The bCPAP turns on, but the Total Flow does not reach its maximum when not connected to an oxygen source.

Probable Cause: Internal leak or obstructed pump filter

Components to Check:
Internal tubing seal & placement
Outlet port sealing O-ring physical integrity
Pump filter physical integrity
Pump physical integrity

The bCPAP turns on, but air does not flow from the outlet or patient port.

Probable Cause: Obstructed outlet port, flowmeter or internal leak

Components to Check:
Outlet port physical integrity
Internal tubing seal & placement
Flowmeter physical integrity

The bCPAP turns on, but the Oxygen or Total Flowmeter does not rise.

Probable Cause: Obstructed flowmeter or internal leak

Components to Check:
Flowmeter physical integrity
Internal tubing seal & placement

The bCPAP turns on, but the water in the pressure regulating bottle is not bubbling when connected to a patient.

Probable Cause: Internal or patient circuit leak

Components to Check:
Internal tubing seal & placement
Outlet port sealing O-ring physical integrity
Patient circuit attachment

REPAIR & REPLACE

Where technically possible and not likely to obstruct clinical care, repairs may be made within the newborn care ward. Use discretion to determine if this is appropriate or if the device should be removed to the biomedical workshop for more testing or repair.

Alert 7.1

All testing, repair and replacement steps should be conducted with the power to the device switched off and the power cable removed from mains power, unless otherwise stated.

Testing & replacing the power supply fuses

Fuses may be located both on the bCPAP housing and on the power supply cable. Fuse integrity may be visually assessed or evaluated by testing the continuity across the fuse. Refer to manufacturer specifications for replacement fuses to ensure that the device remains electrically sound in standard operation.

Testing & replacing the power switch

Power switches should be tested in both the off and on positions to confirm functionality. In the **On** position, the switch terminals should be continuous. In the **Off** position, the switch terminals should show a high resistance, or **OL** in most multimeters.

If the switch shows continuity or discontinuity inappropriately, assess the switch for visible physical or electrical damage. If the switch is visibly damaged or dislodged, assess whether the part can be

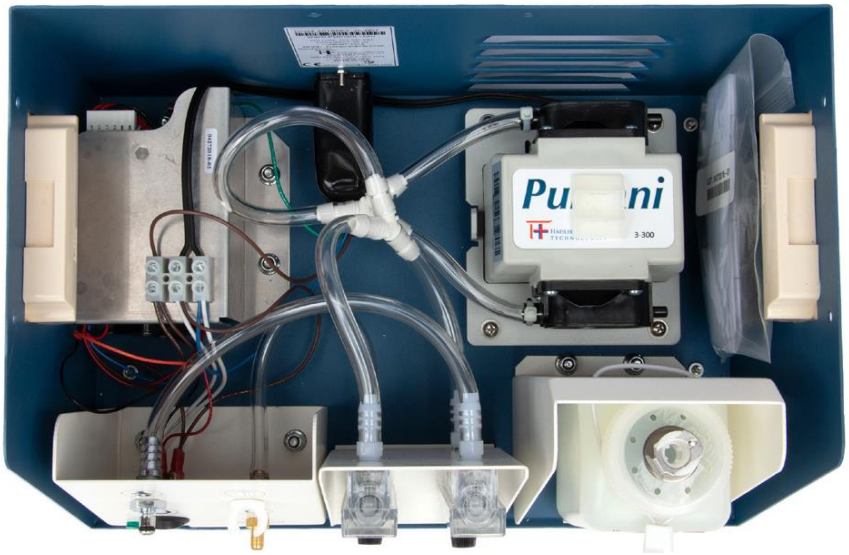
repaired with glue or solder. If it cannot be easily repaired, replace the switch. Refer to the manufacturer specifications for replacement switches to ensure that the device remains electrically sound in standard operation.

Testing & replacing the power supply unit or module

Testing the power supply unit cannot be completed appropriately without checking the alternating voltage at the power supply unit. **This should be completed with caution**, as the power to the device must be switched on to accurately measure the voltage delivered. If the power supply unit or module is damaged, contact the manufacturer to request a replacement part.

Testing & repairing internal leakages

Internal leakages or displaced tubing may contribute to both low Total Flow and delivered pressure. Internal tubing can be assessed for leaks by running soapy water or foam along the suspected tubing, pipes and fittings during operation and checking for bubbles or movement of the liquid. If tubing is displaced, consult the service manual or a functioning device for tubing attachments. **(7.1, 7.2)** Crimp tubing in place with metal crimps or secure with zip ties.



7.1 Correct internal tubing placement.

7.2 Displaced internal tubing.

Testing & repairing the patient or outlet port

Over time, outlet ports may accumulate deposits or debris that block oxygen or pressure flow from the bCPAP. **(7.3)** Ports should be visually inspected using a penlight and may be cleaned using ear swabs or forceps wrapped in gauze soaked in 70% alcohol.

Gaskets or sealing rings are typically placed on the patient port of the device to ensure a tight seal, which is essential for effective treatment. These gaskets may break down with regular cleaning over time. **(7.4)** As the patient port sealing ring deteriorates, the seal on the patient port becomes less secure and affects pressure delivery to the patient. The patient port sealing ring should be replaced as soon as deterioration is observed.

7.3 Patient port.

7.4 Deteriorating patient port seal.

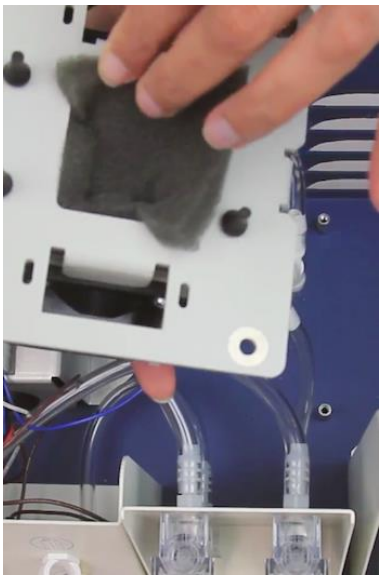
Testing & replacing the pump and pump filter

As the pump intake filter becomes clogged with dust or other debris, intake airflow to the pump becomes constricted and decreases the capacity of the Total Flowmeter. The pump filter should be assessed and cleaned or replaced as needed when the Total Flowmeter is unable to reach its full capacity.

If the filter is clean or has been replaced recently and the Total Flowmeter is still unable to reach its full capacity, the pump should be replaced. **(7.5 – 7.7)** Contact the manufacturer to request a replacement part.

7.5 Unscrew the pump housing.

7.6 Turn over the pump to assess the pump filter. If visibly dirty, replace.



7.7 Push in the replacement pump filter until it fits flush to the housing.

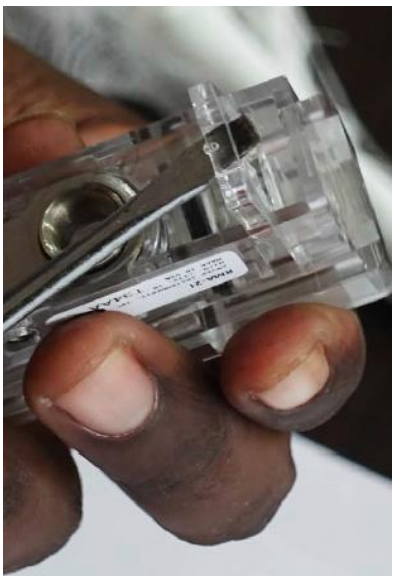
Testing, cleaning & replacing flowmeters

The flowmeter may be damaged through user error or through lack of use and preventive maintenance over time. User error is design dependent; if the flowmeter is not designed to prevent the flowmeter bead from falling into the regulating knob channel, the flowmeter bead can be

damaged or crushed as the flowmeter is closed. In most cases, the flowmeter bead is not a spare part and this damage will require the entire flowmeter assembly to be replaced.

The flowmeter may also develop debris or deposits that affect the movement of the flowmeter bead within the flowmeter channel. **(7.8)** This can be repaired by taking apart and cleaning the flowmeter. When cleaning the flowmeter, use caution during removal of all components as they are small and easily misplaced. **(7.9 – 7.14)**

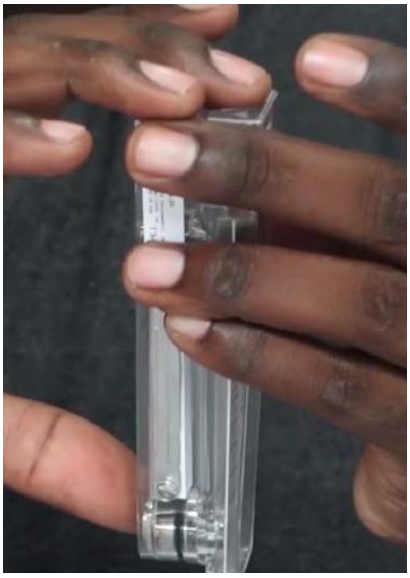
7.8 Debris development in the base of the flowmeter channel



7.9 Slide out the locking plate.

7.10 Remove sealing bolt.

7.11 Carefully remove the ball from the flowmeter chamber.



7.12 Pour rubbing alcohol, or water into the flowmeter barrel. Shake gently to remove debris.

7.13 Prepare a cleaning rod by wrapping a wire with gauze.

7.14 Insert the cleaning rod in the flowmeter barrel and clean.

Testing the patient circuit attachment

bCPAP therapy relies on a tight seal to produce effective pressure in the lungs. Nasal prongs should fully fill the nostrils and the patient's mouth should not be open. If the prongs are well-fitted in the nostrils, nursing staff can troubleshoot the circuit by removing them and occluding the prongs by pinching them shut.

? Alert 7.2 Repurposing Parts

In some cases, parts on the unit may be replaced with a repurposed or recycled part from another piece of equipment being used for parts. **Repurposed parts should be considered with caution and guidance from the manufacturer to ensure specifications of the repurposed part is compatible with the equipment.** This includes spare parts and accessories that may not be compatible with multiple systems.

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