Queensland Clinical Guidelines

Translating evidence into best clinical practice

Clinical Learning Resource

Neonatal CPAP workshop

Queensland Government

Document title:	Neonatal CPAP clinical learning resource
Publication date:	July 2020
Document number:	O20.3-1-V1-R25
Amendment date:	New document
Replaces document:	New document
Author:	Queensland Clinical Guidelines
Audience:	Health professionals in Queensland public and private maternity and neonatal services
Review date:	July 2025
Endorsed by:	Queensland Neonatal Services Advisory Group
Contact:	Email: Guidelines@health.qld.gov.au URL: www.health.qld.gov.au/qcg

Cultural acknowledgement

We acknowledge the Traditional Custodians of the land on which we work and pay our respect to the Aboriginal and Torres Strait Islander elders past, present and emerging.

Disclaimer

This guideline is intended as a guide and provided for information purposes only. The information has been prepared using a multidisciplinary approach with reference to the best information and evidence available at the time of preparation. No assurance is given that the information is entirely complete, current, or accurate in every respect.

The guideline is not a substitute for clinical judgement, knowledge and expertise, or medical advice. Variation from the guideline, taking into account individual circumstances, may be appropriate.

This guideline does not address all elements of standard practice and accepts that individual clinicians are responsible for:

- Providing care within the context of locally available resources, expertise, and scope of practice
- Supporting consumer rights and informed decision making, including the right to decline intervention or ongoing management
- Advising consumers of their choices in an environment that is culturally appropriate and which enables comfortable and confidential discussion. This includes the use of interpreter services where necessary
- Ensuring informed consent is obtained prior to delivering care
- Meeting all legislative requirements and professional standards
- Applying standard precautions, and additional precautions as necessary, when delivering care
- Documenting all care in accordance with mandatory and local requirements

Queensland Health disclaims, to the maximum extent permitted by law, all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages and costs incurred for any reason associated with the use of this guideline, including the materials within or referred to throughout this document being in any way inaccurate, out of context, incomplete or unavailable.

Recommended citation: Queensland Clinical Guidelines. CPAP Clinical Learning Resource. Guideline No. O20.3-1-V1-R25. Queensland Health. 2020. Available from: http://www.health.qld.gov.au/qcg

Queensland Clinical Guidelines and Queensland Health does not imply endorsement or recommendation for the products named in this document. They are used for illustrative and educational purposes only.

Table of Contents

List of Figures

List of Readings

List of Activities

Abbreviations

CPAP	Continuous positive airway pressure
ELBW	Extremely low birth weight
ETT	Endotracheal tube
FiO_2	Fraction of inspired oxygen
FRC	Functional residual capacity
HC	Head circumference
HHFNC	Humidified high flow nasal cannula
HMD	Hyaline membrane disease
ICC	Intercostal catheter
MAP	Mean airway pressure
MAS	Meconium aspiration syndrome
NEC	Necrotising enterocolitis
NIPPV	Non-invasive positive pressure ventilation
NPT	Nasopharyngeal tube
PaO_2	Partial pressure of arterial oxygen
PEEP	Positive end expiratory pressure
PIE	Pulmonary interstitial emphysema
PPHN	Persistent pulmonary hypertension of the newborn
QCG	Queensland Clinical Guidelines
RDS	Respiratory distress syndrome
SpO_2	Peripheral capillary oxygen saturation
SVB	Spontaneous vaginal birth
TLC	Total lung capacity
TTN	Transient tachypnoea of the newborn
TV	Tidal volume
VC	Vital capacity
VLBW	Very low birth weight

Definitions

Anatomical dead space	The volume of air that does not penetrate into gas exchange regions of the lungs.
Absolute humidity	The amount of water vapour per litre of gas volume. Measured in mg/L.
Apgar	A score given to a newborn baby as a method of evaluating condition at birth and adaptation to extra-uterine life.
Atelectasis	Alveolar collapse resulting in absent gas exchange.
Broncho-pulmonary dysplasia (BPD)	Chronic lung disease occurs in preterm babies due to the disruption of lung development and injury. Usually defined as requiring oxygen supplementation at either 28 postnatal days or 36 weeks postmenstrual age.
Chest wall compliance	A measure of the flexibility of the chest wall and rib cage to stretch and expand. Reduced in a newborn baby compared to the adult chest making it suspectable to alterations in lung function, and resulting in chest recession.
Chest wall recession	The highly compliant rib cage is drawn in during inspiration by the increased negative intrathoracic pressures required to expand poorly compliant lungs. May be sternal, suprasternal, intercostal and/or subcostal.
Continuous positive airway pressure (CPAP)	Distending pressure applied to the airways to maintain expansion of the alveoli by providing a constant pressure to the lungs.
Corticosteroids	Steroids administered antenatally to reduce neonatal mortality and morbidity including respiratory distress syndrome and intraventricular haemorrhage. They enhance maturation of the lungs, and improve surfactant production and lung function.
Extremely low birth weight (ELBW)	Newborn baby weighing less than 1000 g at birth.
Functional (physiologic) dead space	The portion of the air that reaches gas exchange regions of the lung but does not receive enough blood flow for gas exchange to occur.
Functional residual capacity (FRC)	The volume of gas that remains in the lungs after a normal expiration (30 ml/kg in newborn term infants without lung disease).
High frequency oscillatory ventilation	Mechanical ventilation that uses small tidal volumes and rapid rates for babies with severe respiratory failure.
Hyaline membrane disease (HMD)	Respiratory distress syndrome in a newborn baby that is most common in preterm infants due to structural and functional lung immaturity. More commonly called respiratory distress syndrome.
Intercostal catheter (ICC)	A catheter inserted into the intercostal space to drain air or liquid.
Mechanical dead space	The first gas inhaled at the beginning of each respiratory cycle. As dead space volume increases less fresh gas can move into the lungs and excessive dead space may lead to increased retention of carbon dioxide.
Nasal columella	The area of tissue between the nostrils anterior to the nasal septum.
Necrotising enterocolitis (NEC)	An inflammatory disorder of the bowel which may lead to death of a portion of the colon, particularly seen in preterm infants.
Needle thoracentesis	Closed chest needle aspiration to remove air or fluid from the pleural space causing a tension pneumothorax.
Oxygen saturation targets (SpO_2)	Targets after 10 minutes of age– • Term baby: 92–98% • Preterm baby: 90–95%
Physiologic dead space	The volume of gas within either the alveoli or pulmonary conducting airways that cannot engage in gas exchange.
Positive end expiratory pressure (PEEP)	The pressure in the lungs at the end of mechanical or spontaneous ventilation.
Pierre-Robin sequence	A rare genetic disease with orofacial abnormalities–micrognathia (small jaw), glossoptosis (downward displacement or retraction of tongue) and cleft palate resulting in airway obstruction.

Definitions (continued)

Pneumo-mediastinum	Air in the mediastinal space.
Pneumo-pericardium	Air surrounding the pericardium that may cause cardiac tamponade.
Pneumothorax	Air in the pleural space caused by extra pleural pressure exceeding intrapleural pressure. It may be asymptomatic and may occur spontaneously.
Pulmonary compliance	Refers to the elasticity of the lung. It also refers to the relationship between a given change in volume and the pressure required to produce that change.
Pulmonary conducting airways	The airway structures that connect the gas exchange units to the outside air and include the nasal passages, pharynx, larynx, trachea, bronchi and bronchioles.
Pulmonary interstitial emphysema (PIE)	Air trapped in the perivascular tissues resulting in decreased pulmonary compliance and overdistention of the lungs.
Relative humidity	Measured as a percentage this is the actual water vapour in a gas relative to its capacity to hold water vapour.
Respiratory distress syndrome (RDS)	Respiratory disease in the newborn baby presenting with increased work of breathing, cyanosis or hypoxia, diminished breath sounds and ground glass on x-ray.
Surface tension	A force at the interface between air and liquid molecules in the alveoli, that has an impact on the ability of the lungs to maintain FRC. It is primarily governed by the presence or absence of surfactant.
Surfactant	Surfactant is a mixture of at least six phospholipids and four apoproteins produced by Type II pneumocytes. It provides a coating in the alveoli to allow for gas exchange. Surfactant deficiency is the underlying cause of RDS in preterm infants.
Tidal volume (TV)	The volume of air that moves into or out of the lungs with each breath (6 ml/kg in well baby).
Total lung capacity (TLC)	The volume of air contained in the lung after a maximal inspiration (63 ml/kg in well baby).
T-piece	Gas driven (air and oxygen) resuscitator designed to provide consistent peak inspiratory pressure and positive end expiratory pressure.
Transillumination	Illumination of the chest from a fibre optic light to identify air in the pleural space.
Treacher Collins Syndrome	A genetic disorder with deformities of the ear, eyes, cheek bones and jaw, and often cleft palate potentially affecting the airway and causing respiratory problems.
Very low birth weight (VLBW)	Newborn baby weighing less than 1500 g at birth.
Vital capacity (VC)	The volume of air maximally inspired and expired (40 ml/kg in well baby).
Work of breathing	Tachypnoea, chest recession (sternal, intercostal, subcostal), nasal flaring and expiratory grunt.

Overview

This clinical learning resource (CLR) will assist nurses and midwives with the care and management of the newborn baby in respiratory distress who requires continuous positive airway pressure (CPAP).

Objectives

On successful completion of the CLR, the participant will:

- Identify newborn babies at risk of developing respiratory distress
- Demonstrate an understanding of respiratory distress in newborn babies including pulmonary physiology
- Identify the signs and symptoms of respiratory distress
- Manage the care of the newborn baby in respiratory distress
- Demonstrate understanding of the physiology of CPAP
- Demonstrate knowledge of the indications for initiating CPAP to newborn babies with respiratory distress following Queensland Clinical Guidelines: *Respiratory distress and CPAP* guideline
- Initiate therapy and provide clinical management of the newborn baby requiring CPAP
- Have sound knowledge of the complexities of nursing management of newborn babies receiving CPAP including complications
- Demonstrate knowledge of associated policies, procedures and guidelines

How to use the CLR

Complete the :

- Readings and related policies, procedures and guidelines
- Written activities and discuss your answers with a resource person
- Reflection activities as required
- Clinical skills assessment [refer to Appendix A Clinical skills assessment

Resources required to complete the package

The following resources will assist with completion of this CLR:

- Current Queensland Clinical Guidelines: *Respiratory distress and CPAP* guideline[1]
- Recommended readings and textbooks
    - May be complemented by your own neonatal textbooks and readings
- Queensland Health Electronic Publishing Service (QHEPS)
- Clinician Knowledge Network (CKN)
- Local policies, procedures and guidelines
- Nurse educator, clinical facilitator/coach/nurse or other resource person

Assessment

Assessment is by successful completion of specific activities using the resources provided or identified throughout the CLR. Nurse educators, clinical facilitators/coaches/nurses or other resource person will review and discuss the responses of all activities listed in the CLR to determine knowledge and awareness of the specific issues addressed.

To gain competency for administering CPAP to newborn babies, complete the following:

- CLR and response booklet
- Successful clinical skills assessment by direct supervision from a nurse educator, clinical facilitator/coach/nurse or other resource person who is competent in the care of the newborn baby having CPAP

Continuing professional development

Completion of this package attracts 28 hours of continuing professional development (CPD). CPD hours contribute to the requirements of the Nursing and Midwifery Board of Australia *Continuing Professional Development Registration Standard: Continuing Professional Developmen*t[2] for nurses and midwives.

Unit 1. Physiology of respiratory distress of the newborn

Learning objectives

On completion of this unit the participant will be able to:

- Demonstrate an understanding of normal lung physiology including lung compliance and the role of surfactant
- Explain the physiology of respiratory distress of the newborn baby
- Identify the predisposing factors to developing respiratory distress
- Identify signs of respiratory distress
- Consider x-ray interpretation and pathology results using Queensland Clinical Guidelines *Respiratory distress including CPAP* guideline[1] as a reference

Introduction

An understanding of neonatal lung physiology relevant to neonatal ventilation requires a sound knowledge of relevant terminology including lung volumes, and various elements of both internal and external respiration. Revise relevant terminology [refer to Definitions
including:

- Tidal volume (TV)
- Functional residual capacity (FRC)
- Total lung capacity (TLC)
- Physiologic dead space
- Mechanical dead space

Reading 1 Keszler 2017 will provide an overview of fetal lung development, influences on lung development and transition to extra-uterine life, as well as a review of neonatal lung mechanics. Gaining an understanding of lung compliance and airway resistance will be of benefit later when the physiology of continuous positive airways pressure (CPAP) is discussed.

Reading 1 Keszler 2017

This reading provides an overview of the concepts related to lung compliance.

Keszler M, Abubakar K. Physiologic principles. In: Goldsmith J, Karotkin E, Keszler M, Suresh G, editors. Assisted Ventilation of the Neonate; 2017. p. 8-30.e3. Elsevier. Philadelphia.[3]

Lung compliance

Reading 1 Keszler 2017 provided an overview of some of the concepts relevant to lung compliance. Lung compliance is a critical concept in neonatal management as much of the care is directed at overcoming the consequences of poor lung compliance or "stiff lungs". A simple explanation of the physiology of breathing explains this concept. The initial inflation of the newborn lung requires a reasonable degree of pressure for a small change in volume–similar to blowing up a balloon. This increased pressure is required to overcome surface tension and recruit (inflate) alveoli. Once inflated it is important that the alveoli are stabilised and can easily reinflate with the next breaths. When FRC has been established, adequate lung volumes can be achieved using lower respiratory pressure.

As the lungs near the peak of inspiration, there is only a small change in lung volume in response to a moderate delivery of pressure. Following expiration in the healthy newborn lung, the lung volume does not return to zero mL but retains a small volume of gas. This is known as the establishment of a functional residual capacity (FRC).

Lung compliance is a significant problem in respiratory distress syndrome (RDS). The stiff or non-compliant lung in RDS requires very high pressure to achieve only small changes in lung volume, and at the end of respiration lung volumes return to near zero mL. The resulting failure to establish an adequate FRC has the effect of increasing the work of breathing for these babies, as each breath requires a large effort to recruit alveoli for gas exchange. Low FRC indicates reduced lung compliance and requires the generation of higher pressure to move the same amount of air as compared with a normal lung.

An additional and significant problem in newborn babies with RDS is surfactant deficiency. Surfactant is a soapy substance that reduces surface tension by preventing the natural tendency of the alveolar walls to collapse on expiration. Surfactant coats the inner lining of the alveolar walls and stabilises it, preventing collapse on expiration. Babies with RDS have surfactant deficiency, which contributes to the loss of FRC and an increase in respiratory effort.

The lungs of preterm babies differ from term babies, both structurally and functionally. Refer to Reading 1 Keszler 2017, (*Figures* 2.2, 2.3 and 2.4) to gain an understanding of the pressure-volume curves of both healthy newborn lungs and those of surfactant deficient lungs. This will help gain an insight into the significance of CPAP.

Issues of lung compliance are particularly relevant to neonatal care. However, there is another aspect of compliance that is also relevant. This relates to chest wall compliance.

In contrast to lung compliance, which is decreased in the preterm infant, chest wall compliance is increased. In adults, chest wall compliance is low because of rigidity provided by the rib cage. However, the poorly ossified bony structures of the preterm neonatal thorax allow for greater compliance. A baby with sternal recession shows a combination of non-compliant lungs and a very compliant chest wall.

Airway resistance

Reading 1 Keszler 2017,outlined two sources of friction (and resultant loss of energy) that cause resistance to air flow in the neonatal lung and airways. Airway frictional resistance accounts for approximately 80% of total pulmonary resistance and can be caused by anatomical structures or ventilatory appliances.[3]

Airway resistance is determined by flow velocity, length and internal diameter of the airways, and viscosity and density of the gases. This concept will be of relevance to our discussion about CPAP devices and interfaces in Unit 3 CPAP administration.

The second cause of resistance to airflow is viscous resistance, which accounts for nearly 20% of total airway resistance. Viscous resistance can be related to any neonatal lung pathology that causes an increase in pulmonary fluid (e.g. delayed reabsorption, basement membrane leaking and left-to-right-shunting, (e.g. patent ductus arteriosus), and is also created by tissue moving against tissue within the lungs themselves as seen with surfactant deficiency.[3]

Assessment and diagnosis

Whilst we have now covered the theory behind neonatal lung development and respiratory distress of the newborn, it is also important to understand the assessment of a baby's oxygenation and respiratory effort.

Reading 2 Pramanik 2015
provides a simple guide to understanding adaptation to extra-uterine life and the causes and clinical presentation of respiratory distress. It is anticipated that a preterm baby will encounter some degree of respiratory distress. Respiratory distress can have several aetiologies and whilst they may incur differing treatment regimens, CPAP is one treatment option for preterm and term babies.

Reading 2 Pramanik 2015

Pramanik A, Rangaswamy N, Gates T. Neonatal respiratory distress. Pediatric Clinics of North America 2015;62(2):453-69.[4]

Activity 1.1 Respiratory distress

Answer the following questions in your response booklet:

a. Identify the clinical signs of respiratory distress of the newborn
b. List the major causes and pathophysiology of respiratory distress in the newborn baby

Unit 2. Continuous positive airway pressure (CPAP)

Learning objectives

On completion of this unit the participant will be able to:

- Define CPAP
- Demonstrate knowledge of the effect of CPAP on respiratory function

Introduction

Using CPAP as a means of supporting respiratory function in newborn babies with respiratory distress was first published in 1971. It continues to be an important strategy for treatment of babies with respiratory problems.[5] CPAP has long been documented as contributing to reduced intubation rates, reduced incidence of chronic lung disease and improved survival.[6] Whilst CPAP has been used for over four decades there continues to be ongoing research.[6] CPAP has been delivered using a number of different devices and pressure generating systems to provide safe and consistent pressure, while minimising adverse equipment related effects.[6]

CPAP physiology

CPAP is defined as providing air and/or oxygen into the lungs under pressure.[6] By maintaining a positive pressure throughout the whole respiratory cycle, collapse of the alveoli at the end of expiration is minimised. As a result less energy is needed to reopen alveoli and initiate a breath, and the total work of breathing is decreased.[6] CPAP increases the FRC of the lungs and improves pulmonary artery oxygen (PaO_2)[3], while enabling the baby to breathe on their own.

Reading 3 Diblasi (2017), Reading 4 Sammour (2020) and Reading 5 Queensland Clinical Guidelines (2020) have been included to help you develop a deeper understanding of the physiology of CPAP. You may read one or all of the readings.

Reading 3 Diblasi (2017)

Diblasi R, Courtney S. Non-invasive respiratory support. In: Goldsmith J, Karotkin E, Keszler M, Suresh G, editors. Assisted ventilation of the neonate; 2017. p. 162-79.e4. Elsevier. Philadelphia.[6]

Reading 4 Sammour (2020)

Sammour I, Karnati S. Non-invasive respiratory support of the premature neonate: from physics to bench to practice. Frontiers in Pediatrics 2020; 8(214).[7]

Reading 5 Queensland Clinical Guidelines (2020)

Queensland Clinical Guidelines *Respiratory distress and CPAP* guideline[1].

The readings so far have explored the physiology of CPAP and how the use of CPAP assists a baby with respiratory distress. The clinical scenario of baby Lucy will be introduced here. Lucy's condition and ongoing management will continue to be explored throughout the CLR.

Activity 2.1 CPAP physiology

Clinical scenario

Lucy was born at 31 weeks gestation by spontaneous vaginal birth (SVB) after the onset of preterm labour. Due to the precipitous nature of Lucy's birth, her mother did not receive adequate corticosteroids to assist with the maturation of Lucy's lungs. Shortly after birth Lucy developed respiratory distress and was transferred to the nursery for further assessment and management. She is subsequently started on CPAP.

Answer the following questions in the response booklet with reference to the clinical scenario:

a) List the indications for CPAP

b) Identify the physiological changes relevant to CPAP that may improve Lucy's condition

Unit 3. CPAP administration

Learning objectives

On completion of this unit the participant will be able to:

- Identify the principles of bubble CPAP
- Demonstrate knowledge of CPAP delivery devices and interfaces
- Measure CPAP appliances and their components relative to each baby

Introduction

CPAP can be generated by a variety of devices including an infant ventilator, T piece device, bubble CPAP apparatus and infant flow drivers.[5] Each system may differ from facility to facility, so one system may be more familiar than another. There is limited evidence to suggest one method of generating CPAP pressure is beneficial over another[5]. The following section explores commonly used devices and does not endorse the use of any particular products or equipment.

Bubble CPAP

Bubble CPAP generates pressure by submerging the expiratory component of the tubing under water to gain a desired level of positive end expiratory pressure (PEEP). The amount of CPAP is determined by the number of centimetres below the water level that the limb is submerged (e.g. 6 cm below the surface equals 6 cmH_2O CPAP).[5] Blended gas is heated and humidified, and delivered to the infant via nasal-prong cannula.[5] The availability, ease of use and inexpensive nature of bubble CPAP means that it is often the preferred method of delivering CPAP to babies with respiratory distress.[5]

Diligent monitoring of bubbling is necessary to ensure CPAP is being delivered. Confirmation of delivery of the prescribed CPAP is by visualisation of active bubbling in the water chamber and an adequate seal at the point of delivery (the nares). The flow rate should produce a 'boil' rather than a 'simmer' bubble. A study by Morley et al[8] reported suboptimal CPAP delivery when using lower flow rates of 3 L/minute (slower bubbling) compared with higher flow rates of 6 L/minute (vigorous bubbling). The gas flow is set at a minimum 6 L/minute to achieve the prescribed CPAP.

Absent bubbling may ultimately mean there is an air leak in the system. Occluding the prongs, helps determine if the loss of CPAP is related to the circuit or the baby. If a bubble is achieved when occluding the prongs, the problem is likely to be at the baby end of the circuit (e.g. incorrect prong size, incorrect position of prongs or loss of pressure from open mouth). If occlusion of the prongs does not generate bubble, troubleshooting the circuit will be necessary (e.g. disconnection of circuitry or temperature cables, condensation build up or issues with gas supply). Occasionally an increase in flow is required to gain the desired level of CPAP, but this should be the last approach to troubleshooting the loss of bubble/pressure.

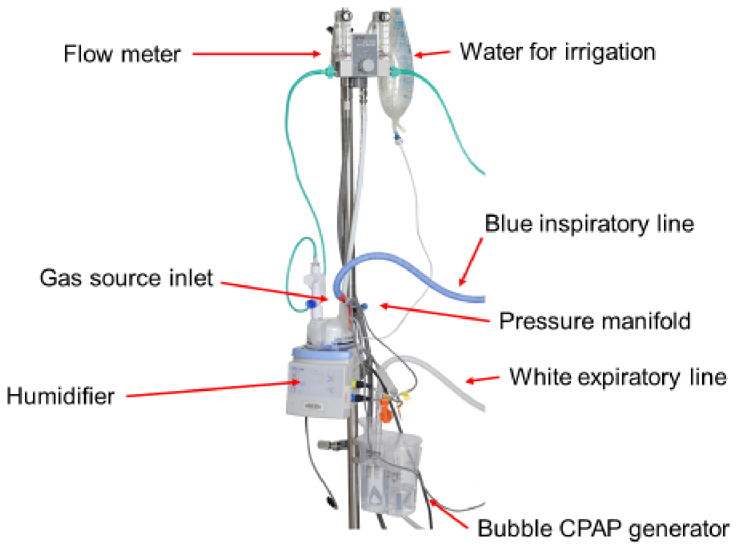


Figure 1. Bubble CPAP

Infant ventilator

CPAP via an infant ventilator is generated via the exhalation valve and there are no pressure oscillations. If the set pressure falls too low, the ventilator alarms.[5] CPAP is manually adjusted independent of flow, and flow rates can be changed manually depending on the type of ventilator. Gas flow is through the attached humidification system.[5]

Figure 2. Infant ventilator

Figure 3. Infant ventilator

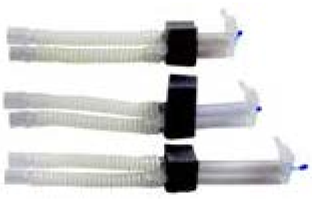
Infant flow driver

The infant flow driver (IFD) provides a variable flow. It has an integrated nasal interface/pressure generator and the pressure is affected by flow. Gas is delivered in response to the infant’s respiratory effort.[5]

Figure 4. Infant flow driver

Patient interfaces

CPAP can be delivered by a variety of patient interfaces such as nasal prongs, nasal cannula, face mask and less commonly nasopharyngeal tube (NPT) or endotracheal tube (ETT). Bi-nasal prongs are now used more commonly. Research has demonstrated that the use of short bi-nasal prongs reduces respiratory failure rates and re-intubation in newborn babies, in comparison to the single long nasopharyngeal prong.[5] There is however, no evidence recommending the use of midline devices over other available bi-nasal prongs.[9]



Midline interfaces

Binasal prongs

Hudson ® prongs

Nasal masks

Figure 5. CPAP interfaces

Regardless of the interface used, the following principles apply to bi-nasal CPAP–

- It is important to ensure the prongs/mask are correctly fitting
  - If too small they will not create the seal necessary to generate the prescribed CPAP, and will move within the nare potentially causing skin/mucosal trauma and may also lead to an increase in airway resistance
  - If too large, damage to the surrounding tissue can lead to blanching, erosion and necrosis
- The most important factor when choosing the type of hat to be used with the CPAP interface relates to the fit
  - A well-fitting hat will assist with achieving an effective seal by reducing movement of the prongs / interface and thus improving the delivery of CPAP
  - Loose hats can cause movement of the CPAP device with subsequent injury to the surrounding skin and nasal structures
  - Too tight a hat will lead to pressure area development, epidermal damage and potentially head moulding

Fisher & Paykel® hat

Hudson hat®

Canberra wrap™

Figure 6. CPAP hats

CPAP devices and interfaces

Reading 6 Gupta (2016) further summarises the physiology of CPAP and provides a detailed comparison between CPAP generating devices and CPAP interfaces. This will assist you to complete Activity 3.1.

Reading 6 Gupta (2016)

Gupta S. and Donn S. Continuous positive airway pressure: physiology and comparison of devices. Seminars in Fetal & Neonatal Medicine 2016; 21(3):204-11[5]

Activity 3.1 CPAP devices and interfaces

Clinical scenario

As the nurse allocated to care for Lucy you are required to apply a CPAP interface and choose a CPAP generating device.

Use an evidence-based approach:

a) Answer the following multi-choice questions in the response booklet.

1. What are the main advantages to using binasal prongs?
2. What are the main advantages to using the mask interface?
3. What are the main disadvantages to the bubble device?
4. What are the main advantages to ventilator generated CPAP?
5. What are the main disadvantages to CPAP via an ETT?

Activity 3.2 Measurements for CPAP interface

Consider the interface measurements needed for CPAP.

a) In the response booklet, describe the measurements required for determining the appropriate equipment size to minimise trauma and maximise the efficacy of CPAP.

Note: This is not an exhaustive list of CPAP interfaces available. Also consider the devices available in the unit where you work.

CPAP interface
Nasal prongs (e.g. TeleFlex Hudson prongs®)
Midline prongs (e.g. Fisher & Paykel Healthcare FlexiTrunk®)
Mask CPAP
Others

Resistance to airflow

In Unit 1Physiology of respiratory distress of the newborn, the concept of airway frictional resistance was introduced. This is particularly relevant to our choices of CPAP interface and to the management of our ventilatory circuitry. The resistance in the conducting airways caused by ventilatory appliances is directly proportional to the length and size of the breathing apparatus, that is the nasopharyngeal tube (NPT), and binasal CPAP prongs. Decreasing the radius of the tube increases its resistance, therefore as the length of the tube increases and the radius of the tube decreases, it may be necessary to increase pressure to overcome the increased airway resistance.[3]

Considering that babies have increased airway resistance due to their narrower airway lumen, lung pathology and prematurity, ill-fitting ventilatory appliances can contribute to a proportionally greater increase in airway resistance.[3] The interest for neonatal clinicians is understanding airway resistance and how to reduce it, and this often relates to the artificial airway and ventilation circuit.

Some ways to reduce resistance include:

- Decreasing turbulence by ensuring that ventilator circuits are free from unnecessary curves and twists, and reducing the presence of condensation that has accumulated in the circuitry
- Minimising the length of the circuit tubing
- Improving flow by shortening the length of the NPT (if used)
    - Shortening the tube also reduces the work of breathing for spontaneous breaths
- Ensuring adequate humidification is critical for the reduction of thick and viscous airway secretions, and avoidance of mucous plugging causing narrowed or blocked airways
- Ensuring that bi-nasal prongs are measured to fit the nares snugly
- Reducing the dead space is by maintaining water at the specified level in the humidifier

Reflection

Reflect on your current practice and think of instances where you have addressed the issue of airway resistance. You may be able to add to the above list.

Weaning CPAP

If CPAP is weaned too early, there is the risk that the baby will develop atelectasis, or start having apnoeic and bradycardic episodes. However, unnecessary continuation of CPAP can result in complications such as nasal trauma, abdominal distension and agitation. Alveolar overdistension is also a risk that may lead to long term complications such as bronchopulmonary dysplasia (BPD). A cautious and gradual approach to weaning CPAP in ELBW and VLBW babies should be considered.

The principles of weaning the baby from CPAP include:

- Ensuring the SpO_2 has been greater than 95% for the previous six hours
- Reducing the FiO_2 before reducing the CPAP pressure
- Starting to wean the pressure when:
    - Oxygen requirement is less than 25%
    - Baby's respiratory distress has improved
    - Apnoeas are self-reverting and of short duration (no longer than 20 seconds)
    - Bradycardias are not less than 100 beats per minute

Observe the baby closely after CPAP has been stopped. If the baby's work of breathing increases or the oxygen saturations decrease, CPAP may need to be restarted.

Refer to the relevant section of Reading 5 Queensland Clinical Guidelines (2020) *Respiratory distress and CPAP*[1] guideline for further information.

Unit 4. Humidification

Learning objectives

On completion of this unit the participant will be able to:

- Explain the fundamentals of humidity
- Identify and demonstrate the management of humidification of non-invasive ventilation

Introduction

Humidification of inspired gases for babies who are ventilated or receiving CPAP has become a fundamental tool in preventing complications. Normally the nasal passages and upper respiratory tract play an important role in the humidification of inspired gases. Air is inhaled as a cool, dry gas and is subsequently exhaled warm and moist. The vasculature of the nose and nasal sinuses are equipped to compensate for this. Thus, the nose, pharynx and trachea recover heat and moisture through normal physiological processes. Bypassing this normal physiological process by the use of ETT, NPT or binasal prongs necessitates active delivery of heated humidified gas.[10] Inadequate humidification has been associated with airway obstruction, trauma to the respiratory epithelium, and caloric and evaporative heat loss.[11]

Reading 7 de Klerk (2012) and Reading 8 Fisher & Paykel (2017) outline the physiological process of the mucociliary support system and its role in reducing the risk of pneumothorax, respiratory epithelial damage and tube obstruction. They also provide the fundamentals to understand the concepts of humidity.

Reading 7 de Klerk (2012)

de Klerk A. Physiology of humidification in critically ill neonates. In: Esquinas AM, editor. Humidification in the Intensive Care Unit: The Essentials. Berlin, Heidelberg: Springer Berlin Heidelberg; 2012. p. 253-66.[12]

Reading 8 Fisher & Paykel (2017)

Fisher and Paykel Healthcare. Nurturing Life 2017. p 1–7[13]

Take a moment to examine the relationship between temperature and humidity of inspired gas temperatures in Reading 7 de Klerk (2012) *(Figure 30.1)*[12]

The graph and readings discuss the concept of saturation of gas, and show that to increase the total capacity of gas to hold water, gases must first be heated. If the inspired gases are not already saturated with water vapour (100% relative humidity) then the gases will take up water from the lung mucosa, thus drying it (and the baby) out.[12] So, what is known about heating gases?

Humidification for neonatal ventilation is mostly managed by heating a chamber of water through which the inspiratory gases must pass on the way to the baby. Internal heating wires minimise the potential for condensation/rain-out that occurs as a result of humidified gases encountering cooler room or cot temperatures.[14] The temperature, to which the heating wire will warm inspiratory gases, is thermostatically controlled by the set patient temperature feature, and sensed by a circuit (patient) temperature probe.[13] When the circuit probe senses that the set temperature has been reached, the heating wire is automatically switched off. Innovation in circuit design has seen the introduction of permeable circuitry and dual heater wires in an attempt to decrease the amount of rain-out. However, the management of rain-out remains a challenge.

Activity 4.1 Humidification

Inadequately heated humidified ventilatory gases delivered to infants receiving respiratory support can cause significant respiratory morbidity.

a) In the response booklet link the respiratory changes caused by inadequate humidification with the pathophysiology.

Activity Response 4.1.a Humidification

Respiratory change
Thickened secretions
Compromised mucociliary transport system
Reduced airway defence
Energy loss
Airway patency and resistance
Inflammation and necrosis of the airway epithelium
Impaired surfactant production

Temperature

So far, it has been established that heating gases is required to maximise humidity. But, how do we know what temperature is the right temperature? Research has indicated that just as insufficient humidity can be problematic, this is also true of too much humidity[14]. So what temperature range is required? Aiming for at least basic physiologic conditions is thought to be adequate.

Clinical tip

Humidification is central to preventing respiratory problems in newborn babies. Wherever possible the use of a humidifier when delivering CPAP should be considered for all babies. This includes babies:

- With ongoing CPAP requirements
- Receiving CPAP at birth
- Awaiting retrieval to a tertiary centre

Activity 4.2 Management of heated humidification

Consider the management of heated humidification for ventilation of gases in the nursery where you work.

a) Review the local policies, guidelines and practices, and examine the configuration of the circuit and humidifiers used in the nursery to answer the questions in your response booklet about humidification.

1. Where is/are the heater wire/s located?
2. Where is the gas temperature probe positioned? Why?
3. Which of the inspiratory and expiratory limbs is positioned uppermost at the manifold? Why?
4. What is the set temperature for the water chamber/inspiratory gas? Is there a deliberate differential? Why?

Reflection

Humidifier and circuit technology are evolving in response to the difficulties managing rain-out in neonatal units. Reflect on the humidifier and circuits available in the unit where you work.

How does varied technology work to reduce rain-out and provide consistently heated and humidified gases?

Condensation

Condensation or rain-out occurs when warm gas that is holding water cools after leaving the humidifier, thus lowering its ability to hold water. There is a demonstrated, significant fall in inspired gas temperature between the points of the heater wire and the airway opening.[12,13] Rain-out becomes a challenge as environmental temperatures influence the cooling of inspired and expired gases, and therefore lowers the maximum capacity to hold water vapor. Rain-out is largely observed when cooler cot temperatures are used and in babies nursed in open cots. Avoid rain-out as condensate gets easily contaminated and may be flushed into the baby's airway risking airway obstruction and pneumonia.[14]

Clinical tip

It is critical to pay close attention to the build-up of rain-out in the CPAP interface. Remembering to empty rain-out prior to re-positioning the baby can reduce the potential of an aspiration event.

Activity 4.3 Condensation

Answer the following questions in the response booklet.

a) Identify the circumstances when rain-out (condensation) may occur
b) Discuss how it can be managed

Unit 5. Complications of CPAP

Learning objectives

On completion of this unit the participant will be able to:

- Discuss the complications relating to CPAP treatment including pulmonary air leaks, pain, abdominal insufflation, hyperinflation of the lungs, pressure injury and CPAP failure
- Identify the signs and symptoms of these complications in a baby
- Identify strategies to prevent and manage these complications

Introduction

Many treatments may have adverse effects. Some adverse effects are worse than others, and some can be avoided or reduced with simple changes in clinical management. This unit will cover some of the potential complications related to CPAP.

Much of the focus in caring for a baby on CPAP is aimed at maintaining the prescribed mean airway pressure which is often a time consuming and labour intensive task. This is vital to minimising the period of respiratory distress and reducing the occurrence of CPAP failure. However, it can sometimes be detrimental to the baby if the development of pressure areas, facial oedema and patient comfort are overlooked. Troubleshooting principles will provide comfort to the baby and reduce the incidence of CPAP related complications including air leaks.

Pulmonary air leaks

Pulmonary interstitial emphysema (PIE), pneumomediastinum and pneumothoraces are the most common air leaks experienced by newborn babies. Pulmonary air leaks have been reported in up to 40% of ventilated babies, many of whom are asymptomatic.[15,16] The most frequent air leak is a pneumothorax. A number of factors can cause a baby to develop a pneumothorax. These are mostly related to the progression of their respiratory distress, but often they can be attributed to the treatment modality or resuscitation they have been given.[16]

Pneumothoraces can have a significant impact on the health outcomes of a baby. The following reading has been included as it provides a summary of pneumothorax and the associated pathophysiology, clinical presentation and management.

Reading 9 Gardner (2020)

Gardner, SL. Enzman-Hines, M, Nyp, M. 2020. Respiratory diseases. In Gardner, Carter, Hines and Hernandez, editors. Merenstein and Gardner's Handbook of Neonatal Intensive Care.768-772.[16]

Activity 5.1 Pulmonary leaks

Clinical scenario

Lucy continues on a CPAP of 8 cmH_2O but has an increasing oxygen requirement currently at 40%. Her work of breathing has increased, and she is struggling to maintain her oxygen saturations within normal parameters. Lucy's pulse oximeter has started to alarm showing a sudden desaturation to 73–75%. Upon closer inspection, you observe that although Lucy is still breathing, she has cyanotic lips and a general dusky appearance. You check whether Lucy is achieving her prescribed CPAP, dial up the FiO_2 and suction her mouth. Lucy's SpO_2 does not improve, and you press the emergency alarm, and the paediatrician/nurse practitioner attends. A chest x-ray is ordered while she is being examined. On examination there is slight chest asymmetry and on auscultation there were decreased breath sounds on the right side. The chest x-ray confirms the diagnosis of tension pneumothorax and a needle thoracentesis is performed. An intercostal catheter (ICC) that stays in for two days is inserted using a sterile technique, and Lucy is later weaned back to 21% oxygen.

Consider the clinical scenario.

a) Identify the clinical signs of a pneumothorax
b) Discuss the required nursing care of Lucy after insertion of an ICC

Hyperinflation of the lungs

An understanding about air trapping or hyperinflation of the lungs is valuable to minimise ventilator associated complications. CPAP that is too low effects FRC and oxygenation, and if the pressure is too high this can result in air trapping.[6,17] Clinically this may appear as hyperexpanded lungs on x-ray, but may also manifest as hypoxemia and hypercarbia as cardiopulmonary circulation is impaired.[6] The key concept we can learn from this relates to our assessment of the baby's response to changes in CPAP. Any acute deterioration observed when there is an increase in CPAP should alert the clinical team of potential hyperinflation or air trapping in the lungs. Additionally, air leaks may be a direct result of hyperinflation.[6]

Pain

Pain and discomfort is considered a complication of CPAP due to the firm fitting nature of the interface, abdominal distension, skin breakdown and pressure injuries, and the greater risk of pneumothorax.[18] Not all babies will require analgesics; ongoing skilled assessment of infant cues and the use of a validated pain tool will determine appropriate and timely intervention.[19] Consider the use of non-pharmacological methods of pain relief as appropriate; modify the environment and sensory stimuli, positioning and containment of baby and non-nutritive sucking.[20,21]

Abdominal insufflation

As CPAP is delivered into the airways, air can subsequently enters the oesophagus and then the stomach.[22] Abdominal distension has been documented in the neonatal population for some years, particularly in reference to babies being treated with CPAP. This has implications when caring for a baby on CPAP. Gastric venting is usually required, and occasionally insertion of a larger bore gastric tube (8 Fg) is necessary.[22]

Observation of abdominal distension is an important aspect of nursing assessment. It is important to differentiate between "CPAP belly" where the resultant gastric aspirate would largely consist of air, or if it is a sign of a more sinister problem such as necrotising enterocolitis (NEC).

Apnoea and feed intolerance may occur as result of abdominal insufflation. It is therefore an important component of nursing care to implement continuous gastric venting and/or regular aspirates.

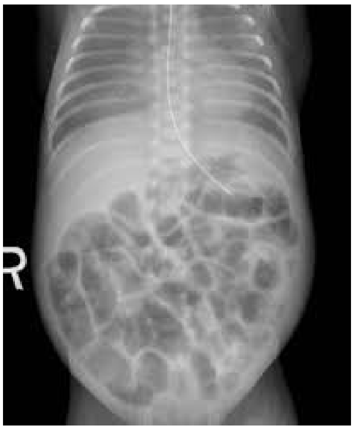


Figure 7. X-ray of baby's abdomen showing insufflation

Reflection

Reflect on current practice in the unit where you work. Is gastric venting a routine procedure? How would you differentiate between "CPAP belly" and NEC?

Failure of CPAP

An important aspect of clinical management is identifying when CPAP has failed to adequately assist a baby with respiratory distress. There is no universally accepted definition. Some evidence suggests that CPAP failure may be predicted when considering variables such as gestational age, maternal history including antenatal steroid administration along with CPAP pressure and oxygen requirement.[23] CPAP failure may include increasing apnoeic episodes, increasing oxygen requirement, increased work of breathing and respiratory acidosis. Clinical assessment is essential to identify if a baby is managing on CPAP or if treatment should be escalated.

Reading 10 Wright (2018) provides an evidence-based approach to predicting and preventing CPAP failure in babies.

Reading 10 Wright (2018)

Wright C, Sherlock L, Sahni R, Polin R. Preventing continuous positive airway pressure failure. Clinics in Perinatology 2018;45(2):257-71.[9]

Activity 5.2 CPAP failure

Review Queensland Clinical Guidelines *Respiratory distress and CPAP*[1] guideline (Reading 5) and complete the activities below in the response booklet.

a. Identify the signs of failure of CPAP as described in the guideline
b. Describe the nursing actions that would be initiated

Clinical tip

Regardless of the failure criteria, it is important to eliminate or remedy the cause of worsening condition prior to escalating treatment. Consider the following:

- Is the prescribed CPAP pressure achieved?
- Are there oral or nasal secretions?
- Has the gastric tube has been aspirated recently?
- Is it necessary to resize the nasal prongs?

Activity 5.3 Maintaining pressure

Clinical scenario

During your shift you notice that Lucy's CPAP is not bubbling. You inspect the circuit, and nothing appears to have disconnected, and the flow is correct.

Consider the troubleshooting measures to ensure that Lucy receives her prescribed CPAP pressure.

a) Answer the questions in the response booklet.

1. What strategies will you use to ensure the prongs remain in the nares?
2. How will you assess the fit of the prongs to minimise air leak?
3. How will you address and minimise oral air leaks?

Activity 5.4 Deterioration

Clinical scenario

You continue to care for Lucy and have had a challenging day managing her seal and achieving her mean airway pressure. You have had to enter Lucy's incubator several times to troubleshoot her CPAP, and over the remainder of your shift you observe that Lucy is having increasing periods of apnoea and desaturation. You update the medical officer/nurse practitioner about her condition, and it is suggested that the pressure and oxygen are increased. Despite the increased pressure baby Lucy shows no signs of immediate improvement.

Using the information provided in the readings and throughout the resource package, answer the following questions in the response booklet.

a) Identify why baby Lucy may be experiencing a deterioration in her health status
b) Identify how CPAP may reduce apnoea in preterm babies

Pressure injury

Research suggests that medical devices account for 50–90% of pressure injuries, some of which may have lifelong impacts.[18] Trauma to the nasal septum, columella and philtrum is a significant complication of nasal CPAP and potentially results in short and long term consequences.[24] Current evidence suggest that nasal trauma has an impact on sepsis, reintubation rates, patient discomfort and developmental outcomes.[6,22]

Many studies have been undertaken to identify if there is any one CPAP interface that causes significantly more adverse effects than another. Unfortunately, there is no interface that has been proven to be less detrimental to skin integrity than any other. Nasal trauma is thought to occur early in treatment and is largely affected by clinical experience and expertise with CPAP, and positioning of the baby. It is therefore critical for all who are involved in the care of sick babies and their families to continuously look for the evidence to guide practice.[22]

Reading 11 Guay (2018) and Reading 12 Haymes (2020)revise the physiology of CPAP, and provide some practical guidance and strategies to ensure pressure injuries are minimised.

Reading 11 Guay (2018)

Guay JM, Carvi D, Raines DA, Luce WA. Care of the neonate on nasal continuous positive airway pressure: a bedside guide. Neonatal Network 2018;(1):24-32[22]

Reading 12 Haymes (2020)

Haymes E. The effects of continuous positive airway pressure (CPAP) on nasal skin breakdown. Journal of Neonatal Nursing 2020;26(1):37-42[18]

Figure 8. Nasal trauma

Activity 5.5 Nasal trauma

Clinical scenario

You are allocated to care for Lucy who has now been on CPAP for four days. During handover the nurse on the previous shift mentions that she had noticed bruising on Lucy's septum when she removed the CPAP interface for cares.

Regarding management strategies for minimising nasal trauma to Lucy:
a) Refer to Reading 11 Guay (2018) and Reading 12 Haymes (2020) to answer the following questions in the response booklet.

1. How will you evaluate if the prongs fit correctly?
2. What is the optimal position of the prongs to reduce or prevent pressure injury?
3. How will you monitor pressure areas including the fit of the hat?
4. How will you ensure movement of the prongs and CPAP interface are reduced?
5. How will you position baby Lucy for comfort and containment?
6. What strategies will you use to prevent 'drag' on the nares by the circuit tubing?

Nasal Seals

Nasal seals (made from a variety of products) can be useful in the management of mean airway pressure. However, it is vital to ensure that a prong upsize has been considered in the first instance. Sometimes a dilemma presents when upsizing prongs which may over distend the nares and cause blanching with subsequent pressure injury or continuing with the current prong size which may exacerbate the loss of mean airway pressure.

The research into protective barriers remains inconclusive due to bias with gestational age and sample size[18]. This highlights that nasal seals should be used with caution. If a nasal seal is used to assist with maintaining mean airway pressure, it is essential the dressing is checked regularly for trapped moisture and changed at regular intervals to allow for assessment of underlying skin integrity. If a pressure injury occurs to the nasal columella the use of a nasal seal may exacerbate the injury by allowing moisture to sit on the injury for extended periods of time so increased surveillance is necessary.

Dermal stripping can occur when the nasal seal is removed, so a gentle approach is required in addition to the use of a silicone based adhesive remover.[19] Remember to remove the nasal seal during trials off CPAP as it may inhibit nasal flaring, a compensatory symptom of respiratory distress.

Helpful tip

If a nasal pressure injury occurs, it is important to identify the strategy to manage it. Continuing with the current method of delivering CPAP may cause further trauma. Consider using another type of binasal prongs to disperse the pressure. Alternating between mask and prong can also assist recovery of the pressure injury.[22]

CPAP Positioning

The following pictures have been provided as a helpful guide to achieving optimal positioning for a baby on CPAP whilst also adhering to developmental care principles.

Positioning for Hudson® prongs

✓ **Good positioning–Hudson® prongs**

- Note the gap between prongs and septum–the nose does not appear snubbed
- Expiratory limb is lowermost (to assist with drainage of rain-out)
- The tubing is going in the opposite direction to the way the baby is facing
- The hat is positioned low at the base of the skull, covers the ears and sits low across the brow without covering the baby's eyes
- The baby's chest is supported with a positioning aid to facilitate prone positioning with Hudson® prongs

Figure 9. Good positioning–Hudson® prongs

Figure 10. Poor positioning–Hudson® prongs

Poor positioning–Hudson® prongs

- This baby is not contained and is unsettled. which goes against developmental care principles and will present difficulties keeping equipment in place and maintaining a seal
- Providing a nest/supportive bedding may assist with comfort and containment of this baby
- The hat is positioned very high on the baby's brow which is impacting the placement of prongs
- The nose appears snubbed and a pressure area is starting to develop
- The expiratory limb is uppermost in this picture (problematic for rain-out)

Positioning for midline interfaces

✓ **Good positioning–midline interface**

- Note the gap between prongs and septum
- The baby's nose does not appear snubbed
- The hat is low on the brow and rear of the skull
- The baby has been positioned in accordance with developmental care principles (e.g. baby well contained and facilitating hand to mouth movement)

Figure 11. Good positioning–midline interface

Poor positioning–midline interface

- Though the gap between prongs and septum cannot be appreciated in this photo, the prongs are being forced upwards and therefore 'snubbing' the nose
- The hat has been positioned poorly (too low and too tight), as seen by the skin fold above the eyes
- Developmental care positioning is inadequate which will result in dislodgment of the prongs or movement upwards against the septum leading to pressure injury

Figure 12. Poor positioning–midline interface

Positioning for CPAP mask

Figure 13. Good positioning–CPAP mask

✓ **Good positioning–CPAP mask**

- Hat is low on the brow
- Foam is used to achieve parallel positioning of midline interface to the baby's face
- Mask is positioned over the nose without obstructing the nares
- Anchor straps are positioned horizontally to avoid placement over the eyes and are attached taut without being pulled too tight
- The nasal bridge is inspected regularly to ensure pressure areas have not formed
- Alternating between mask and prong is preferred, to reduce the occurrence of pressure areas

Images courtesy of the Grantley Stable Neonatal Nursery Image Library (used with permission).

Unit 6. Special considerations

Learning objectives

On completion of this unit the participant will be able to:

- Identify the conditions where the use of CPAP may be contraindicated
- Identify the congenital anomalies that require consideration of alternative CPAP modalities
- Demonstrate knowledge of other modalities of providing respiratory support

Introduction

On occasions clinicians are faced with challenges in providing supportive measures for a baby with respiratory distress. Congenital anomalies are a less common cause of respiratory distress in newborn babies.[25] However, some difficulties are encountered because CPAP is either contraindicated or there is difficulty finding an interface that is appropriate. CPAP may also be contraindicated in some critically unwell babies where delaying intubation and ventilation may compromise them further. CPAP is usually not advisable in babies with a diagnosed gastrointestinal anomaly or diaphragmatic hernia, as abdominal distension/insufflation from CPAP may worsen the respiratory distress. Alternative methods of providing CPAP such as those described below may be useful for some upper airway malformations

Naso-pharyngeal tube (NPT)

Using an NPT increases the work of breathing due to the increased airway resistance produced by the length of the tube. It has been shown to be a less effective method of CPAP delivery when compared with short binasal prongs.

The NPT suitable for CPAP are flexible, ivory Portex™ ETT.
NOTE: It is essential that supplies of these are stored separately from ETT for IPPV, as intubating and ventilating a baby using these tubes is difficult.

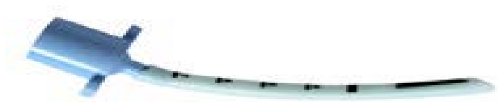


Figure 14. Nasopharyngeal tube

Administering CPAP via NPT may be necessary in the following circumstances:

- Conditions such as Pierre-Robin sequence and Treacher Collins Syndrome
  - The upper airway obstruction that is a feature of these conditions can achieve better airway patency with the longer NPT
- Congenital nasal conditions where binasal devices cannot create a seal (e.g. certain types of cleft/lip palate), or the nasal passages are not patent (choanal atresia)
- Individual assessment of CPAP interface required post operatively following ventriculo-peritoneal shunt insertion

Heated high flow nasal cannula (HHFNC)

HHFNC has been prominent within research publications in recent years as a potential alternative to CPAP, and as a method of weaning off CPAP and/or IPPV. Some evidence suggests that HHFNC is equally efficacious as CPAP.[26] However, the recently published results of the Hunter trial which aimed to determine the efficacy of HHFNC in nontertiary special care nurseries reported higher treatment failure when compared to CPAP.[27] Due to its unpredictable and inconsistent pressure delivery[22], HHFNC is not recommended as an alternative modality for respiratory support in the acute phase of respiratory distress.[28]

Non-invasive positive pressure ventilation (NIPPV)

NIPPV is used in tertiary centres to provide a spontaneously breathing newborn baby with both PEEP and intermittent positive pressure breaths.[29] These breaths are either synchronised and triggered with the baby's breathing or non-synchronised. NIPPV is delivered via a ventilator, and binasal or mask CPAP interface. Due to patient acuity, the specific conditions requiring NIPPV support, and the associated risks for this patient cohort, ongoing use of this modality should be delivered in a tertiary hospital setting.

Activity 6.1 Special considerations

Consider the following statements:

a) Answer true or false and provide a reason or rationale for your answer in the response booklet

1. NPT CPAP is suitable for routine use in a baby requiring respiratory support after birth
2. An NPT increases the work of breathing
3. CPAP is suitable in a baby with a diaphragmatic hernia

Unit 7. Developmental care and positioning

Learning objectives

On completion of this unit the participant will be able to:

- Describe the importance of appropriate positioning of the baby on CPAP
- Describe strategies for supportive care for the baby on CPAP
- Formulate a plan of care to nurse a baby on CPAP

Introduction

Advances in neonatal care and improved survival rates in the preterm and critically ill newborn population has led to a focus on long term neurodevelopmental outcomes.[21,30] Developmental care consists of a broad range of strategies to support brain development in the neonatal population such as positioning, protecting sleep, kangaroo care, minimizing environmental stressors (noise/lights), pain management, feeding and parental involvement.[19,21,30] Reading 13 Griffiths (2019), explores the holistic approach to caring for babies in the intensive care setting.

Reading 13 Griffiths (2019)

Griffiths N, Spence K, Loughran-Fowlds A, Westrup B. Individualised developmental care for babies and parents in the NICU: evidence-based best practice guideline recommendations. Early Human Development.139;2019[21]

Reflection

After completing Reading 13 Griffiths (2019) spend a moment considering how the developmental care strategies are used in your day to day care of newborn babies.

Supportive care

Supportive care is important when caring for a baby having CPAP to ensure that trauma, respiratory distress and hospital stay are reduced. This includes minimal handling and comfort measures such as analgesia and feeding[21]. Consider the measures that can be taken to reduce handling of the baby receiving CPAP. Ensuring that cares are clustered is vital for any sick or preterm baby. Provide nappy changes, position changes, suctioning, temperature monitoring and feeding together at specific times unless otherwise necessary. Sometimes too many interventions clustered together can be overwhelming, so monitor the baby's response and individualise the caregiving activities accordingly.

Remember that during the acute phase of respiratory distress atelectasis will occur when the baby is spending time off CPAP and may take several hours to re-recruit the collapsed alveoli.[31] This increases energy expenditure and can often lead to an increased oxygen requirement. For this reason, it is ideal to have two people attend to the cares at this time. One clinician can apply CPAP while the other performs cares and checks for pressure areas.

Feeding

Achieving adequate growth rates in sick and premature babies remains a challenge in many nurseries. This can be attributed to the increased caloric requirements of a sick or premature baby, and also interruptions and delays to full nutrition during periods of feed intolerance and acute illness.[19] Early feeding has been shown to improve growth rates postnatally and influence the time to reach full enteral feeding thus reducing length of hospital stay.[19] Remember to vent the gastric tube between feeds as this may reduce the risk of gastric distension and vomiting, and increase the comfort of the baby.

Evidence suggests that non-nutritive sucking offers many benefits to the baby receiving CPAP.[21] These include (but not limited to):

- The analgesic effect to painful and stressful procedures[32]
- Better transition from tube to oral feeding
- Improvement in oxygenation[33]
- Physiological stability and relaxation[33]
- Assisting with maintaining mean airway pressure while on CPAP[33]

Suctioning

Maintaining a patent airway is critical. It is often achieved with positioning of the CPAP interface and developmentally focused positioning of the baby.[34] However, suctioning of the oropharynx and nasopharynx although not a routine procedure, is also sometimes required. Suctioning is not a benign procedure and it is essential to assess the baby to identify the necessity for this procedure. It is important to offer comfort measures including facilitated tucking, swaddling and oral sucrose to reduce associated discomfort and pain.[22,34]

Positioning

Recent studies have examined the effect of positioning on neurodevelopmental outcomes by enhancing containment and reducing stress.[21] Some research has proven a slight improvement in oxygenation with prone positioning though did not affect long term outcomes.[21] Side lying and supine positions may be used, and ultimately the optimal position may be the one that keeps the baby contained and comfortable, clinically stable and with no pressure generating on the nares or septum.

Variation of positioning is important to:

- Ensure adequate development of the baby’s head shape
- Provide flexed support of joints
- Facilitate hand to mouth gestures and later, walking and crawling

Gently change the baby’s position every 3–6 hours depending on the baby’s condition and tolerance to handling.

Refer to Reading 13 Griffiths (2019)[21] for further positioning recommendations. Also refer to the CPAP positioning images in Unit 5 Complications of CPAP.

Activity 7.1 Care plan

Use the readings, and local policy, guidelines and procedure, and your clinical experience.

a) Formulate a plan of care for Lucy in the response booklet. Some headings have been suggested but you may wish to add others.

Care consideration
Cardio-respiratory assessment
Ventilator/CPAP management
Gastric venting
Analgesia
Skin assessment
Suctioning
Frequency of position changes
Cares on CPAP
Feeding
Communication with family
Kangaroo cuddles

Unit 8. Summary

Lucy eventually stabilises, and after another few days begins to show signs of improvement. The CPAP is ceased without any further complications. Great work!!

Caring for the newborn baby on CPAP requires meticulous assessment, observations and attention to detail. In addition to knowledge of the physiology behind respiratory distress and CPAP, an awareness of the available equipment and interfaces being used is essential, along with the potential advantages and disadvantages of those methods. CPAP is increasingly being used for more preterm newborn babies and in an increasing number of non-tertiary centres. It is often more time consuming than caring for a ventilated baby and requires skill in positioning the baby, troubleshooting the CPAP device and caring for the family unit. Maintaining current clinical and theoretical knowledge is key to maintaining a high standard of care of the baby on CPAP.

Appendix A Clinical skills assessment

Nursing care of the newborn baby with respiratory distress requiring CPAP

Prior to clinical assessment
☐ Neonatal respiratory distress and CPAP CLR completed
Objective of clinical assessment
The participant will demonstrate: I. The ability to correctly assess the baby with respiratory distress II. Demonstrate the clinical skills required to manage the baby requiring CPAP in a safe manner

Performance criteria	**Achieved**	**Not achieved**
Demonstrated awareness of and performs in accordance with current research, local policies, procedures and guidelines and Queensland Clinical Guidelines: *Respiratory distress and CPAP* and other relevant guidelines by identifying the following: • Frequency of observations • Signs and symptoms of respiratory distress • Management of oxygenation • Blood glucose management • Thermoregulation • Frequency of cares required and rationale including rationale for 1 or 2 person cares • Indications and contraindications to CPAP use • Differences, benefits and risks associated with varying types of CPAP interfaces • Familiarity with available CPAP generator/s, manipulation of settings and relevant safety aspects • Rationale for humidification of the CPAP circuit • Management of CPAP complications including air leaks, pressure injury, abdominal insufflation and hyperinflation • Emergency equipment required for pneumothorax management • Signs of CPAP failure • Guidelines for weaning and ceasing CPAP • Process for consultation and referral to a tertiary centre		
Demonstrated ability to correctly set up CPAP generator with appropriate circuit and humidification		
Demonstrated ability to correctly measure and fit CPAP interface		
Demonstrated knowledge of: • Respiratory distress physiology in the newborn • How CPAP supports the anatomical and physiological difficulties experienced by these babies		
Performed a safety check at the cotside at the commencement of the shift • Safety and resuscitation equipment available and functional, alarm parameters correctly set, CPAP settings as per written orders, fluids infusing as per fluid orders, floors clear of spills/cords • Aware of the evacuation procedure for the unit		
Performed a comprehensive physical assessment of the baby • Systematic approach • Utilises other relevant information to inform assessment , e.g. antenatal and perinatal history, blood gas, biochemistry, haematology, microbiology, chest x-ray, CT/MRI scans		

Performance criteria	Achieved	Not achieved
Formulated an individualised plan of nursing care including: • Involved family in care plan development including religious or cultural needs • Used assessment data as a basis for the plan • Formulated predicted outcomes of the nursing care plan • Developed criteria for evaluation of predicted outcomes • Identified potential problems that may adversely affect the baby • Formulated nursing interventions/activities to support neurodevelopment • Identified nursing interventions to address potential problems and provided rationale • Contributed to and participates in decision making on the ward round • Involved members of the health care team (e.g. physiotherapist, social worker, stomal therapist, pharmacist) • Recognised own abilities and incorporates other nursing staff to assist or provide guidance if necessary		
Documentation is correct and precise and incorporates all aspects of care including assessment findings, baby's response to handling, nursing care provided and any relevant changes to baby's status or care		
Demonstrated evidence of therapeutic interaction by: • Used the correct patient identification process • Provided privacy as able • Explained any procedures to the family • Obtained informed consent from the parents as appropriate		
Positioned the baby in accordance with developmental care principles also considering the disease process		
Aligned practice to local policy, procedures and guidelines, and Queensland Clinical Guidelines: *Respiratory distress and CPAP* guideline		
Applied principles of hand hygiene and aseptic non-touch technique (ANTT) throughout the procedure		
Disposed of waste in line with the infection control policies, procedures and guidelines		
Completion of clinical assessment		
Achieved/Not achieved (please circle)		
Comments:		
Name of participant: **Signature:**	**Date:**	
Name of assessor: **Signature:**	**Date:**	

Appendix B Clinical learning resource package final assessment

Name of participant:	**Participant signature:**
Position:	**Work Unit:**
Assessor name:	**Date:**

This assessment sheet is evidence of completing of the *Respiratory distress and CPAP* clinical learning resource (CLR) workbook and clinical skills assessment equivalent to 28 hours of continuing professional development.

Component of competency	**Date/s of completion**	**Assessor's name**	**Assessor's position**	**Assessor's signature**
CLR workbook				
Clinical skills assessment				

The participant has met expected standard for competency ☐ **Yes** ☐ **No**	
If expected standard not met, further evidence required:	
Complete when further evidence provided:	
Participant's signature:	**Date:**
Assessor's signature:	**Date:**

References

1. Queensland Clinical Guidelines. Respiratory distress and CPAP. Guideline No. MN20.3-V8-R25. [Internet]. Queensland Health. 2020. [cited 2020 June 30]. Available from: https://www.health.qld.gov.au/qcg
2. Nursing and Midwifery Board of Australia. Registration standard: continuing professional development. [Internet]. 2016 [cited 2020 May 21]. Available from: https://www.nursingmidwiferyboard.gov.au/Codes-Guidelines-Statements/Professional-standards.aspx.
3. Keszler M, Abubakar K. Physiologic principles. In: Goldsmith J, Karotkin E, Keszler M, Suresh G, editors. Assisted ventilation of the neonate. [Internet]. Pliladelphia: Elsevier; 2017. p. 8-30.e3. Available from: https://www.clinicalkey.com.au/#!/content/3-s2.0-B9780323390064000028.
4. Pramanik A, Rangaswamy N, Gates T. Neonatal respiratory distress. Pediatric Clinics of North America 2015;62(2):453-69.
5. Gupta S, Donn SM. Continuous positive airway pressure: physiology and comparison of devices. Seminars in Fetal and Neonatal Medicine 2016;21(3):204-11.
6. Diblasi R, Courtney S. Non-invasive respiratory support. In: Goldsmith J, Karotkin E, Keszler M, Suresh G, editors. Assisted ventilation of the neonate. [Internet] 6th ed. Philadelphia: Elsevier; 2017. p. 162-79.e4. Available from: https://www.clinicalkey.com.au/#!/content/3-s2.0-B978032339006400017X.
7. Sammour I, Karnati S. Non-invasive respiratory support of the premature neonate: from physics to bench to practice. 2020;8(214).
8. Morley CJ, Lau R, De Paoli A, Davis PG. Nasal continuous positive airway pressure: does bubbling improve gas exchange? Arch Dis Child Fetal Neonatal Ed 2005;90(4):F343-4.
9. Wright C, Sherlock L, Sahni R, Polin R. Preventing continuous positive airway pressure failure. Clinics in Perinatology 2018;45(2):257-71.
10. Gustavo R, Paulo S, Américo G, Ana Isabel S, Diana A, Sara F, et al. Respiratory care for the ventilated neonate. Canadian Respiratory Journal 2018;2018.
11. Roberts CT, Kortekaas R, Dawson JA, Manley BJ, Owen LS, Davis PG. 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 2016;101(3):F248.
12. de Klerk A. Physiology of humidification in critically ill neonates. In: Esquinas AM, editor. Humidification in the Intensive Care Unit: The Essentials. Berlin, Heidelberg: Springer Berlin Heidelberg; 2012. p. 253-66.
13. Fisher and Paykel Healthcare. Nurturing life. [Internet]. 2017 [cited 2019 October 17]. Available from: https://www.fphcare.com/au.
14. Schulze A. Airway humidification. In: Rimensberger PC, editor. Pediatric and neonatal mechanical ventilation: from basics to clinical practice. Berlin: Springer 2015. p. 275-81.
15. Rocha G, Soares P, Gonçalves A, Silva AI, Almeida D, Figueiredo S, et al. Respiratory care for the ventilated neonate. Canadian Respiratory Journal. [Internet]. 2018 [cited 2020 May 12]; DOI:https://doi.org/10.1155/2018/7472964.
16. Gardner S, Enzman-Hines ME, Nyp M. Respiratory diseases. In: Gardner S, Carter BS, Enzman-Hines M, Niermeyer S, editors. Merennstein and Gardner's handbook of neonatal intensive care nursing: an interactive approach. 9 ed. St Louis, Missouri: Elsevier; 2020. p. 768-72.
17. Donn SM, Sinha SK. Minimising ventilator induced lung injury in preterm infants. Archives of Disease in Childhood - Fetal and Neonatal Edition 2006;91(3):F226.
18. Haymes E. The effects of continuous positive airway pressure (CPAP) on nasal skin breakdown. Journal of Neonatal Nursing 2020;26(1):37-42.
19. Fraser D. Nursing care. In: Goldsmith J, Karotkin E, Keszler M, Suresh G, editors. Assisted ventilation of the neonate. [Internet]; 2017. p. 310-21.e3. Available from: http://dx.doi.org/10.1016/B978-0-323-39006-4.00028-4.
20. Yin T, Yang L, Lee T-Y, Li C-C, Hua Y-M, Liaw J-J. Development of atraumatic heel-stick procedures by combined treatment with non-nutritive sucking, oral sucrose, and facilitated tucking: a randomised, controlled trial. International Journal of Nursing Studies 2015;52:1288-99.
21. Griffiths N, Spence K, Loughran-Fowlds A, Westrup B. Individualised developmental care for babies and parents in the NICU: evidence-based best practice guideline recommendations. Early Human Development. [Internet]. 2019 [cited 2020 May 14]; 139:104840 DOI:http://dx.doi.org/10.1016/j.earlhumdev.2019.104840.
22. Guay JM, Carvi D, Raines DA, Luce WA. Care of the neonate on nasal continuous positive airway pressure: a bedside guide. Neonatal Network 2018(1):24-32.
23. Dargaville PA, Gerber A, Johansson S, De Paoli AG, Kamlin COF, Orsini F, et al. Incidence and outcome of CPAP failure in preterm infants. Pediatrics. [Internet]. 2016 [cited 2020 May 19]; 138(1):e20153985 DOI:10.1542/peds.2015-3985.

24. August D, New K, Ray R, Kandasamy Y. Frequency, location and risk factors of neonatal skin injuries from mechanical forces of pressure, friction, shear and stripping: a systematic literature review. Journal of Neonatal Nursing 2018;24(4):173-80.
25. Hermansen CL, Mahajan A. Newborn respiratory distress. American Academy of Family Physician 2015;92(11):994-1002.
26. Sharma P, Poonia A, Bansal R. Comparison of efficacy of nasal continuous positive airway pressure and heated humidified high-flow nasal cannula as a primary mode of respiratory support in preterm infants. Journal of Clinical Neonatology 2019;8(2):102-5.
27. Manley B, Wright I, Owen L, Foster J, Huang L, Roberts C, et al. Nasal High-Flow Therapy for Newborn Infants in Special Care Nurseries. The New England Journal of Medicine 2019;380(21):2031-40.
28. Iyer NP, Mhanna MJ. Association between high-flow Nasal cannula and end-expiratory esophageal pressures in premature infants. Respiratory Care 2016;61(3):285.
29. Binmanee A, el Helou S, Shivananda S, Fusch C, Mukerji A. Use of high noninvasive respiratory support pressures in preterm neonates: a single-center experience. The Journal of Maternal-Fetal & Neonatal Medicine 2017;30(23):2838-43.
30. Park J, Kim J-S. Factors influencing developmental care practice among neonatal intensive care unit nurses. Journal of Pediatric Nursing. [Internet]. 2019 [cited 2020 May 19]; 47:e10-e5 DOI:http://dx.doi.org/10.1016/j.pedn.2019.03.014.
31. Drescher GS, Hughes CW. Comparison of interfaces for the delivery of noninvasive respiratory support to low birthweight Infants. Respiratory Care 2018;63(10):1197.
32. Vu-Ngoc H, Uyen NCM, Thinh OP, Don LD, Danh NVT, Truc NTT, et al. Analgesic effect of non-nutritive sucking in term neonates: a randomized controlled trial. Pediatrics and Neonatology 2020;61(1):106-13.
33. Ahmadpour-Kacho M, Pasha YZ, Zoya H, Khafri S. The effect of non-nutritive sucking on transcutaneous oxygen saturation in neonates under the nasal continuous positive airway pressure (CPAP). International Journal of Pediatrics 2017;5(3):4511-9.
34. Sweet M, Armbruster D, Bainbridge E, Reiner B, Tan A, Chipps E. A pilot study of responses to suctioning among neonates on bubble nasal continuous positive airway pressure. Advances in Neonatal Care. [Internet]. 2017 [cited 2020 May 19]; 17(6):E3-E11 DOI:10.1097/ANC.0000000000000442.

Acknowledgements

This resource builds on the previous versions developed by QCG with the support of the Women's and Newborn Services, and the Workforce Development and Education Unit/Centre for Clinical Nursing at the Royal Brisbane and Women's Hospital.

Queensland Clinical Guidelines gratefully acknowledge the contribution of Queensland clinicians and other stakeholders who participated throughout the clinical learning resource development process particularly:

QCG Program Officers

Ms Eliza Hughes
Ms Stephanie Sutherns

Working Party Members

Mandy College Nurse Educator, Royal Brisbane and Women's Hospital
Li-An Collie Nurse Educator, Neo RESQ
Anndrea Flint Nurse Practitioner, Redcliffe Hospital
Nicol Franz, Nurse Educator, Caboolture Hospital
Julianne Hite Nurse Educator, Rockhampton Hospital
Katharine Lawlor Nurse Educator, Logan Hospital
Vicki Stevens Nurse Educator, Toowoomba Hospital

Queensland Clinical Guidelines Team

Associate Professor Rebecca Kimble, Director
Ms Jacinta Lee, Manager
Ms Stephanie Sutherns, Clinical Nurse Consultant
Ms Cara Cox, Clinical Nurse Consultant
Ms Emily Holmes, Clinical Nurse Consultant
Ms Eliza Hughes, Clinical Nurse Consultant
Ms Janene Rattray, Clinical Nurse Consultant

Funding

This clinical learning resource package was funded by Healthcare Improvement Unit, Queensland Health