<table>
<thead>
<tr>
<th><strong>Non-invasive ventilation in the newborn</strong></th>
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</thead>
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<td><strong>TRIM Document No</strong></td>
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<td>Policy Reference</td>
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<tr>
<td><strong>Related MOH/SLHD Policy</strong></td>
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<td><strong>Applies to</strong></td>
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<td><strong>Review Date</strong></td>
</tr>
<tr>
<td><strong>Replaces</strong></td>
</tr>
</tbody>
</table>
Policy Name: Non-invasive Ventilation in the newborn

Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>3</td>
</tr>
<tr>
<td>The Aims / Expected Outcome of this Policy/Procedure/Guideline</td>
<td>3</td>
</tr>
<tr>
<td>Risk Statement</td>
<td>3</td>
</tr>
<tr>
<td>Scope</td>
<td>3</td>
</tr>
<tr>
<td>Resources</td>
<td>3</td>
</tr>
<tr>
<td>Implementation</td>
<td>3</td>
</tr>
<tr>
<td>Guidelines</td>
<td>12</td>
</tr>
<tr>
<td>Definitions</td>
<td>12</td>
</tr>
<tr>
<td>References</td>
<td>13</td>
</tr>
</tbody>
</table>
1. **Introduction**

This document provides guidance on the management of respiratory distress in the term and preterm new-born.

2. **The Aims**

Babies with respiratory distress (will be safely managed with nCPAP (continuous positive airway pressure), humidified high flow nasal cannula or

3. **Risk Statement**

SLHD Enterprise Risk Management System (ERMS) Risk # 106 Recognising and Responding to Clinical Deterioration in Acute Health Care

4. **Scope**

Neonatal medical staff
Neonatal nursing staff

5. **Resources**

None

6. **Implementation**

- Distribution and notification of this Guideline via usual means (email, relevant management and ward meetings).
- Education and training programs for nurses, midwives, medical officers and neonatal nurse practitioners
Neonatal Non-invasive Ventilation in the newborn: What we do at RPA:

- **<28+0 weeks** – prophylactic surfactant then IPPV or nCPAP (if thin catheter used)
  - If MAP 8-10cm on ventilator extubate to nCPAP

- **≥28 + 0 weeks with respiratory distress** - commence nCPAP and titrate pressure to work of breathing (maximal pressure 8; up to 10cm in > 31 weeks). Consider surfactant*

  - If increasing FiO2 may require surfactant +/- ventilation*

- **If unstable on nCPAP (8-10cm H2O) consider NIPPV**

- **Wean nCPAP as tolerated to 5cm H20**
  - If stable in FiO2 <25% oxygen
  - Consider HHHFNC (6l/min) if a baby is likely need respiratory support > 7 days

  - Wean HHHFNC by 1l/min every 12-24 hours depending on work of breathing until 3l/min then cease

- **Recemence nCPAP or increase HHHFNC to 6l/min if one or more of the following**: Increased WOB with RR>75/min FiO2 > 25%
  - Frequent apnoea or bradycardia
  - Respiratory acidosis pH<7.20

* see surfactant (preterm and term) guidelines

NIPPV – nasal intermittent positive pressure ventilation
HHHFNC – heated humidified high flow nasal cannula
nCPAP – nasal continuous positive airway pressure

Compliance with this Guideline is recommended
1. CPAP (Continuous Positive Airway Pressure)

1.1 Definitions

Continuous distending pressure (CDP) is a method of delivering low pressure distension to the lungs during the respiratory cycle. Methods of achieving this include positive end expiratory pressure (PEEP) during mechanical ventilation, continuous positive airways pressure (CPAP) applied to the upper airway (usually nose) and continuous negative expiratory pressure (CNEP). In preterm infants the application of CDP either as CPAP or CNEP is associated with reduced respiratory failure and reduced mortality. This guideline will concentrate on the clinical application and management of CPAP, heated humidified high flow nasal cannula (HHHFNC) and nasal intermittent positive pressure ventilation.

2.2 Physiological Effects of CPAP

Continuous positive airway pressure has been shown to increase arterial oxygen content. The mechanisms by which this is achieved are complex and probably due to a combination of the factors outlined below.

1. Increases functional residual capacity.
2. Reduces right to left shunting by reducing the ventilation:perfusion mismatch.
3. Decreases airway resistance by increasing pharyngeal cross-sectional area.
4. Reduces obstructive apnoeas.
5. Stabilises the respiratory rate.
6. Reduces the severity of central apnoea.
7. Protective effect on surfactant.
8. Decreases alveolar oedema.

2.3 Indications for Nasal CPAP – the evidence

2.3.1 Early (prophylactic) CPAP

Cochrane review (7 trials; 3123 babies) of early prophylactic CPAP in preterm babies at risk of RDS showed that prophylactic nasal CPAP reduces the need for mechanical ventilation and surfactant and also reduces the incidence of BPD and death or BPD.

2.3.2. Treatment of respiratory distress.

- Extremely preterm infants (<28 + 0 weeks)

  Extremely preterm infants with respiratory distress should be given early surfactant. This surfactant can be administered through a thin catheter or alternatively via an endotracheal tube (intubated, given surfactant and extubated)
as soon as possible) (Refer to surfactant guideline for preterm infants).

- **Preterm infants (≥28 + 0 – 36 weeks)**

  If a preterm infant has good respiratory effort but has respiratory distress / apnoea the infant may be trialled on CPAP titrated up to 8cm H2O (refer to surfactant guideline for preterm infants for criteria for surfactant). Systematic review has confirmed the benefit of CPAP in reducing the rate of respiratory failure and mortality when used in preterm infants. Another systematic review has shown further benefit to beginning CPAP early when there was clinical and radiological evidence of respiratory distress syndrome rather than waiting until there was further deterioration in terms of oxygen requirement (FiO₂ >0.5). The benefits included a significant reduction in the use of intermittent positive pressure ventilation.

- **Term Infants (≥37 weeks)**

  Term babies with signs of respiratory distress (secondary to meconium aspiration, congenital pneumonia, and respiratory distress syndrome) should be commenced on CPAP with pressure titrated up to 8cm H2O.

### 2.3.3 Post-Extubation

When preterm infants are extubated following IPPV (refer to volume guarantee ventilation policy), nCPAP reduces the incidence of respiratory failure (apnoea, respiratory acidosis and increased oxygen requirements). This is improved further when pressures > 5 cm water are used. Following extubation, infants should be commenced on bubbly CPAP.

### 2.3.4 Apnoea of prematurity

Observational studies suggest apnoea of prematurity is improved by the use of CPAP. However, mask CPAP using 2-5cm water pressure is less effective than methylxanthines for treatment of apnoea of prematurity. If an infant is having recurrent clinically significant apnoea, judged to be due to prematurity (i.e. not secondary to other disease processes e.g. sepsis) the infant should commence on caffeine. A trial of CPAP may also improve the clinical status. There is little data to suggest what level of CPAP should be used; ≥5cms water is the usual starting level at RPA.

### 2.3.5 Anatomical Abnormalities / Obstructive apnoea

Airway abnormalities that predispose to airway collapse may benefit from the application of CPAP. Distending pressure increases the cross-sectional area of the upper airways thereby decreasing the risk of obstruction.
3.4. Technical Issues

3.4.1. What level to start?

The level of nCPAP should initially be targeted towards the work of breathing. A level of 5cms of water is generally the lower limit used at RPA Newborn Care. This level was shown to be significantly better at preventing respiratory failure post-extubation than lower levels\(^{10}\). The mean airway pressure before extubation may help target the level of CPAP to be used. Levels up to 8-10cms of water may be used for infants with poor lung compliance. If the infant continues to deteriorate the clinical situation should be reassessed.

3.4.2. What type of prongs?

Masks have been shown to be as effective as short binasal prongs (which should rest 2-3 mm from the nares and should not be in contact with the columella) in providing nCPAP\(^{43}\). Masks and prongs can be alternated; however, masks are favoured when the nares are in need of a rest.

Delivery of CPAP using a short endotracheal tube situated in the nasopharynx may be considered in infants where facial anomalies such as bilateral cleft lip / palate make use of short prongs impractical or unreliable.

3.4.3. What type of CPAP device?

In a randomised control study comparing bubbly versus continuous (flow driver) CPAP in 140 preterm infants post extubation, Gupta \textit{et al} demonstrated that they were equally effective in the management of RDS; however, if infants were ventilated for \(<\ 14\) days, bubbly CPAP had a higher rate of successful extubation\(^{20}\). Babies on bubbly CPAP also have a statistically significant reduction in the duration of CPAP support. At RPA Newborn care the ‘Fisher and Paykel Bubbly® CPAP circuit’ – this is the preferred device for infants of all gestations and for all causes of respiratory distress.

3.4.4. Trouble-shooting

The best assessment of the effectiveness of CPAP is the clinical condition of the infant especially the work of breathing. If there is any doubt following thorough clinical review, blood gas measurement may be useful.

Oxygenation has been shown to improve with each centimetre of water increase in distending pressure applied. However at a certain point, over-distension of the alveoli will occur and oxygenation may fall. This may be due to capillary compression by the distended alveoli and subsequent shunting of the blood to an area of the lung with decreased ventilation: perfusion ratio\(^ {5}\). Therefore:

- Incremental increases in the pressure may be applied if the improvement in oxygenation is not satisfactory.
• If moderate to high levels of positive airways pressure are being used and arterial oxygen levels fall, or carbon dioxide levels rise then the distending pressure should be reduced.

Chin-strap application during bubbly nCPAP is recommended if the mouth is open and if the circuit is not bubbling (inadequate seal). An air leak via the mouth will reduce the effectiveness of the system by allowing a significant loss of positive pressure. A dummy is an alternative.

3.5. Contra-Indications to CPAP

1. Congenital abnormalities e.g. diaphragmatic hernia, choanal atresia, tracheo-oesophageal fistula.
2. Nasal trauma/severe deformity that might be exacerbated by use of nasal prongs.
3. Clear need for intubation and ventilation.
4. Gastro-intestinal perforation

3.6. Adverse Effects of CPAP

3.6.1 Air leaks.21

In preterm infants with RDS the application of CDP is associated with benefits in terms of reduced respiratory failure and reduced mortality, but an increased rate of pneumothorax. There is a risk of pneumothorax in all babies requiring ventilation or positive pressure; however, the incidence is highest in babies < 1000g. Prophylactic or early surfactant reduces this risk.21,22. Air leaks may occur due to the disease process (alveolar over distension with RDS), with CPAP particularly when the lungs are improving and lung compliance increasing. Clinical signs of air leak include increasing respiratory distress, oxygen desaturation, decreased air entry and asymmetrical chest movement.

3.6.2 Gastric dilatation.

As the continuous distending pressure is applied to the nose, the delivered gas is able to enter the stomach and GI tract. "CPAP belly" is a well-recognised phenomenon that can be reduced by the insertion of an oro-gastric tube (≥6 Fg) on free drainage. It is relatively uncommon but there is risk of aspiration, further respiratory compromise and visceral rupture.

3.6.3 Over distension of the lung.

Over distension by the use of high pressures can cause poor oxygenation and carbon dioxide retention. Cardiac output may also be reduced secondary to impeded venous return.
3.6.4 Nasal Irritation.

The fixation devices can cause irritation, damage or necrosis to the nasal septum or skin. The area should be inspected on a regular basis to avert these complications. Over-tightening of the strapping can also result in irritation and necrosis to the nasal septum (see policy nursing management of CPAP).

3.6.5 Obstruction of the prongs.

Obstruction of the prongs by secretions or other means will stop delivery of continuous distending pressure to the lungs and airways. The pressure will be maintained by the obstruction. Humidification of gases and selective, gentle suction of the airways are important strategies to prevent this problem.

4. Heated Humidified High-flow nasal cannulae (HHHFNC)

Heated Humidified high-flow nasal cannulae (HHHFNC) are gaining popularity as a form of respiratory support in preterm infants as an alternative to nasal continuous positive airway pressure (nCPAP). High flow nasal cannulae have been used as post extubation support, primary therapy from birth for RDS and ‘weaning’ from nCPAP. Definitions of high flow vary; a flow rate of > 1litre/min was used in the recent Cochrane review. The potential benefits of high flow include their easier application and greater access to the baby’s face which improves feeding and bonding. There is also a proven reduction in nasal trauma.

Several observational studies have reported that HHHFNC, at approximately 1 to 5L/min flow with appropriately sized (fill half the diameter of the nares) nasal prongs and with the infant mouth closed, is capable of generating similar positive distending pressures to nCPAP, with similar physiological effects including decreased work of breathing. However, several studies suggest that HHHFNC may provide inconsistent and relatively unpredictable positive airway pressure with little pressure developed when the mouth is left open and variable pressures developed in small infants despite the mouth being closed.

4.1. Humidified high flow nasal cannula as primary respiratory support

The Cochrane reports four randomised trials comparing HHHFNC with nCPAP as a primary therapy for respiratory distress syndrome. The data from one additional trial is unpublished (Nair and Karna). This trial included 67 preterm infants who required nCPAP in the first 6 hours of life; the trial was ceased early due to the recall of high flow circuits secondary to Ralstonia colonisation and bacteraemia. All four of the published RCT trials included in the Cochrane review showed inadequate evidence for HHHFNC as a primary support especially as there were no extremely preterm infants in these studies (<28 weeks). Roberts et al in a multicentre randomized international trial (HIPSTER TRIAL) assigned 564 preterm infants (28 – 36 weeks) who had not received surfactant to nCPAP or high flow. The primary outcome was treatment failure (apnoea requiring IPPV, respiratory acidosis pH<7.2, PaCO2 > 60mmHG, FiO2>40 %) This trial was ceased early due to the high failure rate in the HHHFNC group. HHHFNC should
not be used as a primary mode of respiratory support.

### 4.2. Humidified high flow nasal cannula post extubation

Six randomised trials have compared HHHFN with CPAP as post-extubation support in preterm babies. Gestational age is not available for all trials but the number of extremely preterm babies included in these trials is small (<250 out of 936 babies <28 weeks gestation). The Cochrane review performed a meta-analysis for the outcome of extubation failure (five studies included) and re-intubation within 7 days (six studies) and showed no statistically significant difference between CPAP and HHFNC. Due to the small numbers of extremely preterm babies in these trials, CPAP will be the preferred treatment for RDS post extubation at RPAH.

### 4.3. Humidified high flow nasal cannula to wean preterm infants from continuous positive airway pressure

There are 3 studies looking at HHFNC as an alternative to CPAP when weaning babies from respiratory support. Abdel-Hady et al showed no difference in success of weaning between groups although the HHHFNC had a longer duration of supplemental oxygen and respiratory support. The second trial (Badiee et al) showed the opposite with shorter duration of oxygen support and shorter hospital stay. In both these studies, the babies were > 28 weeks gestation and the flows used were much lower than those used today. Soonsawad et al randomised 101 infants < 32 weeks to HHFNC or CPAP and found no difference in the time to successfully wean with the HHFNC group having significantly less nasal trauma.

Jardien et al showed that when nCPAP pressure is weaned to a predefined level and then stopped completely, the babies have less total time on nCPAP and shorter durations of oxygen therapy and hospital stay compared with those that have NCPAP removed for a predetermined number of hours each day.

A pilot RCT (60 babies) performed at this centre has demonstrated that using HHHFNC to wean babies from nCPAP is effective and is well tolerated. Abruptly weaning infants from nCPAP was not acceptable to some parents. There is also a proven reduction in nasal trauma.

*In view of the above evidence summary, HHFNC will be used as a form of weaning from nCPAP in this unit where babies are likely to require more than 7 days of respiratory support*

### 4.4 Weaning from nCPAP and HHHFNC

The current weaning practice for nCPAP at RPA is initially weaning the PEEP to 5cm H₂O pending an improvement in the work of breathing. If the baby develops a significant increase in the work of breathing and or increasing levels of inspired oxygen then the level of PEEP is increased until adequate support is achieved.

For babies who are stable on nCPAP (i.e. meet the stability criteria below) and are likely to require at least another week of respiratory support, HHHFNC at 6L/min should be
commenced. The infants HHHFNC is weaned (12-24 hourly) until a flow of 3L/min is tolerated and then ceased. Wilkinson et al showed that at flows of 3L/min the average PEEP achieved is around 3cm H2O. If a baby demonstrates 2 or more of the following failure criteria, they are recommenced on nCPAP at 5 cm H2O can be titrated according to the clinical work of breathing or oxygen requirement for at least 48 hours or until stability criteria have been achieved.

4.4.1 Stability Criteria:

- On 5cm H2O nCPAP
- Oxygen requirement less than 25% and not increasing (FiO2 ≤0.25)
- Respiratory rate less than 75
- No significant chest recession
- No significant episodes of apnoea and cyanotic spells (<80% for more than 20 seconds)
- Average saturation >86% most of the time
- Not currently treated for PDA or sepsis

4.4.2 Failure criteria (at least 2 of the following):

- Increase WOB (intercostal recession and use of accessory muscles) with respiratory rate >75
- Increased apnoea and/or bradycardia and/or desaturations >2 in 1 hour for the previous 6 hour period
- Increased FiO2 requirement >25% to maintain oxygen saturations >86%
- pH<7.2
- Apnoea or bradycardia requiring resuscitation

5. Nasal intermittent positive pressure ventilation (NIPPV)

Nasal intermittent positive pressure ventilation (NIPPV) is a simple, effective mode of respiratory support. NIPPV augments continuous positive airway pressure (CPAP) with superimposed inflations to a set peak pressure (typically 15 to 22 cmH2O) therefore providing two levels of positive airway pressure support during the respiratory cycle. NIPPV may be delivered by nasal mask or prongs, which may be short or long, single or binasal. Some devices attempt to synchronize inflations with the infant's respiratory efforts.

The two main reasons for extubation failure in the preterm infant are apnoea of prematurity and respiratory failure (acidosis); NIPPV has been proven to be of benefit in these circumstances. NIPPV reduces the incidence of extubation failure and the need for re-intubation within 48 hours to one week more effectively than NCPAP; however, it has no effect on chronic lung disease nor on mortality. When CLD was examined by device delivering NIPPV, delivering NIPPV by a ventilator was associated with a reduction in CLD in the five trials (298 infants) that could be pooled for this analysis. Air leaks were also reduced in the four trials that reported this outcome.
5.1.1 Indications for NIPPV

NIPPV at RPAH is reserved for those babies with recurrent significant apnoea and/or respiratory failure (pH< 7.2) looking likely to require invasive mechanical ventilation. It may also be used post thin catheter surfactant to prevent mechanical ventilation.

5.1.2 Advantages of NIPPV

- Reduced work of breathing compared with nCPAP \(^{41,42}\)
- Increased tidal and minute volumes compared with nCPAP \(^{41}\)

5.1.3 Initial settings

NIPPV is delivered through the Drager VN 500 ventilator – non-invasive ventilation (PC-CMV). It is non-synchronous

- Initial PIP settings of 16-18cm H2O and PEEP settings of 5-8cm H20.
- Respiratory rate (back-up): 60 breaths/min (consider titrating to respiratory rate)
- Inspiratory time of 0.4
- FiO2 as required to maintain saturations 90-94%

When weaning from NIPPV, wean PIP then back-up rate depending on clinical condition prior to change to nCPAP.

Definitions

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HHHFNC</td>
<td>Heated Humidified high flow nasal cannula</td>
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<tr>
<td>WOB</td>
<td>Work of breathing</td>
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<tr>
<td>FiO2</td>
<td>Inspired concentration of oxygen</td>
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<td>NIPPV</td>
<td>Nasal intermittent positive pressure ventilation</td>
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<tr>
<td>CPAP</td>
<td>Continuous positive airway pressure</td>
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<tr>
<td>PIP</td>
<td>Positive inspiratory pressure</td>
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<tr>
<td>PEEP</td>
<td>Positive end expiratory pressure</td>
</tr>
<tr>
<td>CLD</td>
<td>Chronic lung disease</td>
</tr>
</tbody>
</table>
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