MECHANICAL VENTILATION
Practice Guidelines

These guidelines aim to provide the registered nurse with the guiding principles to effectively and safely manage a newborn on mechanical ventilation. There must be at least one spare ventilator set up and ready for use at all times.

1. The circuit and settings must be checked by two RNs.
2. Initial settings - Mode: SIPPV / VG; Sensitivity: 1; Pressure: 25/5; TI 0.3secs; Rate: 40/min; FiO2: 0.21; I:E ratio 1:2.

Reasons for mechanical ventilation in the newborn include
1. Respiratory distress where the infant requires FiO2 > 0.35 in the first 24 hours, or FiO2 >0.4 to 0.6 after first 24 hours ¹
2. To deliver surfactant
3. Low PaO₂ (hypoxia) and/or high PaCO₂ (hypercarbia)²
4. In infants less than 30 weeks gestation with an x-ray consistent with RDS and increasing oxygen requirements there will be a lower threshold for intubation and mechanical ventilation
5. Infants who do not breathe eg severe neurological insult
6. Stabilisation of the sick unstable infant eg necrotising enterocolitis
7. Prolonged and frequent apnoea not resolved with nCPAP ³
8. Functional or anatomic airway obstruction ⁴
9. For laser surgery

Overriding principles²,⁵
Achieve sufficient pulmonary gas exchange
Minimise work of breathing
Minimise risk of lung injury and other complications related to mechanical ventilation

To be used in combination with the – intubation, extubation, CPAP, surfactant administration, conventional & HFO ventilation, nitric oxide, airway suction, developmental positioning and sedation protocols

Ventilators used in RPA newborn Care
1. Dräger 8000 – This ventilator is routinely used to provide conventional ventilation in the term and preterm infant. Although not a true oscillator the ventilator can be used to deliver high frequency oscillation (flow interrupted - passive expiration) in the very preterm infant less than 1200 grammes. The Dräger 8000 can deliver CPAP, SIPPV, SIMV, PSV, VG, PSV & VG, and HFO (flow interrupted). Nitric oxide can be delivered using the Dräger 8000.

2. Stephanie CE0482 – This ventilator is the preferred ventilator for use in the near term and term infant. The Stephanie CE0482 can be used to deliver nCPAP, IPPV, SIPPV (assist control), SIMV (S-IMV), volume targeted ventilation and HFO. It is a powerful oscillator and is used to deliver HFO in all infants greater than 1200 grammes. Nitric oxide can be delivered using the Stephanie CE0482.

Modes of ventilation used in RPA Newborn Care
1. nCPAP (Continuous positive airway pressure) maintains an elevated end expiratory lung volume in spontaneously breathing infants by providing a continuous flow of heated humidified gas at a set pressure (5-10cmH₂O) ¹. nCPAP in RPA Newborn Care can be delivered using the Dräger 8000 and rarely the Stephanie CE0482 in infants at or near term.
The **Infant Flow Driver** (EME, UK) is used for infants < 1200g and/or less than 1200g, while the **Bubbly® CPAP circuit** (Fisher & Paykel) can be used for all infants and is currently the preferred method – see nCPAP protocol.

2. **VG** (Volume guarantee) this mode of ventilation targets tidal volume – not pressure and is only available on the **Dräger 8000**. VG is used in combination with either SIPPV or SIMV. The aim of VG is to provide a preset tidal volume by automatically adjusting the PIP (peak inspiratory pressure) to achieve the target tidal volume. **SIPPV / VG is now the routine mode of ventilation in this nursery.** Leaks > 40% are not well tolerated in this method of ventilation – see VG Guidelines [http://www.cs.nsw.gov.au/rpa/neonatal/](http://www.cs.nsw.gov.au/rpa/neonatal/)

The **Stephanie CE0482** uses **volume targeted ventilation** and does not automatically decrease PIP as lung compliance improves. PIP must be reduced by the operator. Volume targeted ventilation is used to minimise lung over-distention and therefore minimise lung injury as it compensates for changes in lung compliance, resistance and spontaneous respiratory effort. 

3. **IPPV** (Intermittent Positive Pressure ventilation) – is no longer used in RPA Newborn Care as it is non synchronous and current evidence suggests synchronised ventilation results in shorter days of ventilation. 

4. **SIPPV** (Synchronised intermittent positive pressure ventilation) provides supported (set PIP and PEEP) ventilator breaths synchronised with the onset of each spontaneous breath if it occurs within a ‘trigger window’. **Therefore, every breath the infant takes is supported.** If the infant does not make spontaneous breaths, the ventilator delivers mechanical breaths at the back-up rate set by the operator. The infant therefore “controls” rate of breathing. This mode is used for most infants during the acute period of ventilation and when muscle relaxed.

5. **SIMV** (Synchronised intermittent mandatory ventilation): provides supported (set PIP and PEEP) mandatory ventilator breaths as determined by the back-up rate. The onset of inspiration of a mechanical breath is synchronised with the onset of the infant’s spontaneous breath if it occurs within a ‘trigger window’. All other spontaneous infant breaths above the set rate are only supported by PEEP. If the infant does not make spontaneous breaths, the ventilator delivers mechanical breaths at the back-up rate set by the operator. This mode of ventilation is used usually used for weaning.

6. **HFOV** (High frequency oscillatory ventilation) provides small tidal volumes at a very fast rate. This results in significantly lower alveolar pressure which reduces the risk of lung injury caused by excessive pressure and volume. The **Dräger 8000** (flow interrupted) can deliver up to 1200 cycles/minute (1Hz = 60 cycles per minute) when in high frequency mode. The **Stephanie CE0482** can deliver 300-900 cycles/minute and is the preferred oscillator.

**Ventilation parameters**

The following ventilator settings are individualised according to the needs of each infant and the mode of ventilation in use. The registered nurse is responsible for ensuring the ventilator delivers the correct settings ordered by the medical team/transitional nurse practitioner. The registered nurse will check the ventilation parameters continuously and document any changes made. The registered nurse should query any changes/ settings that are not understood.
The registered nurse may change ventilator settings if the infant’s condition deteriorates immediately after changes to ventilation orders are made. The registered nurse must notify the medical team / transitional nurse practitioner immediately.

1. **Inspiratory time (TI):** set time designated for inspiration during a breath (usually set at 0.3 sec).
2. **Expiratory time (TE):** set interval of time designated for expiration during a breath (change in rate will automatically change this value). Not routinely documented.
3. **Inspiratory : Expiratory (I:E) ratio:** the ratio of inspiratory time compared to expiratory time (usually set at 1:2). The lower the rate set on the ventilator the higher this ratio will be – the measurement does not quantify spontaneous breaths. Inverse I: E ratios no longer used.
4. **Rate (fset):** the set number of supported mechanical breaths delivered over one minute.
5. **Tidal volume:** when on VG the standard volume will be initially set at 4mls/kg
6. **Hz:** The cycles per minute delivered during high frequency oscillation. (1Hz = 60 cycles per minute). Usually start at 10 Hz.
7. **Oxygen concentration (FiO2):** the fraction of inspired oxygen and is set between 0.21-1.00. The registered nurse titrates FiO2 using arterial blood gases, SpO2 and / or TCM PaO2 values.
8. **Flow rate (V’insp) & (V’exp):** the speed in which the tidal volume is delivered. This is usually set at 10l/min when using the Dräger 8000. While in conventional modes the Stephanie CE0482 has a flow rate of 5L/min and this cannot be adjusted by the operator. Both ventilators automatically adjust flow rates when switched to HFO and will deliver flow rates up to 30L/min.
9. **Peak inspiratory pressure (Pinsp or PIP):** the maximum pressure used to inflate the infants lungs during inspiration on a mechanical ventilator.
10. **Positive end expiratory pressure (PEEP):** the pressure the ventilator maintains at the end of expiration to provide continuous distending pressure to the infant’s lungs.
11. **MAP (mean airway pressure):** average pressure generated by the ventilator over each inspiratory / expiratory cycle (value will depend on rate / pressures and tidal volumes).
12. **Trigger sensitivity (Trig):** the volume of gas the infant needs to move to trigger a mechanical breath when the ventilator is on a synchronous mode. The Dräger 8000 has a range of 1(0.02mls) to 10 (3mls). The trigger is normally set on 1 for preterm infants. The sensitivity may need to be reduced for term infants. The registered nurse should discuss with medical team / transitional nurse practitioner (usually set at ≈ 1.6 for term infants). The Stephanie CE0482 has a range of 100 to 290mls. This should be set at 0.5 or above artefact – observe screen and infant to determine sensitivity.
13. **Tidal volume (VT):** the volume of gas inspired or expired during a breath. The desired tidal volume for neonates is 3-4mls/kg. The Dräger 8000 measures expiratory TV.
14. **Minute volume (MV):** the amount of gas that passes in or out of the infant’s lungs during one minute. (Minute volume = tidal volume x rate). The desired minute volume neonates is 200-400mls/kg.

Factors that may increase tidal / minute volume include
- increase in PIP
- decrease in PEEP
- muscle relaxation / sedation
- decrease in pulmonary resistance
- increase in lung compliance
- hyperventilation - increase in spontaneous breathing such as in crying or alert states

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Review July 2012
Factors that decrease tidal / minute volume include
- decrease in PIP
- increase in PEEP
- increase in pulmonary resistance
- decrease in lung compliance - pneumothorax
- hypoventilation – decrease in spontaneous breathing
- restlessness – crying / ineffective muscle relaxation

Nursing Management

Initial assessment of the infant

After intubation of the infant, at admission (birth or NETS) and at handover, thoroughly assess the infant’s condition. This gives a reference point if the infant’s condition changes.

General assessment: Assess the infant’s colour, perfusion, tone, activity, pain/comfort and general appearance.

Respiratory assessment: Observe synchrony, adequacy and symmetry of chest expansion, auscultate quality of breath sounds and note respiratory rate / effort. Note and document if there is a significant leak around the endotracheal tube. Any leak may be significant if ventilation cannot be optimised. Note time surfactant was administered.

Measurement of endotracheal tube (ETT): Measure the ETT from the lips or nares to end of the suction port. This length should be kept at a minimum to prevent mechanical dead space in the ETT, but should be long enough to allow the ventilator tubing to be positioned midline without applying pressure on the lips or nares of the infant.

Documentation of ventilator parameters and settings

- At the commencement of each shift, on admission and / or after intubation the registered nurse will document the size / position of the endotracheal tube, the % leak; the mode of ventilation and sensitivity used. The position of the ETT on the latest x-ray.

- Conventional ventilation - document PIP, PEEP, flow, fset, FiO₂, MAP, MV and VT every hour. Monitor and document % leak (leak greater than 40% is significant as it affects the accuracy of the tidal volume delivered). Discuss with medical team.

- Volume targeted ventilation / VG – document mode, sensitivity, target TV and pressure limit. In addition to documentation for conventional ventilation note range of pressures delivered and range of volumes delivered. If infant is constantly reaching set pressure (alarm) in order to deliver the target TV adequate the pressure limit may be inadequate. Alternatively if infant is improving you may note a fall in the PIP pressure needed to deliver the target TV and the infant may be self weaning.

Humidification

Note adequacy of humidification – there should be some misting in the endotracheal tube and minimal rainout. Ensure sterile water level in the humidifier is sufficient to facilitate adequate humidification and avoid trauma to the airway. Remove excess water from circuit. If rainout is excessive consider adjusting humidity levels and / or insulate the inspiratory limb of the circuit.

Dräger 8000 - The Fisher & Paykel 850 series is used for most modes of ventilation and is automatically set to deliver 37°C at the patient wye. Record the temperature & level of water every hour.

Stephanie CE0482 - Ensure that the humidifier chamber is filled with sterile water to black line. For conventional modes the temperature offset can be set to -2.0 (39.0°C)27. Temperature and level of water should be recorded every hour.

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• **High Frequency Oscillation-** document mode and I:E ratio - *Stephanie CE0482* only. *In addition* to documentation for conventional ventilation note Hz, amplitude or dP, target TV will be ≈ 2mls / kg and note rib expansion (8th – 9th rib) on most recent chest x-ray – see high frequency ventilation protocol.

**Humidification** Note adequacy of humidification – there should be some misting in the endotracheal tube and minimal rainout. Ensure sterile water level in the humidifier is sufficient to facilitate adequate humidification and avoid trauma to the airway. Remove excess water from circuit. If rainout is excessive consider adjusting humidity levels and / or insulate the inspiratory limb of the circuit.

**Dräger 8000** - The Fisher & Paykel 850 series may be used but more commonly the circuit is changed to a low compliance or reusable circuit and the Fisher & Paykel 700 series is used with a low volume humidification cassette (MR225 & water feed set MR190). The temperature is normally set at 39°C ±2. This will deliver gas at the patient wye at 37°C. Record the temperature displayed on the humidifier (39°C ±2) and level of water every hour. Adjustments to the humidity are not uncommon during HFO.

*Stephanie CE0482* - In HFO, the temperature offset can be adjusted to -2.0 (39.0°C) ±7. If rainout occurs, the temperature offset can be adjusted in -0.5 steps, and observed for 30 minutes for any improvement. Do not adjust the temperature offset to less than 0.0 from the recommended settings as this will cause low humidity in the inspired gas. The patient circuit tube warmers should be used to reduce rainout before humidity is reduced. 8

• **Documentation of ventilator changes**
  Changes of ventilator settings are ordered by staff specialists, fellows, registrars or transitional nurse practitioners. These changes need to be documented in the progress notes (near the arterial blood gas results), the intensive care chart and signed by the doctor/ transitional nurse practitioner and RN. The FiO₂ can be adjusted as necessary by the RN.

**Ventilator alarms**
It is important to set the ventilator alarms correctly and note the occurrence of alarms as it may indicate changes in the infant’s condition.

**Dräger 8000**
1. **Alarm Delay** should be set at 20 seconds. In an unstable sick infant and / or an infant who is muscle relaxed, the alarm delay should be short in order to immediately alert the registered nurse if there is a change in the infant’s condition.

2. **MV alarms:** MV should be set according to the infant’s clinical condition. In a sick infant, the MV should be set at +/-10% of the acceptable range. As the infant’s condition improves, or during weaning the MV can be set at up to +/-30% of the acceptable range.
   Target TV is 4-7mls/kg. 1
   Target MV is 200-400mls/kg. 1

3. **High frequency alarm:** The Panting alarm can be set at 20-200 but defaults to 100 when ventilator is switched off. The high frequency alarm will be activated when the rate of the ventilator is higher than the level set by the operator. This may occur if the infant is active and triggering excessive breaths (check sensitivity). Confirm alarm with infant’s respiratory as mucous / water in the circuit will trigger auto breaths and inadvertent hyperventilation.
4. Apnoea alarm: The apnoea alarm defaults to 20 seconds. It should be set at lower limits if the infant is ventilator dependent.

5. Tube obstruction: This alarm will be triggered if the ETT / circuit is blocked with secretions or if it is kinked.

6. Circuit leak: This alarm will alert the registered nurse to a dislodged tube or leak in the circuit.

7. Humidification (Fisher & Paykel 850 / 750 series) will alarm if the temperature is not reaching target levels – see humidification for convention and high frequency oscillation.

The Stephanie CE0482
The alarm limits can be set automatically in limits above and below the current ventilator setting values. This is done by selecting Alarm limits with the rotary dial and selecting Automatic. Alarms may also be set manually.

Confirm that the ventilator and the humidifier base are connected to the blue back-up power points. Ventilator tubing is changed every 7 days to reduce the risk of colonisation and ventilator acquired pneumonia (VAP). Ventilator tubing changes are only performed if the infant is clinically stable (not HFO or nitric oxide). Ventilator changes are performed by 2 RNs. Ensure the registrar/fellow is in the unit.

Nursing management and additional observations
Monitors: Ensure monitor alarms are checked at the beginning of each shift and/or prn and are set according to relevant protocols and/or condition of infant. Document same on the intensive care flow chart. Ensure alarms are active before the infant is left unattended eg when called to answer telephone enquiries etc.

Infants greater than/equal to 28 weeks may have both pulse oximetry and transcutaneous oxygen / CO2 monitoring used. Pulse oximetry is used for all infants less than/equal 27 weeks gestation. As skin matures usually more than two weeks postnatal age) and there is a need to monitor CO2, application of transcutaneous oxygen / CO2 monitors is appropriate.

Manual ventilation: An anaesthetic bag with manometer or Neopuff® with appropriate size mask must be available for each infant on assisted ventilation or when oxygen requirements are greater than 50%. These devices must be connected to blended gas and control set at infant’s target oxygen concentration. Document same on the intensive care flow / oxygen chart. Ensure gas flow is turned off after checking system and when not in use. This will avoid accidental hyperoxygenation.

Suction: Ensure that the suction tubing connections are correct at the beginning of each shift. Document same on intensive care flow / oxygen chart. Suction pressure is set at minus 100mmHg. Ensure suction is off when not in use – negative pressure causes excess noise and possible trauma if in contact with the infant’s skin. Suction tubing is changed daily and the circuit is routinely changed Tuesdays, Fridays and Sundays. Suction is generally not performed within 6 hours of surfactant administration – see suction protocol.

Central venous and arterial line placement: Verify placement of venous and arterial central lines. If the infant has central and/or arterial lines, proper placement should be confirmed by inspection of x-rays. Monitor central line and arterial line insertion site and document pressures hourly – see umbilical / PICC and arterial line protocols http://www.cs.nsw.gov.au/rpa/neonatal/
Arterial blood gases - For frequency, method of collection and interpretation – see Arterial blood gas, arterial line & i-Stat protocols.


**Sedation:** A morphine infusion is usually prescribed for infants who are intubated and ventilated in order to provide sedation and comfort – see intubation / sedation protocol Change the infant’s position with nursing care. Continuously assess the infant’s level of comfort and alert the fellow/registrar if additional sedation is required. Where extubation is considered likely within the next 6 – 12 hours infants may not be sedated.

**Positioning and pressure care:** Minimal handling is used for most infants needing mechanical ventilation. Position the infant to promote flexion and support the ETT in correct alignment to avoid pressure on the nares or lips. The infant can be positioned supine, left lateral, right lateral and prone. Change position before suction and / or with nursing care as appropriate. The prone position can be used to promote oxygenation after umbilical lines have been removed.

Infants who are muscle relaxed, those with oedema and / or shock are at increased risk for pressure areas – observe and document condition of skin especially the around the ears, sacrum and heels. Avoid pressure from electrodes, temperature probes and tight tapes etc. Observe for areas of erythema from use of transcutaneous probes and re consider application. Frequently check creases in the neck, axilla and groin regions where accumulation of moisture may facilitate development of excoriation and thrush. Consider use of a soft developmental care mattress.

**Chest physiotherapy**

RNs should have a good knowledge of each body position and its use to promote oxygenation and drainage of secretions. Chest physiotherapy is not routine and the potential advantages for an individual must be discussed with the duty neonatologist prior to its use – see protocol Chest Physiotherapy http://www.cs.nsw.gov.au/rpa/neonatal/ RNs must be skilled at providing chest physiotherapy and the physiotherapist should be consulted to provide additional support and guidance. The RN should stay and assess the infant’s condition during chest physiotherapy to administer additional oxygen and support as required.

**Supporting parents**

Admission to the NICU and the need for mechanical ventilation can be stressful for the parents. Neonatal nurses are in a unique position to promote attachment and relieve parental stress. Informing parents about their infant’s condition, the need for mechanical ventilation and frequently updating them about their infant’s progress are essential to good nursing care.

**Minimising risk and possible complications associated with ventilation**

The registered nurse should have a comprehensive knowledge about the possible complications of mechanical ventilation in order to minimise risk, prevent problems and provide immediate intervention when necessary.
### Prevention of Endotracheal and Ventilator Complications

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<th>Potential Problem</th>
<th>Nursing Management – strategies to prevent complications</th>
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<tr>
<td>Mal position / accidental dislodgement of endotracheal tube(^{15,16,17,18})</td>
<td>Confirm placement of ETT with CO(_2) detector(Pedicap® Nellcor)  &lt;br&gt;Confirm position on chest x-ray - ETT should be at T2 -T3  &lt;br&gt;Secure the ETT with correct taping at nares / mouth with correct alignment of tube and circuit  &lt;br&gt;Document position of ETT and confirm position at beginning of each shift and after handling  &lt;br&gt;Measure length of ETT from lips / nares to suction port after handling or suction  &lt;br&gt;Avoid over extension of the neck and ensure body position is correctly aligned and well supported  &lt;br&gt;Avoid excessive drag on the ETT which may cause dislodgement – ensure the circuit is secured  &lt;br&gt;Provide adequate sedation if infant is restless.  &lt;br&gt;Watch for symmetrical chest movement and listen to the quality of breath sounds  &lt;br&gt;Ensure alarms on ventilator &amp; humidification are set appropriately</td>
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<tr>
<td>Occlusion of endotracheal tube(^{16,17,18,19,20})</td>
<td>Individualise suction to keep ETT free of secretions and mucous  &lt;br&gt;Observe chest expansion and oxygenation after surfactant administration  &lt;br&gt;Provide delivery of pre warmed, humidified gas to prevent tenacious secretions and mucus plugging  &lt;br&gt;Prevent excessive rainout by insulating circuit (preferred) or decreasing humidity  &lt;br&gt;Ensure ETT tube is not kinked and the circuit is correctly supported  &lt;br&gt;Ensure alarms are set appropriately  &lt;br&gt;Use pulmonary mechanic monitoring to observe for asymmetry of volume graphs</td>
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<tr>
<td>Leak around endotracheal tube(^{16,17,20})</td>
<td>This is best avoided by ensuring an appropriately sized endotracheal tube at intubation  &lt;br&gt;Observe for leak at beginning of shift or after handling  &lt;br&gt;Report leak and possible compromise of ventilation  &lt;br&gt;Sudden leak may mean ETT has been accidentally dislodged  &lt;br&gt;Re intubation may be required if ventilation compromised</td>
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<tr>
<td><strong>Ventilator connections or circuit complications</strong></td>
<td>Check ventilator circuit, that is inspiratory &amp; expiratory limbs are correctly attached at beginning of shift and after nitric oxide is added. Ensure humidifier is turned on and set at target temperature. Avoid excessive rainout but observe misting in ETT. Ensure ventilator and humidification alarms are appropriately set. Ventilator circuit should connect with ETT on the flat – circuit should <strong>never</strong> be above the ETT.</td>
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<tr>
<td><strong>Airway and Lung Injury including prevention of barotrauma / volutrauma &amp; pneumothorax</strong></td>
<td>Frequently inspect nares / mouth during oral hygiene for pressure or other trauma from ETT / suction. Ensure ETT is secured without pressure on nares or lips. Deliver pre-warmed, humidified gas to prevent airway injury. Plan extubation as soon as infant’s condition permits. Avoid excessive PIP – avoid over ventilation. Maintain TV ( \approx 3-4 \text{ mls} / \text{kg} ). Do not drive CO(_2) too low – discuss target levels with duty neonatologist / fellow. Initiate prompt changes to ventilation with improvement to lung compliance after surfactant – set alarms appropriately. Manage un synchronised ventilation using sedation / position techniques. Reduce sensitivity setting in larger more mature infants. Prevent rainout using insulation of circuit (preferred) or reducing humidification. Ensure misting is observed in ETT and proximal circuit. Perform arterial blood gases frequently to facilitate weaning / optimise ventilation.</td>
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Long term complications
Retinopathy of Prematurity
Chronic Lung Disease
Cerebral palsy

Target oxygen levels appropriate to gestation, post natal age and condition on infant to prevent hyper oxygenation
Calibrate and set alarms on oxygen analyser
Only attach blended air / oxygen to anaesthetic bags & Neopuff®
Set alarms on all ventilators and all devices used to monitor oxygenation

Prevent airway damage through good nursing management and attention to detail as described above

Prevention of preterm birth
Prevention of nosocomial infections

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<td>Target greater than 90%</td>
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<tr>
<td>Infant in oxygen</td>
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<td>90%-95%</td>
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<tr>
<td>Transcutaneous  TcO₂ mmHg</td>
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<td>50-60 mmHg</td>
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<tr>
<td>Transcutaneous  TcCO₂ mmHg</td>
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<td>45-55 mmHg</td>
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<td>Infant in air</td>
<td>SpO₂%</td>
<td>Target greater than 95%</td>
</tr>
<tr>
<td>Infant in oxygen</td>
<td>SpO₂%</td>
<td>92-98%</td>
</tr>
<tr>
<td>Transcutaneous  TcO₂ mmHg</td>
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<td>60 – 80 mmHg</td>
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For the term infant with Persistent Pulmonary Hypertension of the Newborn (PPHN) then discuss target oxygen and alarm limits with staff specialist & document on NICU chart. Modify target oxygen only after discussion with staff specialist / Fellow.

Transcutaneous  TcCO₂ mmHg 45-55 mmHg 40-60 mmHg
References


