1.0 PURPOSE:

1.1 To provide a process for the respiratory management of neonatal patients in:
- Neonatal Intensive Care Unit (NICU)
- High Risk Newborn Resuscitation Room (Resus)
- Neonatal Transport Program (Transport)
- Intermediate Care Nursery (IMCN)

Note: All recommendations are approximate guidelines only and practitioners must take into account individual patient characteristics and situation. Concerns regarding appropriate treatment must be discussed with the attending neonatologist.

2.0 PRACTICE OUTCOME:

2.1 To provide appropriate ventilation to minimize ventilator induced lung injury (barotrauma, volutrauma, atelectotrauma, oxygen toxicity) and optimize oxygenation to prevent chronic lung disease.

2.0 GENERAL GUIDELINES

Note: for a complete list of abbreviations used in this guideline see Appendix A.

2.1 To determine ventilation strategy consider:
- Pathophysiology of the respiratory disease process
- Clinical assessment of the patient
- The limitations of the ventilator chosen
- Patient ventilator interaction
- Oxygen saturation
- Ventilation-based respiratory mechanics
- Blood gases

2.2 Ventilation plans, documented in orders and progress notes include:
- Mode of ventilation
- Initial ventilator settings
- Parameters for potential weaning or escalation if necessary
- Timing of blood gas sampling

2.3 Obtain arterial blood gas as soon as possible after initiating ventilation.
Note: If an arterial sample is not possible, a central venous gas such as from the umbilical vein will give a measure of ventilation – venous pCO₂ is approximately 6mmHg > arterial. Venous pH is generally 0.03 lower than arterial.

2.4 Assess patient and monitor pulmonary graphics for:
- Chest over-distention / hyperinflation (q1h).
- Blood pressure changes resulting from change in ventilation. (q1h) if arterial line present.
- Pain and agitation (at least q4h).

2.5 Immediately following intubation, if medications to induce paralysis (RSI) have been used either for the intubation or for other indications, set V̇g to 4.5 ml/kg and set the rate to 50 breaths per minute (bpm) to prevent hypercarbia. If infant remains paralyzed then do an arterial blood gas as soon as possible (within ~ 20 mins) following the intubation to assess mechanical ventilation needs. (See Child Health Clinical Practice guideline 80.120.1311 Endotracheal Intubation: Assisting With).
2.6 If the ETT leak is > 40% investigate the cause of the leak and if necessary consider reintubation with a larger tube unless there is a clinical contraindication to the procedure.

2.7 **Routine Blood Gas Parameters Targets:** (arterial and capillary except where indicated)

- \( \text{PO}_2 \): 50-70mmHg (arterial only)
- \( \text{PCO}_2 \): 45-55 mmHg (may be higher as long as pH is >7.2)
- pH: > 7.2
- \( \text{HCO}_3^- \): > than 17.5 mmol/l
- BD: no lower than -6
- BE: no higher than +6
- Lactate: < 2

*Deviations from these should be made for cardiac patients and those with chronic lung disease. Parameters will be set according to the pathophysiology and documented in the clinical record.*

2.8 Determine frequency and timing of blood gas sampling with RRT, physician/NNP/Clinical Assistant and bedside nurse in consultation.

2.9 Any time pCO\(_2\) is greater than 70 or less than 35 mmHg with a resulting pH <7.20, draw a blood gas no more than 30 minutes post parameter change. In some cases, such as with BPD, pCO\(_2\) >70 and might be acceptable. Others with HIE, Co\(_2\) <35 as part of washing Co\(_2\) to compensate the metabolic acidosis and these are acceptable for such cases.

2.10 Change patient’s position q4h or as tolerated. Include prone as tolerated.

2.11 Consider extubation according to the process and criteria outlined in Appendix B.

2.12 When considering reintubation of a previously intubated neonate follow the steps and criteria outlined in Appendix C.

3.0 **ASSIST CONTROL WITH VOLUME GUARANTEE (AC + Vg)**

3.1 **Selection Criteria**

3.1.1 Assist Control with Volume Guarantee (AC/Vg) is used for patients with moderate to severe lung disease.

3.2 **Management Guidelines**

3.2.1 Rate:
- Infant breathing spontaneously start at 40 breaths per minute (bpm).
- Infants coasting with ventilator and severely depressed infant start at 50 bpm.

3.2.2 Inspiratory Time (Ti): .25 - .40 seconds
- Take into consideration the flow waveform to identify best inspiratory time i.e. inspiration comes to zero flow with minimal pause to allow for best synchronization between ventilator and patient.

3.2.3 Flow: 6-10 lpm. (Set to lower range for smaller patients and upper flow range for larger patients).

3.2.4 Positive End Expiratory Pressure (PEEP): +5 to +7 cmH\(_2\)O depending on pathology of the lung disease and cardiovascular profile of the patient.
3.2.5 Volume Guarantee (Vg): set 3.5 – 5 ml/kg.
If Vg of 5.0ml/kg required, consider a chest x-ray to determine:
   a) Position of endotracheal tube and lung inflation.
   b) Whether using high frequency ventilation would improve ventilation and reduce
      ventilator-induced lung injury.

4.0 PRESSURE SUPPORT (PC PSV + Vg)

4.1 Selection Criteria

4.1.1 Pressure Support Ventilation with Volume Guarantee (PSV + Vg) for patients with an intact
       respiratory drive who are recovering or who have mild or no lung disease. And to assess
       readiness for extubation after AC/VG.

4.2 Management Guidelines

4.2.1 Review the MAP after switching to PSV and if necessary increase the Positive End
       Expiratory Pressure (PEEP) to maintain MAP and stabilize lung volume. (Patient may
       become tachypneic if MAP is inadequate).

4.2.2 Set Ti 50% longer than the patient's measured spontaneous inspiratory time.

4.2.3 Set the backup rate to 10 - 20 bpm.

4.2.4 Initiate ventilation with volume guarantee (Vg) set at 4 ml/kg. Adjust within range 3 – 5 ml/
       kg based on arterial blood gases and monitoring of pulmonary graphics.

4.2.5 For any patient under 40 weeks gestation who require tidal volumes > 5ml/kg determine risk
       for volutrauma with data found in the ventilator menu. Consider alternate ventilation
       strategies (i.e. AC/VG or high frequency ventilation) or changing PEEP.

4.2.6 For small premature infants (approximately<1500 grams) use PSV+Vg for no more than 2
       hours to evaluate respiratory drive and determine readiness for extubation.

5.0 NASAL CONTINUOUS POSITIVE AIRWAY PRESSURE (NCPAP)

5.3 Selection Criteria

5.3.1 NCPAP modes for patients with an intact respiratory drive who are recovering, who have
       mild, or no lung disease, or who are weaning from mechanical ventilation.

5.3.2 Trigger Pressure Assist (TrPA) or SNIPPV for very small infants or as a transition from other
       ventilation modes after extubation.

5.4 Management Guidelines

5.4.1 After extubation set PEEP at + 6 (or higher according to the infant’s condition) cmH2O. If
       using TrPA set pressure assist at 9/+6 mmH2O and Ti at 0.3-0.4 seconds, rate 20 -30 per
       minute.

5.4.2 Maintain the CPAP during all procedures including routine hygiene, weighing, changing
       CPAP equipment etc. Two people are often required in order to ensure that FRC is not lost.
5.4.3 Perform hourly assessments:
- Check the hat and prongs/mask ensuring that the nose and ears are in normal position and eyes are clearly visible.
- Ensure generator is stable and secure.
- Assess infant comfort.
- Ensure delivery of the required level of NCPAP.
- Assess work of breathing.
- Record set and measured PEEP and FIO₂.
- Assess skin integrity.

5.4.4 Select optimum prong or mask size. Alternate prongs & mask q 3-6 hours. If prongs do not fit, alternate between 2 sizes of mask.

5.4.5 Use pacifiers and appropriate sized hats with chin straps as necessary to decrease air leak from the infant's open mouth.

5.4.6 Routine suctioning is not required. Assess patency of nares q3-4h. Clean prongs or mask with alcohol q6-8h. Allow to air dry and do not store in an airtight container.

5.4.7 Place indwelling orogastric tube and open to air (except for approximately 30-40 minutes post-feeds) Use an 8Fr for babies >1000 gm weight and 6 Fr for those <1000 gm. Consider aspirating the feeding tube to maintain patency and decompress the stomach q3-4h.

5.4.8 Place positioning devices such as a firm pad under the infant's chest to maintain optimum airway position.

5.4.9 Assess nares for skin breakdown q6-8h and more often if breakdown noted. Cover reddened areas with hydrocolloid dressing materials until skin is intact. Alternate between prongs and mask.

5.4.9 If infant < 28 weeks gestation:
1) Start with mask.
2) Do not routinely alternate from mask to prongs for 24-48 hours after birth to prevent loss of FRC. Select whichever provides the best seal for that neonate.
3) Maintain ordered pressure (CPAP level) at all times during care and sleep.

6.0 HIGH FREQUENCY VENTILATION (HFV)

6.1 Selection Criteria

6.1.1 HFV- two mode options: Jet High Frequency Ventilator (HFJV or Jet) or High Frequency Oscillatory Ventilator (HFOV or Oscillator) may be selectively chosen for severe lung pathology.

6.1.2 The Jet High Frequency Ventilator (HFJV or Jet) has passive exhalation and increased inspiratory gas velocity compared to HFOV. Consider it for:
- Air leak syndromes (i.e.: pulmonary interstitial emphysema, tracheobronchial fistula)
- Excessive secretions (i.e.: pneumonia, Meconium Aspiration Syndrome)
- Pulmonary hemorrhage
- Non-homogeneous lung disease
- Hemodynamic compromise (when HFV is required but MAP is a concern, one can usually ventilate at a lower MAP).
- Diaphragmatic Hernia
- Congenital cystic adenomatoid malformation
- Severe prematurity patient under 25 weeks
- Hypoplastic lung
- Pulmonary interstitial emphysema
• Esophageal atresia with tracheo-esophageal fistula
• Tracheobronchial fistula
• Acute Respiratory Distress Syndrome
• Persistent Pulmonary Hypertension of the Newborn (PPHN) on inhaled nitric oxide (iNO)

6.1.3 High Frequency Oscillatory Ventilator (HFOV or Oscillator) has active exhalation and increased expiratory gas velocity compared to HFJV. Consider it for:

- Severe Respiratory Distress Syndrome (RDS)
- Acute Respiratory Distress Syndrome (ARDS)

6.1.4 Before initiating HFV review:

- Pathophysiology of the disease process
- Patient suitability
- Patient diagnosis
- Adequate fluid volume status
- Adequate cardiac contractility (heart must maintain adequate performance with constant MAP from oscillation)

6.1.5 Initiate HFV when there is inability to adequately oxygenate or ventilate using the conventional ventilation to its limits. (For example tidal volume required greater than 5ml/kg, rate set at 60 bpm with the pCO2 at an unacceptably high level.) Consider HFV when the following circumstances persist for at least 2 hours after a dose of artificial surfactant:

- The MAP on conventional ventilation is greater than 12.0 cm H2O.
- The tidal volume set on the ventilator of 5ml/kg is not adequate to ventilate the patient. Tidal volume is set to birth weight for the first 2 weeks of life. Dry weight should be used if the baby is edematous.
- The peak inspiratory pressure (PIP) is consistently greater than 25cm H2O, despite all efforts to optimize conventional ventilation.
- The FiO2 cannot be weaned to less than 60% despite all efforts to optimize conventional ventilation.

6.1.6 Relative contraindications for HFOV:

- Poor cardiac function
- Dehydration state (low fluid volume)

6.3 Management Guidelines

6.3.1 Monitor the patient with a transcutaneous oxygen saturation monitor.

6.3.2 Do chest X-rays as often as required to help determine lung inflation.

6.3.3 Do a blood gas within 30 minutes of initiating HFV and after any setting change.

6.3.4 Have an RRT present during endotracheal suctioning. In most situations maintain both the Jet and iNO settings during suctioning. Depending on the clinical situation, in some cases it may be necessary immediately prior to suctioning the RRT to decrease iNO to zero, suction, then immediately increase the iNO back to preset value in order to avoid large increase in iNO.

6.4 HFOV (Babylog 8000 plus or VN 500)

6.4.1 MAP: Start 2 cm H2O Higher than the MAP on conventional ventilation. Increased until the lung is open (demonstrated by chest x-ray), and O2 saturation is acceptable and the FiO2 can be weaned.

- Once MAP has been optimized consider weaning the MAP.
6.4.2 Amplitude (Delta Pressure) used for CO₂ management:
- The baby must have adequate chest movement described as ‘gently wiggling down to the abdomen’. Consider starting with amplitude double the MAP then adjust according to blood gas and X-rays.
- If the delta pressure (Amplitude) is close to 3 times greater than the MAP, consider decreasing the frequency (ie avoid getting close to delta P:MAP ratio of 3:1).

6.4.3 Frequency: Set at 8 Hz and adjust to the clinical pathology of the patient.
- Consider lower frequency when air trapping is suspected.
- If frequency is decreased, consider decreasing delta pressure.
- Observe chest wiggle before and after frequency change.

6.4.4 Use the Babylog primarily for babies who are less than 1200 grams, and not for babies >2000g. The VN 500 can be used for all newborns and may be the better choice for less work of breathing, comfort and overall better ventilation than the Babylog.

6.4.5 For the Babylog 80000 plus, set MAP with the PEEP control.

6.4.6 If using the Babylog, set the Amplitude as percentage with zero being the lowest amount of power and 100% is the most power that can be generated.

6.4.7 For HF Vg on the VN500, target high frequency tidal volumes to 2.0+/− 0.5 ml/kg (lower volume can be used if CO₂ values permit).

6.4.8 Compare the DCO₂ to the blood gas CO₂ (and monitor tidal volumes). As DCO₂ goes up CO₂ goes down.

6.4.9 If recruitment breaths must be used, set a maximum of 5 bpm background breaths. Closely monitor the background breaths to achieve tidal volumes of 3.5 to 5ml/kg.

6.6 HFJV

6.6.1 Frequency: set according to the pathophysiology.
- Start with frequency of 240-360 bpm depending on the clinical indications and size of the baby.
- Lower frequencies should be used anytime inadvertent PEEP (peep measured higher than set) and/or hyperinflation on chest x-ray have been detected.

6.6.2 On time or Jet Ti: set at 0.02 sec but can be increased to 0.034 sec (maximum) for larger infants and infants who are reaching the set upper limit of PIP on the Jet. Increasing the Jet Ti can result in increased tidal volume delivered by the Jet. If Ti is increased the Jet rate must be less than 300 bpm to prevent air trapping.

6.6.3 PIP: Set high enough to achieve chest wiggle and desired blood gas CO₂.
- Any change in PIP affects tidal volume.

6.6.4 PEEP: Set to optimize lung volume which is determined by chest x ray and is reflected by a stable FiO₂.
- To maintain a constant delta pressure, a concomitant change in PIP should be considered with each change in PEEP.

6.6.5 Intermittent Ventilation (IMV) Breaths(recruitment breaths): Not required for most patients.
- Consider IMV breath rate 1-5 bhp if lung collapse present.
- Consider increasing PEEP.
- On a conventional ventilator use low pressures (PIPs) and long inspiratory times (0.4 to 0.5 seconds). Conventional PIP set must be lower (2-3 cmH2O) than PIP set on the Jet.
- Discontinue as soon as the lung has been recruited.
7.0 PRIMARY AUTHORS

7.1 John Minski, Respiratory Therapy Clinical Specialist, NICU HSC
7.2 Dr. John Baier, NICU Assistant Medical Director, HSC
7.3 Dr. Ruben Alvaro, NICU Assistant Medical Director, SBH
7.4 Dr. Michael Narvey, Section Head, Neonatology
7.5 Doris Sawatzky-Dickson, NICU Clinical Nurse Specialist, HSC
7.6 Karen Bodnaryk, NICU Nurse Educator, HSC

8.0 REFERENCES


APPENDIX A

Abbreviations

AC: Assist Control ventilation mode
Bpm: Breaths per minute
BE / BD: Base excess or Base deficit
CMV: Conventional mechanical ventilation.
DCO2: Diffusion co-efficient (Draeger ventilators)
ETT: Endotracheal Tube
FiO2: Fraction of inspired oxygen
FRC: Functional residual capacity
HCO3: Bicarbonate
HFV: High frequency ventilation
HFJV: High frequency jet ventilation
HFOV: High frequency oscillatory ventilation
IMV: Intermittent ventilation
iNO: Inhaled nitric oxide
MAP: Mean airway pressure
NCPAP: Nasal continuous positive airway pressure
N-PASS: Neonatal Pain Agitation and Sedation Score
pCO2: Partial pressure of carbon dioxide
pO2: Partial pressure of oxygen
pH: Measure of the molar concentration of hydrogen
PEEP: Positive end expiratory pressure
PPHN: Persistent Pulmonary Hypertension of the Newborn
PSV: Pressure support ventilation
RSI: Rapid Sequence Intubation
SNIPPV: Synchronized Nasal Positive Pressure Ventilation
Ti: Time of inspiration
TrPA: Trigger Pressure Assist
Vg: Volume guarantee
APPENDIX B

Extubation Criteria

Extubation should be considered when all the following criteria are met
a. PaCO2 below 65 mm Hg with a pH higher than 7.20
b. FIO2 below 0.35
c. Ventilation parameters
   i. Conventional ventilation or HFJV: MAP < 10 cm of water
d. Demonstration of adequate respiratory reserve
   i. CMV: Trial of PSV VG for 15 min – 1 hour
   ii. HFJV: 5 minute trial of CPAP at pressure 2 cm H2O below MAP on HFJV

Consider optimizing caffeine prior to extubation.

Extubate if no previous attempt within the last 72 hours

In case of a disagreement among team members call Neonatologist
APPENDIX C

Reintubation Criteria

Steps To Take When Considering Reintubation
1. Perform physical exam and assess patient for possible reasons for a deterioration
2. Consider
   a. Ordering a blood gas & chest x-ray
   b. Consider repositioning prone
   c. Consider a mini load and increased dose of caffeine

If after addressing the above steps, reintubation **should not be considered** unless one of the following criteria have been met:

1. Significant apnea
   a. Need for 3 episodes of PPV in 3 hours after caffeine been optimized
   b. One apnea requiring PPV for longer than **2 minutes**

2. Respiratory failure
   a. pH < 7.20 and pCO₂ > 65 on 2 consecutive blood gases (cap or art)
   b. Hypoxemia: persistent FiO₂ > 0.5 using nCPAP of at least 7 cm H₂O

Ideally discuss with Neonatologist prior to reintubating if criteria met, or if other circumstances indicate need for reintubation