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High Frequency Oscillatory Ventilation in Neonates

Guideline Responsibilities and Authorisation

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Procedure Review History

Version	Updated by	Date Updated	Summary of Changes
1	Pera Ratana-Holdcroft Javeed Travadi	Jul 2024	Medical & Nursing Guidelines merged **0396** High frequency oscillation ventilation – Nursing care of infant on HFOV & **2625** High frequency ventilation of neonates withdrawn Recruitment process detailed Volume target during HFOV outlined Ongoing care section updated

High Frequency Oscillatory Ventilation in Neonates

Contents

High Frequency Oscillatory Ventilation in Neonates

1 Overview

1.1 Purpose

To outline the specific procedure for the care of babies needing High Frequency Oscillatory Ventilation (HFOV) specifically for the ventilator used in Neonatal Intensive Care Unit (NICU) at Waikato Hospital. This procedure is based on the best practice guidelines according to Lippincott Procedures.

1.2 Staff group

Health NZ Waikato staff working in Neonatal Intensive Care Unit (NICU).

1.3 Patient group

Babies in NICU

1.4 Indications

- Severe surfactant deficiency HMD not responding to conventional ventilator settings (e.g. peak inspiratory pressure PIP >25cm H_2O in babies below 1500g and 30cm in babies above 1500g; need for tidal volumes VT ≥ 8mL/kg)
- Severe parenchymal lung disease (e.g. meconium aspiration syndrome, pneumonia) with or without persistent pulmonary hypertension (PPHN)
- Pulmonary hypoplasia (secondary to Preterm prolonged rupture of membranes (PPROM), diaphragmatic hernia)
- Pulmonary Interstitial Emphysema (PIE), pneumothorax
- As directed by SMO

NOTE: Caution is needed when HFOV is used with high mean airway pressures as this may result in impaired venous return and subsequent reduced cardiac output causing hypotension requiring inotropic support or volume expansion.

1.5 Definitions

DCO_2	CO_2 diffusion coefficient, also known as the gas transport coefficient It describes the minute ventilation in HFOV i.e. freq x VT^2 An increase in DCO_2 corresponds with a decrease in $PaCO_2$
Delta-P/Amplitude ΔP	The peak-to-trough swing across the mean airway pressure, resulting in a volume displacement and a visual CHEST WIGGLE. ΔP is the difference between the maximum and minimum oscillatory pressures. HFOV = CPAP (continuous positive airway pressure) with chest wiggle. Chest wiggle factor is a visible vibration of the chest wall from the shoulder to the umbilicus.
Frequency	This is the respiratory rate during HFOV expressed in Hz (Hertz) ranging from 5-15 Hz/minute 1 Hz = 60 breaths (respiratory cycles)
Gas exchange in HFOV	Oxygenation is directly related to FiO_2 and the lung volume. In HFOV, the mean airway pressure is used to distend the lung volume to the optimal limits (best point of compliance) by recruiting the atelectatic lung units. Carbon dioxide level (pCO_2) – inversely related to the alveolar ventilation Minute ventilation in HFOV = freq (Hz) x VT^2 (see DCO_2 below)
High Frequency Oscillator	A machine which uses a piston to generate oscillatory wave form at the airway opening with the following characteristics: - Frequency above 2 Hz (1 Hz = 60 breaths/min) - Active inspiration and expiration - Tidal volumes less than the anatomical dead space (1 – 3 mL/kg)
High frequency oscillatory ventilation (HFOV)	HFOV is an alternative way to give respiratory support to the newborn baby with respiratory failure. It is a type of mechanical ventilation that uses constant distending pressure with pressure variations oscillating around the mean airway pressure at a very high rate (300 to 900 respiratory cycles per minute). It may be used as a first or primary mode of ventilation, particularly in babies with pulmonary hypoplasia or CDH.
I:E ratio	Inspiration to Expiration ratio during HFOV This is typically set at 1:2 (default setting) In extreme cases it may be altered as advised by NICU consultant
Ti	Inspiratory time It is dependent on: • Frequency (Hz) – A lower frequency increases Ti • I:E ratio – an I:E of 1:1 indicates a larger Ti as opposed to I:E of 1:2 (however, 1:2 is preferred – see below)
Tidal volume (VT) **Stroke volume**	The tidal volume (VT) in HFOV equals dead space volumes It is dependent on: • Oscillation amplitude (delta-P). The VT increases if amplitude increases which reduces the PaCO2.Ti (inspiratory time) • Ti - In HFOV as the Ti of the respiratory cycle increases it results in a larger VT

2 Clinical Management

2.1 Competency required for nursing staff

- Registered nurse who has completed ventilator orientation and obtained competency
- Registered nurse undergoing ventilation training under the supervision of a preceptor

2.2 Equipment

- Ventilator with HFOV mode (SLE 6000).
- In-line suction catheter in situ before initiating HFOV. This is to minimise disconnections and de-recruitment of lung volume.
- Sterile water 1-litre bag (for F&P humidifier).

2.3 Procedure

High Frequency Oscillatory Ventilation (HFOV) is an alternative modality of providing respiratory support to the neonate requiring invasive ventilation. HFOV was first described in 1977 and can be understood simply as providing 'CPAP with wiggles'. It reflects a gentler form of ventilation using supra-physiological breathing rates. HFOV may often be used as a primary mode of ventilation.

High frequency oscillators use a piston to generate an oscillatory wave form at the airway opening with the following characteristics:

- Frequency ranging from 5-15 Hz (1 Hz = 60 breaths/min)
- Active inspiration and expiration
- Tidal volumes (VT) less than the anatomical dead space (1 – 2 mL/kg)

Initiation and management of HFOV:
For optimal results it is imperative that the following supportive care is in place to correct:

- Hypotension

  Repletion of intravascular volume

  Good myocardial contractility

  Adequate venous return

- Pulmonary Hypertension

  Correct acidosis and normalise pCO_2

  Optimise systemic blood pressure

  Inhaled Nitric oxide (iNO)

Initial Settings *(indicative only – consult with SMO for appropriate individual settings)*:

A. Frequency (varies with the disease process)

- Severe HMD - (Bwt < 1500g) 12 – 15 Hz
  (Bwt > 1500g) 8 – 12 Hz
- MAS/ Pneumonia - 6 – 10 Hz
- Pulmonary Hypoplasia - 10 – 12 Hz
- Cystic PIE - 5 – 6 Hz

B. Amplitude (Delta-P)

- Start at about one and half times the maximum PIP on conventional ventilator or twice the maximum MAP on the HFOV.
- Adjust the pressure to get an adequate chest wiggle (wiggle visible up to the upper abdomen).

C. I:E ratio

- Start at ratio of 1:2. This may occasionally need to be adjusted to 1:1 **after** discussion with SMO.

D. Mean Airway Pressure (MAP)

Low Volume strategy:
MAP is set at the same level as of conventional ventilation. Useful in babies with significant pulmonary hypoplasia or air leak syndrome.

High Volume strategy / Open Lung Ventilation:

Set MAP to achieve 'open lung ventilation' through optimal MAP via alveolar recruitment. The basic steps of recruitment are described below (also see Figure 1 and an example in Figure 2) – **always** discuss with consultant Neonatologist (SMO) for finer details of recruitment. The time period of recruitment, highest MAP and lowest/highest FiO_2 should always be recorded in patient's clinical notes. [**Deactivate OxyGenie during recruitment**].

1. If transitioning from conventional ventilation (patient triggered ventilation - PTV) to HFOV, set initial MAP at 2cm of H_2O above the MAP on conventional ventilator. If starting HFOV as primary mode, set initial MAP at 12-14 cm of H_2O (or as advised by SMO).
2. Increase MAP by 2cm every 3-5 minutes.
3. Wean FiO_2 to achieve desired oxygen saturation (SpO_2)
4. Continue increasing MAP by 1-2 cm (do not exceed 25cm of H_2O) until no further improvement in FiO_2.
5. Now slowly decrease the MAP in steps of 1-2 cm every 3-5 minutes, keeping the oxygen saturation within the target range and ensuring no change in FiO_2 required to maintain target SpO_2.

6. If SpO_2 drops (required FiO_2 increases) at any stage – critical MAP to maintain 'open lung' has been crossed.
7. Stop weaning MAP
8. Increase MAP to 4 cm above that in step 6 – wait for 5 minutes
9. Reduce MAP to achieve final MAP = step 6 MAP + 2 cm

Figure 1

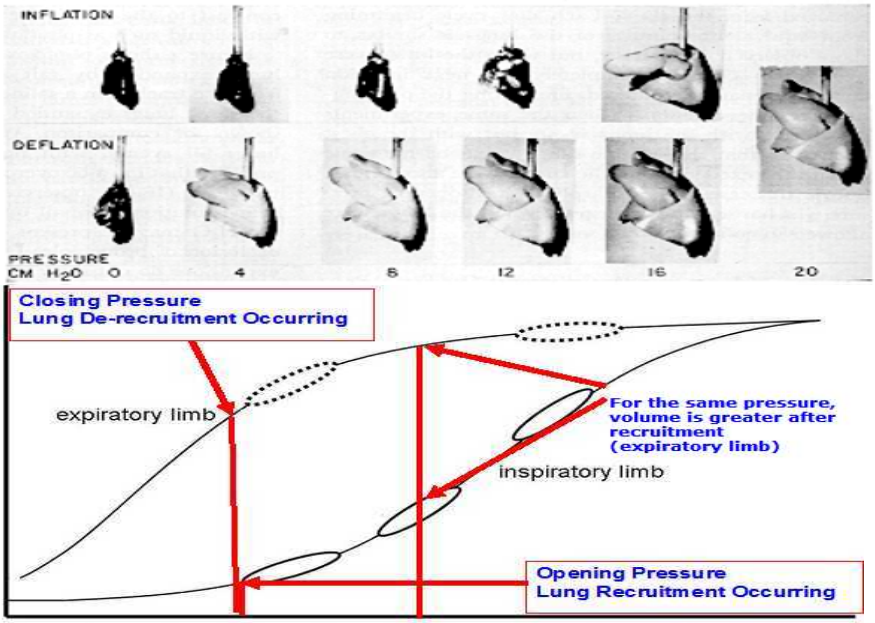
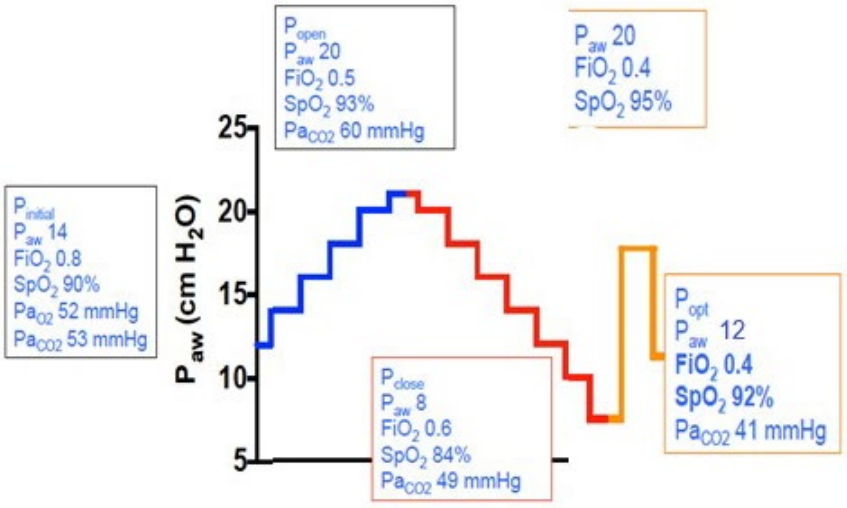


Figure 2: Recruitment manoeuvre (**example only**)



Mean Airway Pressure (MAP) settings for specific lung pathology:

- HMD & MAS/Pneumonia – perform alveolar recruitment manoeuvre.
- Pulmonary Hypoplasia & Cystic PIE – modified careful recruitment *OR* set the MAP at 10 to 14cm of H_2O (**always** consult with SMO).

Diseases to avoid recruitment manoeuvre (unless discussed with SMO):

- PPHN with normal lung parenchyma (Primary PPHN)
- Pulmonary Hypoplasia
- Congenital Diaphragmatic Hernia (CDH)

2.4 Volume targeted ventilation in HFOV

HFOV provides much smaller tidal volumes, equal to dead space (anatomical + equipment). Targeting tidal volume in HFOV allows for a more stable $PaCO_2$ with auto-adjustment of amplitude to provide consistent minute ventilation delivery. This is particularly important in HFOV since the tidal volumes during HFOV have a significant impact (VT^2) on minute ventilation and CO_2 clearance.

Always discuss with SMO for appropriateness of using HFOV + VT

Setting target VT in HFOV:

i. Starting setting = 2mL/kg (range 1.5 – 3mL/kg)
ii. Adjust tidal volume settings by 0.1-0.2ml/kg (increase for high CO_2; decrease for low CO_2)

NOTE: The minimum total VT setting possible for the SLE6000 varies from 2-3ml. HFOV + VTV will therefore not be suitable for babies with weight <2kg.

The table below provides a quick guide to other ventilator settings when using HFOV + VTV:

	Role in HFOV + VG	**Settings**	**Trouble shooting**
MAP	Same as HFOV without VG	Use either low lung volume or open lung volume strategy as appropriate (see above).	Hyperoxia: Reduce FiO_2 first, then MAP. Hypoxia: Increase FiO_2 first then MAP. MAP can be increased or decreased as per the clinical condition and x-ray. Consider re-recruitment manoeuvre as required.
Amplitude ΔP	The tidal volume decides the ΔP and it will vary Continued over page	Set the Amplitude at 5-10 cm above Continued over page	Low or high CO_2 needs adjustments in targeted VT rather in amplitude. Continued over page

	depending on the underlying lung dynamics.	the amplitude needed to deliver desired VT.	If target VT not achieved with maximum set amplitude, adjust amplitude as necessary.
Frequency	Same as HFOV without VG.	Set frequency as per the lung pathology and gestation.	Adjusting the frequency will not affect the CO2 as ventilator will alter amplitude to maintain the set tidal volume.
I:E ratio	Same as HFOV without VG.	Start at 1:2	In exceptional cases, this may need to be adjusted to 1:1 – always discuss with SMO

2.5 Further Management

- After the baby is stabilised on the initial setting obtain a blood gas within 30-minutes.
- Consider a chest X-ray within 2-hours of commencing HFOV.
- Re-adjust the settings as required (also see Figure 3)

A. **Oxygenation** (PaO_2 / SpO_2):

- If high - decrease FiO2 or MAP
  - Aim to decrease FiO2 to <0.4 (supplemental oxygen < 40%) – OR as dictated by baby's condition and determined by SMO
  - Once desired FiO2 achieved and maintained, reduce MAP carefully by 1cm decrements as directed by SMO
- If low - increase FiO_2 or MAP (re-recruitment or modified recruitment manoeuvre may be required – consult with SMO)

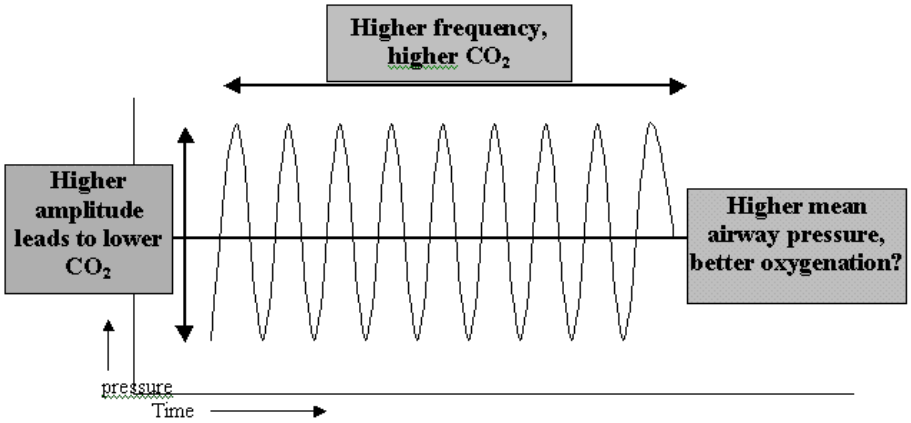
B. **Carbon Dioxide** ($PaCO_2$):

- If high - increase amplitude (delta-P) and / or decrease frequency (NOTE: in exceptional cases, I:E ratio may need to be adjusted to 1:1 – **always** discuss this with SMO)
- If low - decrease amplitude or increase frequency

Note:

(i) Start with optimal frequency for gestation and lung pathology.
(ii) Adjust amplitude to maximal acceptable prior to adjusting frequency.
(iii) Always look for mechanical and other iatrogenic reasons like blocked/ displaced tube, pneumothorax, over-inflation or atelectasis before changing ventilation settings.

Figure 3



2.6 Weaning and Extubation

- When - FiO_2 < 40% ; MAP <12cm H2O
- How - Ensure optimal frequency for gestation / disease condition

  Decrease amplitude until optimal desired $PaCO_2$

  Decrease MAP to 8 to 12cm H_2O (may be done simultaneously with reduction in amplitude – as dictated by patient condition and blood gases)

At this point, either extubate to bubble CPAP, or Tr-NIPPV (if prolonged period of ventilation OR extreme preterm neonate) as directed by SMO.

2.7 Ongoing Care & Monitoring

a. Initiating HFOV is the responsibility of the medical staff and HFOV settings (and subsequent changes) must be documented in the Level 3 treatment sheet.

b. Check settings as per prescription.

c. Visibly assess infant's chest vibration and note changes:

- Chest wiggle is an indicator of tidal volume. Even small changes in the wiggle may indicate a significant change in the neonate's condition.
- Decreased or absent chest vibration may indicate presence of ET tube secretion, obstructed ET tube, circuit or air leak, or reduced lung compliance from lung collapse or pneumothorax.

d. Recording and documentation requirements for infant on HFOV

- Frequency (Hz)
- Amplitude (Delta-P)
- Mean Airway Pressure (MAP)

- I:E ratio
- DCO_2 (minute ventilation on HFOV)
- Delivered VT (tidal volumes being delivered)
- Monitoring for ventilated infants as per NICU Nursing Procedure: Nursing care of ventilated infant (0432)

e. Consider chest x-ray for infant before, and within 2-hours of commencing HFOV to ensure adequate alveolar expansion and to check that hyperinflation has not occurred.

- Over-expansion may be indicated by the presence of more than 9 posterior ribs and/or flattened diaphragm shadow. This could impair venous return which can lead to a drop in blood pressure (BP) and oxygenation.
- Fewer than 8 posterior ribs and poor aeration of the lungs may indicate under-expansion.

f. Observe infant for potential complications:

- Hyperinflation may result in, and is manifested by, decreased cardiac output. Signs & symptoms: decreased peripheral pulse, peripheral shutdown, decreased BP and desaturation.
- Atelectasis is a potential complication that results in alveolar collapse and fluid trapping.
- Air trapping may occur as a result of rates that are excessively high, allowing air to enter alveoli without sufficient time to exit. This is especially true with use of I:E ratio of 1:1.
- Pneumothorax may be gradual over several hours. Signs & symptoms: deterioration of blood gas, SpO2, ↓BP, decreased vibration on affected side.
- Associated to Intraventricular haemorrhage.
- Necrotising tracheal bronchitis
- Under/over humidification

ETT suctioning:

- No routine suctioning.
- Refer to NICU Procedure: Endotracheal Suctioning in Newborn Intensive Care Unit (5962)

When: Decreased chest wiggle / reduced VT or reduced DCO2 (when previously higher on same settings

Increase in $PaCO_2$

Visible secretions in ET tube

Changes in vital signs / Coughing/increase in spontaneous respiration

How: Always use closed suctioning system

Increase supplemental oxygen by 5-10% (for ≯ 1 min)

Do not disconnect for suction or changing suction catheter because it is important not to lose MAP

Consider recruitment manoeuvres post suctioning in consultation with the medical team.

NOTE:

- When infant is unstable on high frequency ventilation, the inline suction catheter should only be changed if absolutely necessary, e.g. Leaking, blocked catheter or markings are unable to be seen through catheter sleeve.
- Remember: disconnection from HFOV may lead to alveolar collapse. A recruitment manouvre may be required after any disconnection.

1. Positioning

- Two nurses are required for repositioning: one to turn the infant and one to stabilise the ET tube and ventilator tubing/s.
- Repositioning should be individually assessed, e.g. infant physiological status and condition of skin integrity.
- Do not disconnect tubing during repositioning.

2. Disconnection is discouraged

- Unless mechanical failure or severe deterioration of infant's condition because disconnection can cause alveolar collapse and loss of lung volume.

3. Sedation

- Infant may require sedation to facilitate ventilation and promote comfort. Always discuss with SMO before considering commencement of sedative medications.

4. Support for family

- Provide accurate, consistent information.
- Parents to participate in cares as infant's condition allows.
- Consult with medical and nursing team if skin to skin or cuddles are appropriate.

2.8 Potential complications

- Hyperinflation
- Atelectasis
- Air trapping
- Pneumothorax
- Intraventricular haemorrhage
- Necrotising tracheal bronchitis
- Under/over humidification

3 Audit

3.1 Indicators

- All infant's on HFOV have a documented prescription including a clear description of the required settings
- Physiological assessments of infant's on HFOV are taken in accordance with this procedure
- All complications and incidents associated with HFOV are fully investigated and actions taken to prevent or reduce the risk of a reoccurrence in the future.

4 Evidence base

4.1 References

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4.2 Associated Health NZ Waikato Documents

- Arterial Lines in Neonates – Catheterisation, Sampling and Management in NICU (Ref. 1638)
- Endotracheal Suctioning in Newborn Intensive Care Unit (NICU) (Ref. 5962)
- High frequency ventilation of neonates (Ref. 2625)
- Neonatal pain and sedation: Assessment and nursing management in NICU (Ref. 1684)
- NICU Drug Manual
- Nitric oxide management in NICU (Ref. 4938)
- Nitric oxide usage (Ref. 1553)
- Nursing care of ventilated infant (Ref. 0432)