GUIDELINE

Ventilation: High Frequency Oscillatory Ventilation (HFOV)

Scope (Staff):	Nursing and Medical Staff
Scope (Area):	NICU KEMH, NICU PCH, NETS WA

Child Safe Organisation Statement of Commitment

CAHS commits to being a child safe organisation by applying the National Principles for Child Safe Organisations. This is a commitment to a strong culture supported by robust policies and procedures to reduce the likelihood of harm to children and young people.

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Aim

The purpose of this guideline is to provide clinicians with HFOV criteria for use, and the functions of each mode to ensure safe respiratory support to the ventilated neonate.

Risk

Inappropriate respiratory support for the ventilated neonate increasing the risk of ventilation acquired complications.

Theory

High Frequency Oscillation Ventilation (HFOV) uses tidal volumes that may be less than or equal to the anatomical dead space volume at a very high frequency(rate) (8 –

15 Hz = 480 – 900 breaths per minute). Theoretically adequate ventilation can be provided with reduced sheer force on the airways potentially reducing lung trauma from ventilation. In HFOV the optimal oxygenations occurs when the lung alveolar have achieved maximum alveolar recruitment without causing over distension.

At KEMH, HFOV is delivered by the Fabian FOV ventilator and at PCH by the Drager Babylog VN500 ventilator.

The SensorMedics ventilator is to be used in situations at the discretion of the treating Neonatal Consultant where other ventilators have not met the baby's ventilation or oxygenation needs. There is not a VG option on the SensorMedics. This ventilator is available at both KEMH and PCH. See Appendix 1: SensorMedics Ventilator Setup and Calibration QRG

Clinical Indications

The greatest advantage of HFOV is in homogeneous lung disease with a relatively uniform and fast time constant. HFOV is not recommended in dyshomogeneous lung disease particularly where there is overdistention or gas trapping.

HFOV, like conventional ventilation, tends to over-distend compliant airways without adequately ventilating areas of collapse. The active negative pressure expiration can also induce expiratory airway collapse and further promote gas trapping. For non-homogenous lung disease HFJV can be a better option.

Key point

It is recommended to **not** muscle relax infants receiving HFOV. Infants can (and should) have spontaneous gentle breathing on HFOV.

Volume guarantee and HFOV

HFOV-VG allows the setting of a predefined tidal volume, irrespective of other ventilator variables such as frequency, the ventilator will adjust the amplitude as required (up to the predefined maximum amplitude) to achieve the set tidal volume.

There are benefits of using VG during HFOV to maintain more consistent and stable arterial $PaCO_2$, and hence theoretically a more stable cerebral blood flow. HFOV-VG may be particularly advantageous in clinical situations where resistance or compliance is likely to be changing such as after administration of surfactant. VG also facilitates the uncoupling of ventilation and oxygenation during recruitment manoeuvres. It is recommended to not muscle relax infant's on HFOV. Babies can (and should) have spontaneous gentle breathing on HFOV.

HFOV Settings

Ventilation is the amount of gas shifted in and out of the lung, this controls the CO_2. In HFOV this is proportional to rate times the square of the tidal volume and is referred to as DCO. This value is displayed by the ventilator. The DCO_2 required to maintain normocarbia has complex dependencies; it correlates best with weight squared (kg^2), is dependent upon optimal lung volumes (see below), and in some models is less at

higher frequencies. The measure is also ventilator dependent (the Draeger VN500 drops performance at higher frequencies).

Starting settings

Starting settings should be discussed with the treating consultant taking into account the underlying pathology of the neonate. The starting VG may need to be adjusted once an adequate lung volume is achieved.

This table gives suggested starting points for DCO_2 by weight (calculated as 60 $ml^2/s/Kg^2$). Only for babies up to 2kg.

		8 Hz	10 Hz	12 Hz	15 Hz
Infant Wt (Kg)	**DCO2 (ml^2/s)**	**Starting tidal volume mL**			
0.5	15	1.4	1.2	1.1	1.0
0.6	22	1.6	1.5	1.3	1.2
0.7	30	1.9	1.7	1.6	1.4
0.8	38	2.2	2.0	1.8	1.6
0.9	50	2.5	2.2	2.0	1.8
1	60	2.7	2.4	2.2	2.0
1.1	73	3.0	2.7	2.5	2.2
1.2	86	3.3	2.9	2.7	2.4
1.3	100	3.6	3.2	2.9	2.6
1.4	120	3.8	3.4	3.1	2.8
1.5	135	4.1	3.7	3.4	3.0
1.6	155	4.4	3.9	3.6	3.2
1.7	175	4.7	4.2	3.8	3.4
1.8	200	4.9	4.4	4.0	3.6
1.9	220	5.2	4.7	4.2	3.8
2	240	5.5	4.9	4.5	4.0

Adjusting DC02/VG

Discuss the target pH with on-duty consultant. Control of CO2 is through targeting DCO2. If pH is too low and CO2 high, aim to increase DCO2 in ~ 10% increments, similarly if alkalotic or CO2 low decrease DCO2 by 10%. These changes will only require a 0.1 to 0.2 change in the targeted TV if using VG mode or if not using VG mode, change the amplitude.

Amplitude

Amplitude together with frequency determines the removal of CO2 (ventilation) When starting on HFOV a high initial amplitude maybe needed to achieve the desired CO2 clearance. Monitoring of the chest “wobble” and PCO2 will aid choosing the amplitude setting. If using HFOV +VG once the CO2 clearance is stable, set the amplitude

approximately 10% above what is required to achieve the set VT. This allows for some variation but will also generate an alarm if there is a significant worsening in compliance.

Frequency

The frequency choice will depend largely upon the subjective impression of the lungs, the underlying pathology and the weight of the baby. For smaller preterm babies, use 10Hz-15Hz. For larger term babies, frequencies of 7-8Hz are often used. It is rarely necessary to alter the frequency. If the frequency is changed in VG mode the DCO2 will also change and the VT will require adjustment.

I:E Ratio

I:E ratio is usually set at 1:2. In larger babies a trial of 1:1 may be used if there is insufficient power to meet VT. However, in theory, the shorter 1:1 ratio may transmit more pressure to the distal lung and improve oxygenation but at the expense of potential air trapping and inadequate gas release.

Leak

The effect of ETT leak with HFOV VG is very similar to the effects of leak when using CMV with VG and leak. The effective ventilation is little changed with leaks up to 40% but higher leaks prevent accurate assessment of tidal volume

Oxygenation

Oxygenation is a product of mean terminal airway pressure and FIO_2.

Setting MAP

The mean airway pressure (MAP) is set in HFOV and should be adequate to maintain an open airway (usually 10 -14 cmH_2O, higher maybe needed). Set the MAP to maintain FiO2 < 0.6 and to keep O2sats within target range where possible. Recruitment through a hysteresis loop may be beneficial. However, overdistention of the lung with too high a MAP can induce volume trauma and impair respiratory function and also impede pulmonary blood flow and reduce cardiac output. Lung inflation can be assessed with lung ultrasound or Chest Xray.

Monitoring on HFOV

- When commencing HFOV a senior doctor should remain by the bedside until the infant is considered stable (often up to an hour after commencing) as rapid changes in pCO2 can occur.
- SaO2 monitoring and gestational age appropriate transcutaneous CO_2 ($TcCO_2$) are essential as there may be rapid swings in CO_2. Preferably, the TcCO2 should be placed prior to switching to HFOV. Note end tidal CO_2 cannot be reliably measured

on HFOV. A blood gas within 15 – 20 minutes should be performed to monitor pCo2 to assess $TcCO_2$ accuracy.

- Adequate chest wobble should be assessed clinically. Failure of wobble needs to be addressed: ETT tube position and patency, leak, need to increase amplitude or TV.

Weaning HFOV

It is possible to wean directly from HFOV to CPAP. MAP should be low (≤10 cmH2O) and the infant needs to demonstrate a stable respiratory pattern. This may only be evident if the HFOV is transiently turned off. For some, switching to conventional ventilation prior to extubation may be more appropriate.

Nursing Physical and Airway Assessment for a Neonate on HFOV

- Neonate is nursed initially in the supine position. Pay close attention to ETT position to prevent accidental dislodgment and excess pressure on nasal tissue from the rigid tubing. Use of the plastic block on the side edge of the warmer enables more stability of the tubing. Ensure the bullet port is in situ on the HFO tubing.
- Visual assessment includes activity, posture, behavioural state, chest wall vibration (indicates tidal volume) and symmetry. Chest wall vibration will be affected by the diameter of the ETT, mucous plugging and ETT displacement. A change in the magnitude of chest wall vibration in the absence of alteration in the oscillatory parameters should be investigated immediately.
- Respiratory rate cannot be measured by the ventilator (but spontaneous respiratory rate can be counted manually). Auscultation of heart tones, breath sounds and bowel sounds can be assessed by briefly interrupting the oscillation (CPAP will be maintained). Breath sounds can be assessed during oscillation to note air entry and symmetry of oscillatory intensity. Changes in pitch or rhythm of delivered breaths, may indicate changes in ETT position or need for suctioning.
- Suction should only be performed when absolutely necessary and is not required routinely for HFOV. Frequent, even temporary disconnections are discouraged as this results in immediate loss of alveolar recruitment, hence in-line suctioning should be used.
- Periods of disconnection should be minimised. It may be necessary to temporarily increase MAP (20 % for 2 minutes) to re-recruit lung volume if indicated by deterioration in arterial oxygen saturations post-suctioning. Every time the tubing is disconnected consider brief (max 5 min) increase in mean airway pressure of 1-2 cmH2O.
- TCM monitoring (gestation appropriate) is required to observe trends in PaO2 and PaCO2 without the need for excessive blood gases. Monitor ABG's closely, especially 20-30 minutes after a ventilation parameter change.

- Pre and post ductal oxygen saturations may be required if PPHN is present.
- Assess infant for pain and document pain scores.
- Document Delta P and DCO2 as well as the ventilation settings hourly if on VN500 or Fabian ventilator. Seek medical review for any sudden change in DCO2.
- On VG mode extra documentation is needed as per table below.

	PRESCRIPTION	DOCUMENTATION
Ventilation Mode	HFO ± VG	HFO ± VG
		Fi02
MAP	MAP	MAP
If not in VG-mode		
Amp	Amp	ΔP (is achieved amplitude)
		VThf *
		DCO2 * (will fluctuate a bit)
If in VG-mode		
Ampl max	Ampl max	ΔP* (achieved amplitude)
VT	Set VT and set VT/Kg	VT * (achieved)
		DCO2 (should be relatively stable)

Related CAHS internal policies, procedures and guidelines

Neonatology Clinical Guidelines

- Extubation: Planned and Unplanned
- Pain Assessment & Management
- Skin Care Guideline
- Ventilated Neonate: Nursing Care of

References and related external legislation, policies, and guidelines

Drager Technology for Life: https://www.draeger.com/Library/Content/hfov-bk-9102693-en.pdf

Ackerman, B.J., et al., High-Frequency ventilation in preterm infants and neonates. Paediatric Research (2023) 93:1810-1818

This document can be made available in alternative formats on request.

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Appendix 1: SensorMedics Ventilator Setup and Calibration QRG

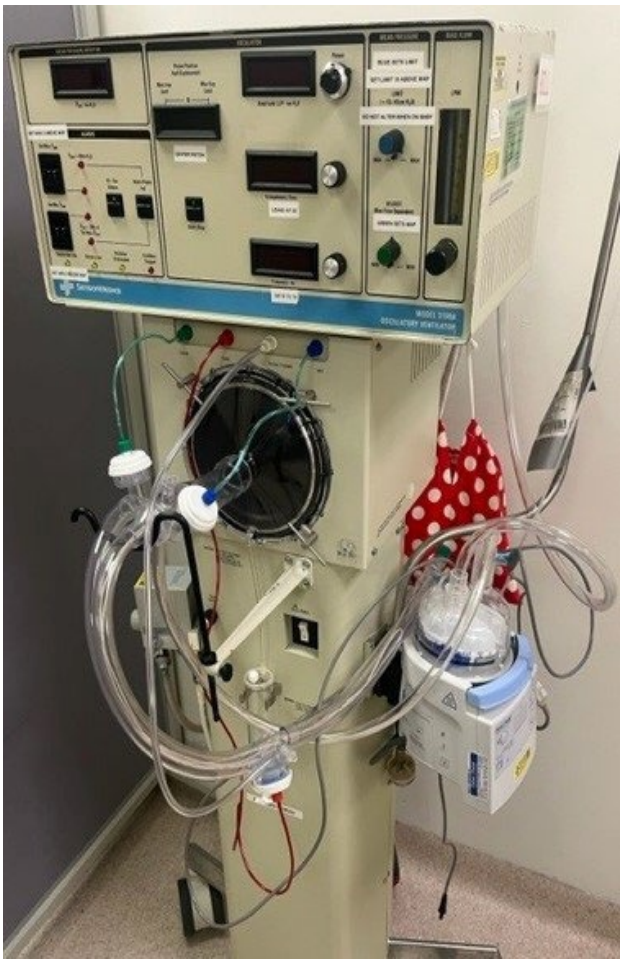
SensorMedics Circuit Setup

Equipment requirements

- SensorMedics Patient Circuit
- SensorMedics Water Trap & Bellow
- SensorMedics Diaphragm caps x 1 pkt of 3
- Humidifier chamber MR290
- MR850 Temperature probe and Heater wire adaptor

Procedure

1. Secure Water Trap into clips first to enable easy alignment of the Bellow. Align the Bellow into the grooves and secure with clamps.
2. Ensure the 3-way tap on the bottom of the Water Trap is OFF to air.
3. Place prepared Humidifier chamber into MR850 Humidifier.
4. Add Patient circuit. Line up circuit so that the 2 valves in the control assembly are positioned at 10 and 2 and then secure onto the Bellow.
5. Connect the pressure line with white connector to the corresponding white valve.
6. Connect inspiratory limb from the Patient circuit onto the humidifier chamber.
7. Connect tubing from Ventilator (located at the rear of the ventilator) to humidifier chamber.
8. Click the Diaphragm caps onto all 3 valves on the Patient circuit.
9. Secure coloured tubing to diaphragms. (Colours correspond to functions and are at correct lengths; **MAP- green**, **Limit - blue** and **Dump - red**)
10. Connect the Heater wire adaptor from the Humidifier to the circuit.
11. Insert the temperature probe at the humidifier and the patient end of the circuit.
12. Ensure Green stopper is placed in the patient end of the circuit. Spare stoppers are kept in bag on the SensorMedics.
13. Calibrate.



SensorMedics Circuit Calibration

1. Turn on ventilator. Power switch located near water trap on lower front panel.
2. Ensure green stopper is in patient circuit “Y”.
3. Ensure 3-way tap at base of water trap is in “OFF” position.
4. Turn Mean Pressure LIMIT (blue) and ADJUST (green) controls to MAX.
5. Turn bias flow on until the lower third of the ball, at eye level, is at 20 lpm.
6. Press and hold RESET.
7. Observe MAP display to immediately rise to between 39-43 cm H2O.

Trouble shooting if MAP is not achieved between 39-43 cm H2O

- Check there are no leaks in the circuit – particularly all the stoppers.
- Check the diaphragm caps are inflating (only check using the blue or green tubing)
- If COMPLETELY satisfied that there are no leaks, use the small screwdriver provided to adjust the screw in the patient circuit calibration until the MAP displays 39-43cm H2O.
- If the MAP goes above 50cm H2O the ventilator will “dump”. This prevents the neonate receiving a MAP more than 50cm H2O. Check that the bias flow is not more than 20 (lower third of ball)
- If all the above steps do not work, then change the circuit (leave the faulty circuit for the equipment nurse) and repeat circuit calibration.

Preparing SensorMedics for patient use

1. Position SensorMedics at end on of warmer/incubator.
2. All power cord and hoses to run-down right-hand side of bay.
3. Plug power into UPS.
4. Attach air and oxygen hoses.
5. Check Blender is set at the required value.
6. Plug humidifier into essential power.
7. Green stopper in end of circuit.
8. Calibrate – bias flow to 20lpm (lower 1/3 ball) – LIMIT and MAP controls to max - Press RESET button – MAP 39-43
9. **Reduce bias** flow until read-out in MAP display is 10 above ordered Map. For example, if ordered MAP is 12 then 22 should be displayed.
10. Set LIMIT available. Reduce limit control (**blue**) until MAP display is also 10 above ordered MAP. The read-out will also be 22 using above example.
11. Document limit available.
12. Adjust MAP (**green**) control until ordered MAP value is displayed.

13. Adjust power control until 2 is displayed on the outside of locking dial (in the window) and 0 on the inside dial.
14. Leave I:E time as 33.
15. Hertz are determined by Medical staff.
16. Set MAX alarm limit 3 above ordered MAP i.e. ordered MAP is 12 them MAX alarm will be set at 15.
17. Set MIN alarm limit at 3 below ordered MAP i.e. ordered MAP is 12 then MIN alarm will be 9.
18. Remove green stopper and replace with test lung.
19. Press RESET to re-pressurise circuit.
20. Press START/STOP to test Oscillator
21. SensorMedics is ready to attach to patient. (N.B.The circuit must be pressurised for the oscillator to be enabled).

The SensorMedics must be calibrated before each use or if the power is turned off.