

Recommendations and Guidelines for Implementation **of High Frequency Oscillatory Ventilation (HFOV)**

I. Physician Order Privileges and Restrictions:

1. To ensure competent administration of this single ventilator resource, implementation of HFOV must include approval from an ICU fellow or attending physician.
2. HFOV should not be implemented as an initial form of mechanical ventilation. The indications and subsequent initial parameters for HFOV evolve from pre-existing parameters during conventional mechanical ventilation.
3. Due to the possibility of explosion, under no circumstances should the SensorMedics 3100 ventilator be used in the presence of flammable anesthetics.

II. Indications and Patient Selection:

1. Patients with severe ARDS requiring an $\text{FiO}_2 \geq 0.60$ with a mean airway pressure (P_{maw}) $> 24 \text{ cmH}_2\text{O}$ may be considered for a trial of HFOV if a “lung protective” target $\text{P}_{\text{plat}} < 30 - 35 \text{ cmH}_2\text{O}$ cannot be maintained with pressure control ventilation. In practice, patients considered for HFOV have generally been tried on “high” PEEP and/or pressure control ventilation (PCV) with extended inspiratory times to raise P_{maw} . A $\text{P}_{\text{maw}} = 24 \text{ cmH}_2\text{O}$ while on conventional ventilation is a reasonable threshold to consider changing to HFOV. Early institution of HFOV in patients deteriorating on conventional mechanical ventilation may be important to improved survival, although this has not yet been rigorously established.
2. Failure to improve the oxygenation within the first 24 –48 hours is indicative of a poor response to HFOV, which may be prognostic for a decreased likelihood for survival. For example, patients with late phase fibroproliferative ARDS, when the alveolar architecture is severely damaged, are less likely to respond.

III. Patient Preparation:

1. Prior to starting a patient on HFOV, it is imperative that the patient’s airway is suctioned and known to be patent. If fiberoptic bronchoscopy is indicated, it should be performed *before* initiating HFOV.
2. Ensure adequate titration of sedation, analgesia, and neuromuscular blockade while the patient is still on conventional ventilation. The patient’s intravascular volume status should be reassessed given that a higher P_{maw} will be used with HFOV, leading to the potential for hypotension secondary to elevated intrathoracic pressures and reduced preload.

IV. Initial HFOV Settings:

1. OXYGENATION:

The main determinant of oxygenation during HFOV is the P_{maw}, which is generally initiated at 5 cmH₂O higher than the P_{maw} noted during conventional ventilation. Hemodynamically unstable patients may be started on a P_{maw} either the same or 2 – 3 cmH₂O above P_{maw} during conventional ventilation. Brief hypotension shortly after starting HFOV is usually managed with a trial of fluid boluses to improve preload. FiO₂ is usually set at 1.00 after the transition to HFOV, and then tapered using oximetry guidance to maintain SpO₂ ≥ 90%. If the SpO₂ (or PaO₂) has not improved enough to allow weaning of FiO₂, the P_{maw} is raised in 2-3 cmH₂O increments at 30 – 60 minute intervals in the hopes of improving lung recruitment. The time course of oxygenation change after initiation of HFOV (or after increasing P_{maw}) is variable. Some patients may slowly improve oxygenation only after a period of several hours. Vigilance and patience are required during the early phase of treatment. The maximum P_{maw} generally obtained with the SensorMedics 3100B is 45 – 55 cmH₂O. Patients with large bronchopleural fistulas or endotracheal cuff leaks may have difficulty achieving a desired P_{maw} without increasing the bias flow. In some patients with very severe air leaks, a maximum bias flow (60 lpm) may be required.

2. VENTILATION:

The main determinants of PaCO₂ elimination are the pressure amplitude of oscillation (P) and the frequency setting (hertz). Increasing the amplitude and *decreasing* the frequency (Hz) will increase the delivered tidal volume and lower the PaCO₂. Conversely, decreasing amplitude and *increasing* frequency (Hz) will reduce delivered tidal volume and allow PaCO₂ to rise. The amplitude is generally initiated at either a value where the patient's chest vibrates down to their mid-thigh. Alternatively, initial amplitude may be set to observe adequate "chest wall vibration". Initial frequency is usually set at 5 Hz. Patients who demonstrate rapidly rising PaCO₂ on HFOV should have aggressive increases in amplitude (10 to 20 cmH₂O) and reduced Hz to the lowest value achievable (3 Hz on the SensorMedics 3100B). An adjunct to improving PaCO₂ elimination is to briefly disconnect the patient from HFOV and vigorously manually ventilate with a PEEP-valve equipped bag. Aggressive action is required for a rapidly rising PaCO₂ during initiation of HFOV because improvements in PaCO₂ do not occur as quickly as when changes are made to conventional ventilators. An ABG should be drawn 15 to 20 minutes after starting HFOV to determine the trend of the PaCO₂. Subsequent ABG's are generally obtained at 30 to 60 minute intervals until stabilization occurs.

V. Guidelines for Initial HFOV Settings:

1. Prior to initiating HFOV, perform a recruitment maneuver on the oscillator by increasing P_{aw} to 40 cmH₂O for 30-40 seconds. *NOTE: the oscillator should be OFF during the maneuver.* Immediately abort the maneuver if hemodynamic compromise occurs.
2. Set initial P_{aw} at 5 cmH₂O above conventional ventilator P_{maw}.
3. Set power to achieve initial amplitude at chest oscillation to mid-thigh.
4. Set Hz at 5. Set IT to 33% (may increase to 50% if difficulty with oxygenation; this may further raise carinal pressure an additional 2 – 4 cmH₂O).
5. If oxygenation worsens, increase P_{maw} in 2 – 3 cmH₂O increments q 30 minutes until maximum setting (approximately 45 – 55 cmH₂O).

6. If PaCO₂ worsens (but pH > 7.2), increase amplitude in 10 cmH₂O increments q 30 minutes up to the maximum setting. After maximum amplitude is achieved, if necessary, decrease Hz to the minimum setting of 3 Hz.
7. If severe hypercapnea occurs, with pH < 7.2, bag patient, set maximum amplitude, Hz at 3, and try a small cuff leak (5 cmH₂O and then compensate bias flow); rule out endotracheal tube obstruction.
8. If oxygenation improves, gradually wean FiO₂ to 0.40, then slowly reduce Pmaw 2-3 cmH₂O q 4 – 6 hours until 22 – 24 cmH₂O range.
9. When the above goal is met, switch to PCV (initial settings: peak pressure titrated to achieve delivered V_T 6 ml/kg IBW, Pplat < 30 - 35 cmH₂O), I:E 1:1, PEEP 12 cmH₂O, rate 20 – 25, Paw should be 20 cmH₂O (+/- 2 cmH₂O).

VI. Weaning from HFOV:

The principle goal of using HFOV in treating patients with ARDS is to achieve a nontoxic FiO₂ (<0.60) while minimizing ventilator induced lung injury. When patients respond with improved oxygenation, the first weaning maneuver therefore is to reduce the FiO₂ before any reduction is considered in Pmaw. A reduction of FiO₂ to 0.40 with a target SpO₂ > 90% before attempting reductions in Pmaw is recommended. If the patient can maintain a SpO₂ > 90% on a FiO₂ 0.40, a gradual reduction of Pmaw (e.g. decrease 1– 2 cmH₂O q 30 minutes as tolerated) should be attempted. If the SpO₂ decreases during Pmaw reduction, resume the previous Pmaw that was able to maintain a SpO₂ > 90% on FiO₂ 0.40. Perform an ABG and CXR for every total Pmaw reduction of 5 cmH₂O. Once a Pmaw of 20 – 24 cmH₂O has been achieved while maintaining a FiO₂ of 40%, the patient can be switched back to a trial of conventional ventilation. (See V. (9) Guidelines for Initial HFOV Settings) Obtain an arterial blood gas 15 - 20 minutes after transfer to conventional ventilation to guide further ventilator adjustments.

VII. Potential Complications:

1. HYPOTENSION

Occasionally, patients will develop hypotension shortly following transfer to HFOV or as Pmaw is raised. This usually implies relative hypovolemia and responds to intravenous fluid boluses and/or vasopressors as indicated.

2. PNEUMOTHORAX

Tension pneumothorax occurring during HFOV may not cause changes to the displayed Pmaw or amplitude as the patient develops progressive hypotension and desaturation. A high index of suspicion is necessary for pneumothorax and confirmation (if time permits) requires an immediate CXR. It may be difficult by auscultation alone to detect the side of the pneumothorax during HFOV secondary to background noise of the ventilator and the diffuse transmission of airway sounds. The visual loss of chest oscillation that usually occurs on the affected side may provide an important physical sign.

3. ENDOTRACHEAL TUBE OBSTRUCTION

Subtotal occlusion of the endotracheal tube may result in refractory hypercapnea. An abrupt rise in PaCO₂ and loss of visual chest oscillation in an otherwise stable patient may be secondary to an obstructed or narrowed endotracheal tube. A suction catheter should be passed immediately to ensure patency of the endotracheal tube.

VIII. References:

Derdak S, Mehta S, et. al. **High Frequency Oscillatory Ventilation for Acute Respiratory Distress Syndrome in Adults – A Randomized, Controlled Trial.**
Am J Respir Crit Care Med, Vol 166.pp 801-808, 2002

Ritacca FV, Stewart TE. **High-Frequency Oscillatory Ventilation In Adults – A review of the literature and practical applications**
Critical Care 2003, 7: 385-390

Derdak S. **High Frequency Oscillatory Ventilation for Acute Respiratory Distress Syndrome in Adult Patients**
Crit Care Med, 2003 Vol. 31, No. 4 (supp.)

Krishnan JA, Brower RB. **High-Frequency Ventilation for Acute Lung Injury and ARDS**
CHEST, 2004; 126;518-527

Mehta S, Granton J, et. al. **High Frequency Oscillatory Ventilation In Adults – The Toronto Experience**
CHEST, 2004; 126;518-527