1. INTRODUCTION

High frequency oscillatory ventilation (HFOV) is an alternative mode of ventilation that may be considered for acute respiratory distress syndrome (ARDS) in adult patients who are failing conventional ventilation (CV). HFOV should be considered as rescue therapy. Respiratory Care Practitioners (RCP) caring for patients on HFOV needs to have a full understanding of pathophysiology and be able to perform advanced and frequent patient assessment that is unique to HFOV.

2. PURPOSE

To provide guidelines for the initiation of therapy and management of patients on HFOV.

3. POLICY

3.1 HFOV is used for patients inside the ICU's only, i.e. (GICU1, GICU2, SICU, EDICU)

3.2 HFOV may be considered for those patients who are not responsive to conventional MV, when one or more of the following criteria are met:

3.2.1 Fractional inspiratory oxygen (FiO2) is 1.0 with a positive end expiratory pressure (PEEP) ≥ 12 cmH2.
3.2.2 Plateau pressures (Pplat) ≥ 30 cmH2O
3.2.3 Mean airway pressure (mPaw) ≥ 24 cmH2O
3.2.4 Worsening refractory respiratory acidosis.
3.2.5 Oxygen saturation ≤ 90 with FIO2 of 100% and PEEP of ≥12 for up to 60 minutes.
3.2.6 If the patient met the above criteria and other rescue therapies failed than patient is a candidate for HFOV.

3.3 Patients on HFOV therapy with known or suspected air borne disease such as Mycobacterium tuberculosis, Chickenpox, H1N1, Influenzae A, Coronovirus, etc. require Airborne Precautions (i.e. negative pressure room, N95 high particulate mask).

3.4 Health Care Professionals (HCP) who provide direct patient care for patients on HFOV must wear surgical mask at all times, unless on Airborne Precautions in which case a N95 high particulate mask should be worn.

3.5 INDICATION:

The indications are as follows but not limited to:

3.5.1 Ventilator-associated lung injury

3.5.2 Alveolar hemorrhage
3.5.3 Large air leak with inability to keep lungs open
3.5.4 Abdominal Compartment Syndrome
3.5.5 Failure of conventional mechanical ventilation
3.5.6 Refractory hypoxemia
3.5.7 Increased intracranial pressure
3.5.8 Persistent pulmonary hypertension
3.5.9 Acute Respiratory Distress Syndrome
3.5.10 Pulmonary Interstitial Emphysema
3.5.11 Bronchopulmonary fistulae

3.6 CONTRAINDICATION:
3.6.1 Higher intrathoracic pressures
3.6.2 Right ventricular preload; require volume administration ± inotropic support
3.6.3 Pneumothorax
3.6.4 Migration/displacement of ETT
3.6.5 Bronchospasm
3.6.6 Airway obstruction from mucus plugging, secretions, hemorrhage, or clot
3.6.7 Barotrauma
3.6.8 Pneumomediastinum
3.6.9 Subcutaneous emphysema
3.6.10 Multiple organ failure
3.6.11 Refractory acidosis
3.6.12 Intraventricular hemorrhage
3.6.13 Cellular injury
3.6.14 Increased pulmonary capillary wedge pressure

4. RESPONSIBILITIES

4.1 Respiratory Care

4.1.1 Senior Respiratory Care Practitioner's responsibilities:

4.1.1.1 Assure HFOV availability and proper calibration.

4.1.1.2 Active participation in management of patients on HFOV.

4.1.1.3 When patient condition warrants, directly contact the attending Consultant/team-leader and relay details of the patient's condition and any associated changes in HFOV settings.

4.1.1.4 Assure proper and thorough communication between the bedside RCP, bedside nurse, and attending physician, regarding changes in patient's condition and HFOV settings.

4.1.1.5 Perform a lung recruitment maneuver (LRM) as indicated and ordered.

4.1.2 Respiratory Care Practitioner's responsibilities:

4.1.2.1 Assess and determine the patient's need for HFOV and relay to the physician for appropriate action.

4.1.2.2 Obtain the order for HFOV initiation.

4.1.2.3 Check availability of HFOV and related equipment.

4.1.2.4 Assess the need for any medical interventions that can be performed prior to initiation of HFOV in order to prevent interruption of HFOV once initiated.

4.1.2.5 Set-up, monitoring, and management of HFOV.

4.1.2.6 Monitor patient's general condition, vital signs, and blood gases (ABG's).

4.1.2.7 Relay adverse effects and ABG's and any actions taken to the attending physician and bedside nurse.

4.1.2.8 Identify life threatening situations (i.e. pneumothorax) associated with HFOV and immediately notify the physician for further intervention.

4.1.2.9 Perform the necessary documentation prior, during, and post HFOV administration.

4.2 Physicians:

4.2.1 Initiation of HFOV.

4.2.1.1 Order initiation and administration of sedatives and paralytic agents as medically required.

4.2.2 Optimize patient's hemodynamic status in order to prevent hypotension secondary to elevated intra-thoracic pressure associated with higher mPaw.

4.2.3 Order lung recruitment manoeuvre (LRM) while patient is still on conventional ventilation if deemed appropriate.

4.2.4 Take an active role in the management of patients on HFOV.

4.2.5 Consult with the bedside RCP/shift in-charge RCP regarding all setting changes.

4.2.6 Provide pertinent articles, troubleshooting guides, and other material to interested RCP's and physicians.

4.3 Nurses:

4.3.1 Administration of any necessary medications.

4.3.2 Continuous monitoring of patient's vital signs and communicate changes in the patient's condition to the physician and bedside RCP.

5. DEFINITION OF TERMS

HFOV is a method of ventilation that delivers small tidal volumes (less than or equal to anatomical dead- space volume) at a rapid respiratory rate~ 5-10 HZ (1 hertz (Hz) = 60 breaths/minute (bpm).
I:E Inspiratory and expiratory phases are both active as a result of the positive (inspiration) and negative (expiration) oscillations around the mPaw causing gas movement throughout the conducting airways.
Bias flow of fresh humidified gas intersects the oscillatory pathway to eliminate carbon dioxide (CO_2) from the circuit.
Oxygenation is adjusted mainly by *mPaw* and *FiO2*. CO_2 depends mainly on the *amplitude* (ΔP) and *frequency setting (Hz)*.

6. APPLICABILITY

This policy applies to all ICU staff who give direct patient care to patients receiving HFOV. This includes respiratory care practitioners (RCP), physicians, and nurses.

7. PROCEDURES

7.1 Preliminary Steps:

7.1.1 Obtain appropriate equipment and supplies.

7.1.2 Use heated humidifier, not a heat-moisture exchanger (HME).

7.1.3 Review medical records and verify physician's orders for appropriateness.

7.1.4 Select appropriate HFOV (3100B ≥ 35 kg and 3100A < 35 kg patients).

7.1.5 Properly assemble and calibrate the circuit prior to patient application. Ensure close suction catheter and a smooth kink free interface between the ventilator circuit and the endotracheal tube.

7.1.6 A baseline chest x-ray within the last 2 hours prior to initiation of HFOV must be available.

7.1.7 Ensure a manual resuscitation bag with PEEP valve 20 cm H_2O is connected to oxygen and available at the head of the bed.

7.2 Patient Interaction and Equipment Preparation:

7.2.1 Properly identify the patient as per the PSMMC patient identification policy.

7.2.2 Wash hands and using appropriate PPE's as per Infection control approved policy

7.2.3 Position patient in optimal position (30-45 degrees) based upon the patient's condition.

7.2.4 Ensure optimal sedation and paralysis and perform LRM on CV as ordered.

7.2.5 Evaluate patient for baseline physiologic status (breath sounds, vital signs, sputum) while on CV.

7.2.6 Suction patient prior to initiating HFOV and ensure patency of the endotracheal tube. If the patency is questionable, a bronchoscopy prior to initiation of HFOV may be indicated.

7.2.7 Adjust high frequency ventilation for initial settings:

7.2.7.1	Bias Flow	25-40 (30) liters/minute
7.2.7.2	mPaw	3-5 cmH2O >mPaw on CV or (25-30)
7.2.7.3	Amplitude	20 cmH2O + PaCO2 to a maximum of 90
7.2.7.4	Frequency	5-6 Hz
7.2.7.5	Inspiratory Time %	33%

7.2.8 Connect ventilator circuit to patient's airway.

7.2.9 Ensure appropriate alarm settings.

7.2.9.1 High Pressure 10 cmH2O above set mPaw
7.2.9.2 Low Pressure 10 cmH2O below set mPaw

7.2.10 Observe chest for adequate wiggle up to mid thighs and adjust amplitude as needed.

7.2.11 Chest x-ray must be ordered 30 to 60 minutes after initiation of HFOV.

7.2.11.1 Chest x-ray must be used to evaluate the position of the diaphragm, screen for pneumothorax (pleural, medistinal, or subcutaneous) and prevent lung hyperinflation by counting the intercostal spaces.

7.2.11.2 Note: Rib spaces that have increased over time may indicate lung recruitment to the point of over-distention.

7.2.12 Obtain ABG within 30 to 60 minutes after initiation of HFOV and every 2-4 hours thereafter or more frequently if patient's condition warrants.

7.2.13 Target pH 7.20 to 7.35 and target PaO_2 55 to 80 mmHg. Target SpO_2 88 to 95%.

7.2.14 Patient assessment and ventilator check should be performed as follows:

7.2.14.1 On initiation, ventilator check must be performed every 30 minutes during the 1st hour of initiation, and then every hour until patient stabilized. i.e. post initiation of HFO, vent checks at 30 min, 60 min, 2nd hour, 3rd hour when the patient is compromised. Once the patient is stabilized vent checks can be done routinely, every 3 hours.

7.2.14.2 Close monitoring should be done at the same time as the ventilator checks depending on the patient's condition. i.e. at 30 min, 60 min, 2nd hour, 3rd hour when the patient is compromised. Once the patient is stabilized, a thorough patient assessment must be done at least twice per shift.

7.2.15 Thorough and frequent assessment of patient on HFOV.

7.2.15.1 Assessment should go system by system.

7.2.15.2 Components of assessment include the following:

7.2.15.2.1 Assess for spontaneous respiratory effort by examining the patient, assuring:

7.2.15.2.2 Artificial airway patency

7.2.15.2.3 Visual Inspection

7.2.15.2.4 Palpation of chest for crepitus, or pneumothorax.

7.2.15.2.5 Evaluation of chest x-ray

7.2.16 Initial settings and adjustments are performed rapidly to obtain target oxygenation. Thereafter, ventilator adjustments (except for dangerous hypoxemia) are made no more frequently than every two hours to assure a steady state.

7.2.17 If oxygenation worsens, increase mPaw in 1-2 cmH_2O increments to maximum of 40 cmH_2O unless contra- indicated by treating physician.

7.2.18 Note: Extreme caution should be used when exceeding 36 cmH_2O due to adverse effects i.e. Pneumothoracies, hemodynamic instability.In some cases, a higher mPaw (maximum 50 cmH_2O) may be needed to manage obese patients or patients with chest wall diseases. An increase in inspiration time to 50% can be done to improve oxygenation.

7.2.19 If $PaCO_2$ worsens, but pH $\geq$ 7.20, increase ΔP in 10 cm H_2O increments to a maximum of 90 cm H_2O. After maximum ΔP is achieved, decrease frequency by increments of 1 to a minimum of 3 Hz.

7.2.20 If severe hypercapnea persists with a pH $\leq$ 7.20, manually ventilate the patient utilizing a PEEP valve 20 cmH2O and assess endotracheal tube patency. A fiberoptic bronchoscopy may be necessary to ensure patency of the proximal airways. Set maximum ΔP, Hz 3, and institute a cuff leak as following:

7.2.20.1 Oral suction,

7.2.20.2 Reset low pressure alarm to 10 cmH_2O below mPaw,

7.2.20.3 Remove air from endotracheal cuff pilot balloon while monitoring mPaw until a decrease of 5 cmH_2O in mPaw occurs,

7.2.20.4 Increase bias flow until mPaw is restored to its previous level

7.2.20.5 Restore alarm limit to 5 cmH_2O below the mPaw.

7.2.20.6 Remove the cuff leak before performing an LRM or while manually ventilating the patient.

7.2.21 When hypercapnea persists with a pH ≤ 7.20 despite maximum settings, cuff leak, and a partial airway obstruction and/or blockage of the endotracheal tube is ruled out, immediately relay the information to the attending physician for appropriate action before considering a shift back to conventional ventilation.

7.2.22 LRM's must be *physician ordered* and performed with the physician in attendance.

7.2.22.1 LRM's are used to improve oxygenation after de-recruiting events (i.e. suctioning, bronchoscopy, circuit disconnect) or for patients who continue to have marginal oxygenation during HFOV.

7.2.22.2 Adverse effects of LRM's include: Barotrauma or Cardiovascular compromise

7.2.22.3 Assuming no adverse effects, LRM is repeated up to 2 more times to total of 3 times, in a 24 hour period if the PaO_2 does not increase at least by 20%.

7.2.22.4 LRM's are performed for 40-60 seconds by increase FiO_2=100% then stop the piston and raising the mPaw up to 40 cmH2O or 10 cm H_2O above the original set mPaw.

7.2.22.5 Following the LRM, return the HFOV to previous settings and consult the attending physician for any increases in mPaw.

7.2.22.6 The endotracheal cuff leak must be removed during the LRM.

7.2.22.7 Do not perform LRM's in patients with hypotension or pneumothorax and active air leak.

7.2.22.8 Terminate the LRM immediately if associated with:

7.2.22.8.1 Hypotension (mean arterial blood pressure < 60 mmHg or decrease by > 20 mmHg)

7.2.22.8.2 Changes in heart rate (> 140 bpm or <60 bpm)

7.2.22.8.3 development of cardiac arrhythmias

7.2.22.8.4 Desaturation (decrease in oxygen saturation to less than 85% or decrease of more than 5%).

7.2.22.9 Do not repeat an LRM for at least 24 hours in patients in whom previous LRM had to be terminated.

7.2.23 Endotracheal tube position should be checked regularly and maintained. As a result of high levels of mPaw during the HFOV, migration of the endotracheal tube proximally in the trachea may occur.

7.2.24 Fluctuations in mPaw of > 5 cmH_2O may indicate a leak in the circuit, inadequate flow, or the patient is initiating spontaneous respirations. In this instance, the bedside RCP must assess the patient for presence of spontaneous respirations and alert the physician to increase sedation and/or a paralytic agent if indicated. If fluctuations in mPaw continue, troubleshoot for leaks in the circuit. If no leaks are evident, slowly increase the flow and monitor the mPaw for stabilization.

7.2.25 The bedside RCP must assess frequently for pneumothorax as patients on HFOV are at a high risk. The bedside nurse and attending physician must be alerted immediately at any suspicion of a pneumothorax. Early recognition includes sudden changes in vital signs, including tachycardia, hypotension, an increase in inotropes and decreased oxygen saturation. On examination, subcutaneous emphysema (crepitus) may be present and in cases of tension pneumothrorax a tracheal shift to the unaffected side may be evident. There may be an absence of breath sounds on the affected side during auscultation. To facilitate auscultation, the RCP will clamp the ETT to prevent derecruitment, remove the patient from HFO and manually ventilate using a 20 cm H_2O PEEP valve.

Note: Once pneuomothorax has been ruled out and the patient is still compromised, other causes must be investigated.

7.2.26 Suction with vigorous manual ventilation may be necessary to clear any obvious filling of the endotracheal tube with edema, blood, or foam as this will impede the ability to oxygenate and ventilate during HFOV.

7.2.27 If oscillator stops, usually due to accidental patient disconnection or leakage in the circuit, manually ventilate the patient and troubleshoot the leakage. Return to HFOV and press the restart button to resume oscillation.

7.3 Patient Evaluation and Termination of HFOV

7.3.1 Wean FiO2 slowly to ≤ 0.60 while maintaining acceptable oxygen saturation of $\geq$ 88%.

7.3.2 After achieving FiO_2 of 0.5, attempt to wean mPaw by 1-2 cmH2O every 4 hours while maintaining oxygen saturation of ≥ 88%.

7.3.3 Consider change to pressure control ventilation (PCV) when $FiO_2 \leq 0.5$, mPaw is between 15-20 cm H_2O, and oxygen saturation continues to be ≥88% and the patient has remained on those settings for a minimum of 12 hours.

7.3.4 When shifting the patient to PCV use the following:

7.3.4.1 Delivered tidal volume ~ 6 ml/kg
7.3.4.2 PEEP ~10 cm H2O
7.3.4.3 Adjust for mPaw same as HFOV.

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