HIGH FREQUENCY OSCILLATORY VENTILATION (HFOV)

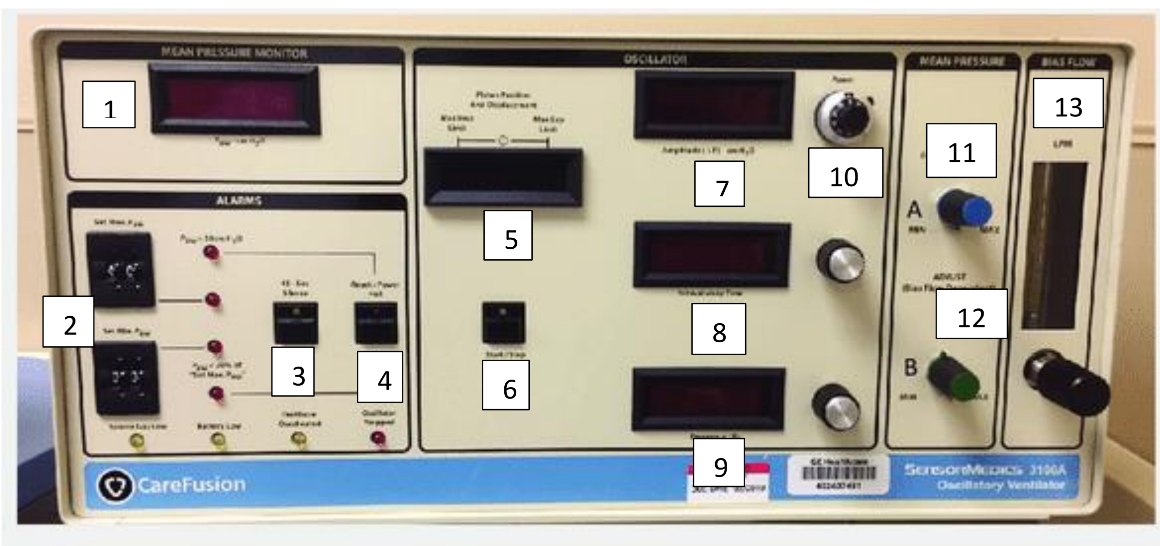
What is High Frequency Oscillatory Ventilation?

High frequency oscillatory ventilation (HFOV) is a type of ventilation that uses a constant distending pressure with pressure variations that oscillate around the mean airway pressure (MAP) at very high rates and small tidal volumes.

How is HFOV and CMV different?

In conventional mechanical ventilation (CMV) large pressure changes (the difference between PEEP and PIP) create physiological tidal volumes and gas exchange which is dependent on the patients expired gas exchanged. In HFOV you are reliant on a multitude of different mechanisms of gas exchange. The science behind it includes a constant distending airway pressure is applied (MAP), over small tidal volumes, at a high frequency (measured in Hz). Also involved is radial mixing by means of Taylor dispersion, collateral ventilation, coaxial flow, Pendelluft ventilation and cardiogenic mixing. Although that might seem like a lot of information it is because it is! Understanding the whole concept of HFOV will allow you to help make suggestions and troubleshoot accordingly.

The SensorMedics 3100A Oscillatory Ventilator



There are two types of HFOV the 3100A and the 3100B.

3100A is for <35kg

3100B is for >35kg

Therefore, we use the 3100A for our neonates. We have two 3100A at Edward.

1. MAP- Mean Airway Pressure	8. Inspiratory Time
2. MAP High and low alarms	9. Frequency (Hertz)
3. Silence Button	10. Power
4. Reset/Power Fail	11. MAP Limit
5. Piston Position	12. MAP Adjust
6. Start/Stop	13. Bias Flow
7. Amplitude (Delta P)	

Indication

The following conditions are indicative when HFOV is beneficial:

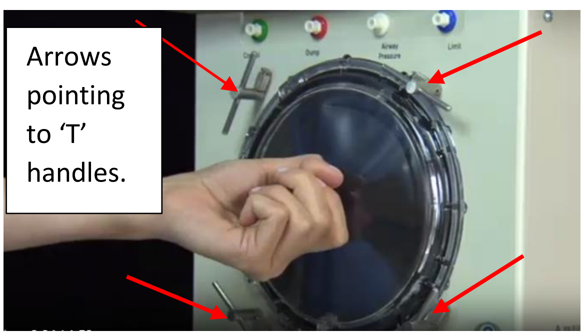
Persistent Pulmonary Hypertension of the Newborn, Meconium Aspiration Syndrome, Air leak syndromes (pneumothorax, pulmonary interstitial emphysema), or if the patient is having increasing CMV settings to prevent further barotrauma. This list is not all inclusive.

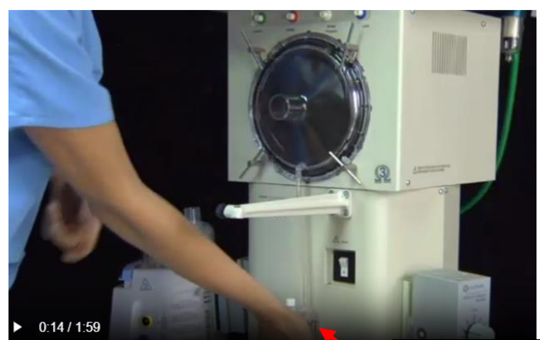
Set-Up

If setting up a HFOV from scratch, go to the basement and grab the back-up oscillator. The oscillator parts are then found on the back wall where the nitric supplies are found (far back wall where the adult supplies are). You will need (1) package of bellow with water trap, (1) patient circuit, (1) package of white diaphragm caps, (1) package of color-coded lines, (1) oxygen analyzer, (1) blue T piece specific for HFOV and (1) Green HFOV swivel adapter, (1) water chamber. These supplies can be found in the adult and neonatal supply areas.

Follow this step-by-step guide to setting up a HFOV

1. Attach the bellows water trap assembly using the four ‘T’ handles and turn it a quarter turn.
2. Snap in the water trap into the metal clip on the front of the HFOV.

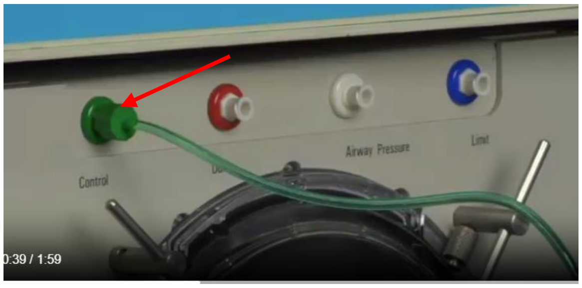


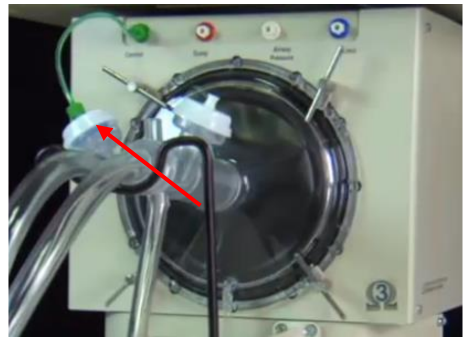


3. Connect the circuit to the center port on the bellows.
4. Snap the three white cap diaphragms into place on the patient circuit.

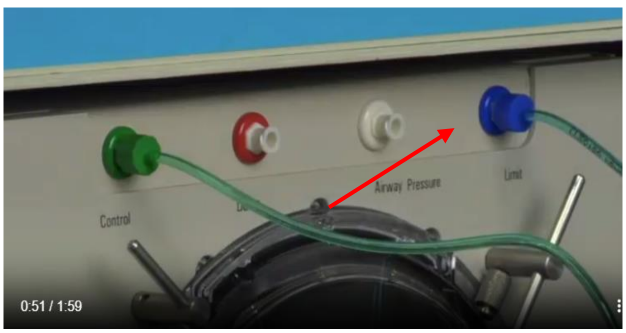
5. Attach the three-color coded tubes to the corresponding valve caps.

6. Green to the mean airway pressure control valve located on the expiratory limb of the circuit.

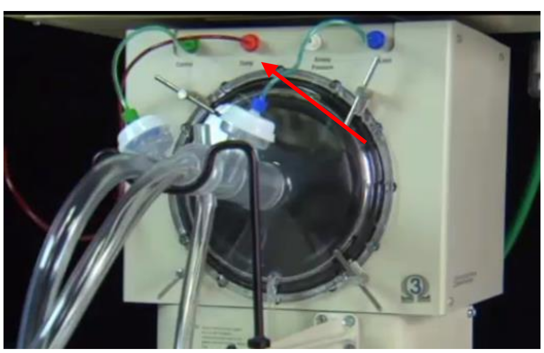


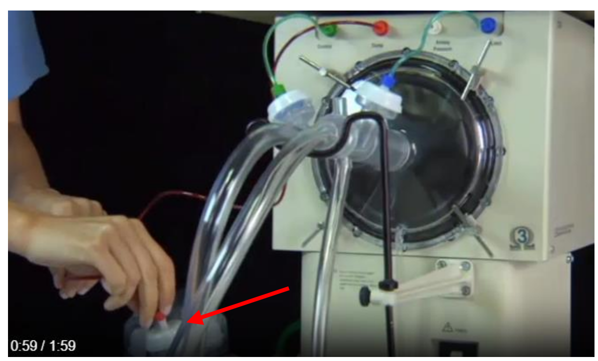


7. Blue to the limit valve on the inspiratory limb of the circuit.

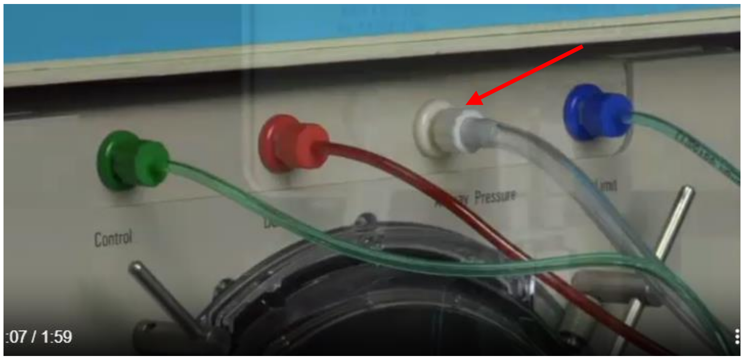


8. Red to the dump valve located on the expiratory limb of the circuit.

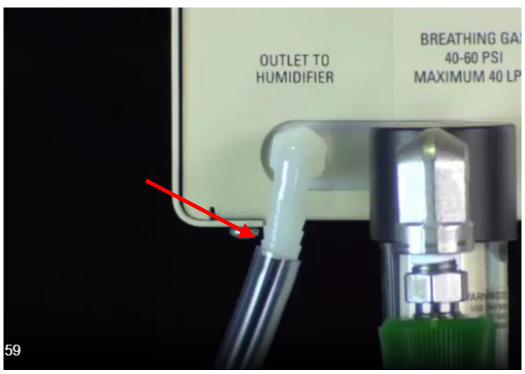


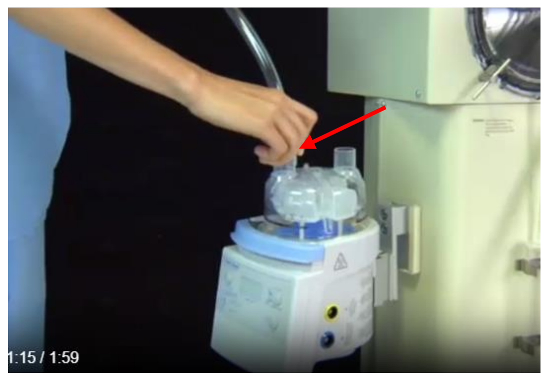


9. Attach the pressure sensing line found attached to the circuit to the airway pressure line.



10. Attach one end of the connection tubing to the back of the HFOV marked outlet to humidifier. The opposite end of the tubing is to be connected to the inlet of the water chamber.

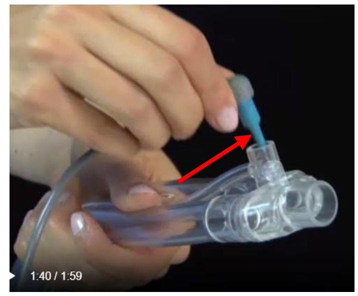




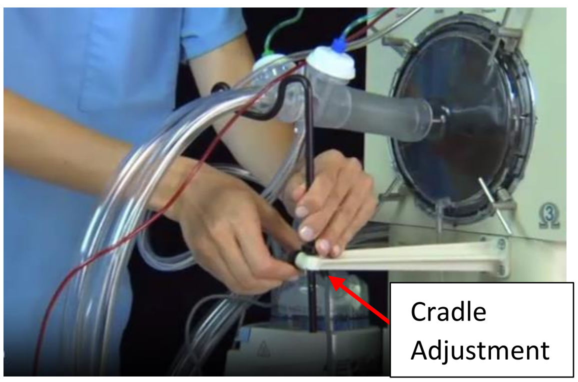
11. Connect the bias flow tubing from the ventilator circuit body to the outlet of the water chamber.

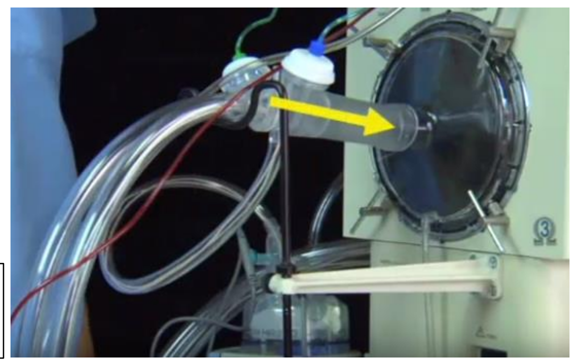
12. Connect the temperature probes.



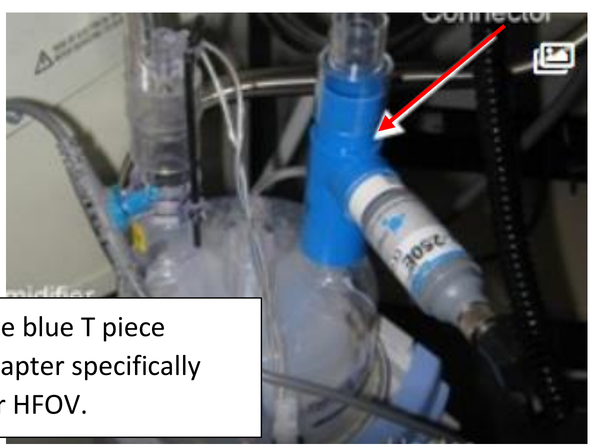


13. Use the cradle adjustment to maintain proper circuit height and angle. The proper angle should allow for condesation to run downward and fall into the water trap.





14. Set up the oxygen analyzer. Perform a high and low calibration to ensure its functionality. Attach the blue T piece adapter to the water chamber on the dry side and place the oxygen analyzer in the open hole (Make sure there is a ring on the analyzer, or you will get a loose seal) Watch to make sure that analyzer is near what the FiO2 that is set.



Pre-Use Check

There are **two** checks to be done before placing a patient on HFOV. Both are found on the HFOV itself. One on the top and one on the side. At this time, be sure to place your green HFOV swivel adapter at the end of the circuit with the rubber stopper to calibrate everything properly.

Check #1

Patient circuit calibration

Perform the patient circuit calibration procedure before ventilating a patient. Each circuit that used on the oscillator must be calibrated. The circuit calibration procedure verifies that the circuit is and will hold pressure. Perform this procedure before placing a patient on the 3100A HFOV.

1. Insert the stopper in the patient circuit wye and turn on the bias flow gas.
2. Rotate the ADJUST and LIMIT control to Max.
3. Set the Max Paw alarm to Max.
4. Set the bias flow to exactly 20 LPM *(the middle of the ball is at the line—you may need to bend down to see this precisely).*
5. Depress and hold RESET *(with the oscillator off).*
6. Observe the mean pressure display and adjust the patient circuit calibration screw *(if needed)* for a reading of 39 to 43 cmH_2O.
   a. Before adjusting the calibration screw, confirm there are no leaks, confirm the bias flow is at 20 LPM and the circuit is set up correctly. See the troubleshooting guide for more information.
   b. Use caution when adjusting the calibration screw. Do not over tighten or apply excessive force because equipment damage may occur.

Check #2

Ventilator performance check

The ventilator performance check ensures the 3100A HFOV is functioning properly. Perform this procedure before placing a patient on the 3100A HFOV. Insert the stopper in the patient circuit wye and turn on both gas sources.

1. Turn the Adjust control to the 12 o'clock position.
2. Set the bias flow to exactly 20 LPM *(the middle of the ball is at the line—you may need to bend down to see this precisely).*
3. Pressurize the system by pressing and holding Reset and Adjust for a mean pressure of 19 to 21 cmH_2O.
4. Set the frequency to 15.0 Hz, % I; time to 33 and press START/STOP to start the oscillator.
5. Set the power to 6.0 and center the piston.
6. Observe the following parameters using the appropriate altitude range and verify they fall within the ranges specified *(see chart on next page).*

Reasonable Initial Settings for a Neonate

MAP: Neonates: 2-5 cm above MAP on CMV

MAP, if starting immediately on HFOV: Neonates: 8-10 cm H20

For the initial set-up, it is important for the safety of the patient and the operation of the HFOV, that the MAP adjust knob is to be used first to zone in where the MAP is. After finding the mean pressure point, the limit should be slowly turned to the point that you see a drop in MAP. After finding that point, you quarter turn the limit knob back to set the limit. **Think of this as a pressure pop off alarm (high PIP) but with no numerical value**. It is extremely important to pay attention to this and ensure that the adjust is never higher than the limit.

When you use the limit to set the MAP instead of the adjust knob you could cause potential damage and danger to the patient due to where the pop off valves and sensors valves are located. The purpose of the limit valve control is to make sure that there is not an accidental overpressure situation in the piston and over pressure in the patient circuit.

An example: Would you use your alarm setting to set the pressure for a pressure-controlled mode in CMV? No! So do not do this on HFOV!

Additionally, if you get in the habit of doing this the pressure limiter may cause the circuit to dump and depressurize the circuit and require a restart of the HFOV with appropriate adjustments or it will not function at all because the pressure is too high.

Amplitude ΔP **(Delta P)/Power**: For a neonate, adjust ΔP until there is noticeable chest wiggle from the nipple line to the umbilicus. When you are needing to go higher up on the ΔP, your power will go up. The ΔP/power knob has a lock on it, if you want to make a change pull down on the lock to make changes. When you are done making a change, relock it. Initial settings might be:

Weight in kg	Power
<2kg	2
2.1-2.5kg	3
2.6-4kg	4
4.1kg-5kg	5

Bias flow

Premature	Near Term
15 lpm	15-20 lpm

Frequency (Hertz)

Preterm neonate	Term Neonate	Infant/Child
10-15 Hz (900bpm)	10-12Hz (720 bpm)	10Hz (600bpm)

Inspiratory time

Set to 33% (I:E ratio of 1:2) This is almost NEVER touched.

FiO2

Set the FiO2 to whatever the patient needs at that moment. Use the blender on the HFOV to the desired FiO2. Use the oxygen analyzer to see what the FiO2 you are at.

What do all these settings mean? How do I make changes?

Clinical indicator		Therapeutic intervention	Treatment rationale
FiO_2 above 0.60			
High $PaCO_2$ with:	PaO_2 = acceptable PaO_2 = low PaO_2 = high	Increase ΔP Increase mPaw, ΔP, FiO_2 Increase ΔP, decrease FiO_2	Increase ΔP to achieve optimal $PaCO_2$ Adjust mPaw and FiO_2 to improve O_2 delivery Decrease FiO_2 to minimize O_2 exposure
Normal $PaCO_2$ with:	PaO_2 = acceptable PaO_2 = low PaO_2 = high	No action Increase mPaw, ΔP, FiO_2 Decrease FiO_2	No action Adjust mPaw and FiO_2 to improve O_2 delivery Decrease FiO_2 to minimize O_2 exposure
Low $PaCO_2$ with:	PaO_2 = acceptable PaO_2 = low PaO_2 = high	Decrease ΔP Increase mPaw/FiO_2, decrease ΔP Decrease FiO_2, ΔP	Decrease ΔP to achieve optimal $PaCO_2$ Adjust mPaw and FiO_2 to improve O_2 delivery Decrease FiO_2 to minimize O_2 exposure
FiO_2 below 0.60			
High $PaCO_2$ with:	PaO_2 = acceptable PaO_2 = low PaO_2 = high	Increase ΔP Increase FiO_2, increase ΔP Increase ΔP, decrease mPaw	Increase ΔP to achieve optimal $PaCO_2$ Increase FiO_2 to improve PaO_2 Decrease mPaw to reduce PaO_2
Normal $PaCO_2$ with:	PaO_2 = acceptable PaO_2 = low PaO_2 = high	No action Increase FiO_2 Decrease mPaw, FiO_2	No action Increase FiO_2 to improve PaO_2 Decrease mPaw and FiO_2 to reduce PaO_2
Low $PaCO_2$ with:	PaO_2 = acceptable PaO_2 = low PaO_2 = high	Decrease ΔP Increase FiO_2, decrease ΔP Decrease mPaw, decrease ΔP	Decrease ΔP to achieve optimal $PaCO_2$ Decrease ΔP and increase FiO_2 to improve $PaCO_2$ Decrease mPaw

Almost everything on HFOV is directly related. Meaning if you make a change to one value you will have to make changes to get to your other previous values.

Mean Airway Pressure (MAP)

This is a constant distending pressure that pushes open the alveoli and optimizes gas exchange. It supports OXYGENATION.

Too high of a MAP may compromise venous return, decrease blood pressure, and cause desaturation. It does not happen all the time, but it is something to watch out for, especially when you are initiating HFOV.

There are two ways that effect oxygenation when using HFOV. FiO2 and MAP. Going up on the MAP will improve oxygenation. It is a constant pressure delivered. You can go up by adjusting the adjust knob (green knob) higher, increasing the limit knob (blue knob) or increasing the bias flow. It is important to know that you must be extremely cautious with changes since a little change can make a big difference.

FiO2

The other factor that supports OXYGENATION.

Amplitude a.k.a ΔP (Delta P)

This delivers tiny tidal volumes that are oscillating the lungs and producing the chest wiggle. It controls the VENTILATION. To achieve your ΔP you must adjust the power knob. This manipulates the distance the diaphragm moves and the ΔP swing around the MAP.

Too low of a ΔP you may see underventilation. Too high of a ΔP you may cause a Ventilation Induced Lung injury (VILI).

Bias Flow

It is a constant flow of gas in the circuit, provides oxygen, removes CO_2 and helps generate MAP. Use the lowest flow that allows you to achieve the desired settings. Know that larger patients and higher amplitudes and MAP's will require the use of a higher flow.

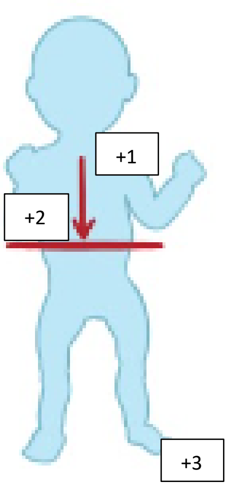
Chest Wiggle Factor (CWF)

Where should you see wiggle? In the NICU, the infant's umbilicus

Know that if your wiggle is poor your CO_2 will most likely be high. Keep an eye on your wiggle since it will help you visually see compliance.

CWF should be reassessed after position changes.

If you see a diminished or absent wiggle you should consider decreased pulmonary compliance. Check to make sure your ETT is not obstructed (needing suctioning) or consider that the patient is having a bronchospasm.



Unilateral wiggle would indicate that your ETT may be displaced or a pneumothorax.

A CWF to the clavicles (CWF of +1) would indicate that your wiggle is not ideal. If you troubleshooted indications of low wiggle and nothing is wrong with the patient, you may need to go up on the power.

A CWF to the umbilicus (CWF of +2) would indicate that your wiggle is where it needs to be for a neonatal patient. Ensure that the patient maintains this and does not begin exhibiting signs of decreased pulmonary compliance. If need be, you may have to go up on your power.

A CWF to the toes (CWF of +3) would be more ideal for a pediatric patient. Continue to monitor to ensure that your wiggle remains in satisfactory positioning.

<u>Frequency (Hertz)</u>

1Hertz (Hz)= 60 bpm (breaths per minute)

For most situations a frequency range of 10-15 Hz has been found to be effective for both premature and near-term patients. In normal practice, as the patient's weight increases, initial frequency is decreased. Frequencies between 6-10 Hz are common in children, with lower frequencies more typically seen and used for larger children. Most of the time the frequency control remains unchanged throughout the therapy. As frequency decreases total cycle time (TCT) increases. Remember that TCT is how long a whole breath takes.

<u>Power</u>

As you start going up on your ΔP, the power control is increased. They are directly related. When this happens the piston displacement increases, the tidal volume increases, and ventilation increases.

<u>Piston</u>

Labeled as piston placement and displacement, it is imperative that the piston is centered for the HFOV to work properly. This is a visual parameter as seen in the picture below. If the piston is displaced (shifted from the center) the HFOV will continue to work but over time the bellow will become overheated from the unevenness. Think of this like driving on two wheels of a car. Additionally, when the piston is in center position, the delivery of the ventilation is improved therefore your patients gas exchange is better. When your piston is centered you are allowing for increased carbon dioxide elimination. Anytime you reposition the patient or make a change to the settings on the HFOV, you will

have to check to see if your piston is centered. If it is not centered, use the piston centering knob found near the water trap. It is a touchy knob so be sure to turn slowly. If the piston is more to the left, turn the knob to the right to recenter it. Inversely, if the piston is showing it is more to the right, then turn the knob to the left to recenter it.

<u>Alarm</u>

The only two alarms on the HFOV is a MAP high and a MAP low. You will set this +3 and -3 of whatever the set MAP is. Example: The MAP is set at 16. You would set the alarm by using the rotational alarm wheel and pushing it up or down to get the number you want. So, if your MAP is 16, your MAP high would be set at 19 and MAP low set at 13.

<u>Once on HFOV:</u>

Lock all four wheels of the HFOV once you are in a good position. You may have to use a towel or two to help the position of the heavy HFOV circuit. You can lightly place tape to help attach it to the towel.

ABG: Make sure a blood gas is ordered within 1 hour of placing patient on HFOV.

CXR: A CXR will be ordered to look for over expansion. Ideal expansion is 7-9 ribs.

Charting:

See guideline for HFOV Charting.

Troubleshooting:

- **The bellow does not look straight during pre-use check:** If it's not centered correctly the four 'T' clamps will not turn correctly, so you need to realign the bellow if this happens.

1. **Failing the pre-use check?** Check the following things:
   - Make sure the water trap is closed.
   - Check to be sure that the Bias Flow is on 20 LPM. Get eye level and ensure it's where it needs to be if not at 20 lpm for pre-use check increase Bias Flow slightly.
   - Remove and check the limit, control and dump caps/diaphragm valves. Replace them if the circuit still fails to calibrate.
   - Observe mean pressure display and make a slight adjustment using a screwdriver where it's marked Patient Circuit Calibration until you get a reading of 39-43cm H2O. If you need to turn it too much, replace it with a new circuit.

- **Pressurizing the circuit:** Ensure there is no leak in the system. **Hold the RESET button to pressurize the machine then hit START/STOP.** Make sure the baby is connected to the oscillator or you have the green rubber stopper on the circuit to restart the oscillator.

- **Drifting MAP:** If your MAP is fluctuating, consider the following:
  - Condensation in the circuit. Make sure to see that the cradle adjustment is at a slight angle to allow for condesation to run downward and fall into the water trap.
  - Patient is breathing over HFOV/looks uncomfortable- Consider sedation.
  - Airway patency? The patient may need to be suctioned.
  - Is the limit valve higher than the adjust valve? The oscillator has too much pressure and will need to be manipulated.
  - Is the drifting MAP out of nowhere and FiO2 needing to be increased? Consider a pneumothorax and get a CXR.
- **Is the HFOV making a weird squeaking noise?** Is the limit and adjust knobs completely maxed out? (Cannot be advanced further to the right). You will have to perform a manual pressure dump maneuver. This is when you must increase the bias flow so that you can decrease the adjust and subsequently the limit. This practice needs to be done carefully since you are manipulating pressures as you do this. Be sure to be slow but quick. Slow in the way that you do not want to go too fast and completely drop the MAP, since that will cause the alarm for the MAP to go off and possibly completely depressurize. Be mindful of everything if you do this. Watch the patient's response to the change and the vital signs. This is also why it is important to

have wiggle room with the bias flow. Even though the flow meter says it goes up to 60 lpm, it will not go higher than 40 lpm on a 3100A.

Other important information:

- Changing water bags—Make sure to never let the HFOV run out of water. When changing the water bag do it in a quick manner and have the next water bag ready to go. Remember that you are causing a leak when it is not attached to the water bag (which could depressurize the HFOV).
- On the back of the HFOV, in a respiratory supply bag keep (1) extra set of color-coded lines and (1) package of white caps. This is in case something happens to the ones on the HFOV. You do not want to run and find these supplies in an emergency.
- Keep the green rubber stopper taped on the HFOV. If you need to start nitric, do not toss the small plastic piece that you removed to place the sample line, keep it taped to the HFOV or place it in a small bag then place it in the respiratory supply bag on the back of the HFOV.
- When you need to reposition the baby, always do it in pairs. A RN and a RT at bedside always. One person needs to have their hands on the ET tube while the RT moves the oscillator tubing or the oscillator itself.
- Emptying the water trap—Do this at least every six hours or as needed. Be sure to not empty it all the way (doing so might make the HFOV depressurize). You can use a clean glove and have the water pour into it.

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