High Frequency Oscillatory Ventilation

What is HFOV?
HFOV theory
Machines and HFOV
Who is it for?
When and how to start
Running on HFOV
Weaning from HFOV

What is HFOV

HFOV is an unconventional way of ventilating the lung. It was developed as a way of avoiding baro/volutrauma associated with conventional ventilation in severe lung disease. Here large inspiratory pressure are needed to inflate the lung only for collapse to occur when the air comes out. However, once the alveoli are opened, they can be held open at pressures much lower than the peak inspiratory pressure, if deflation did not occur at any point (as conventionally happens in expiration). The airway pressure is kept fairly constant and gases moved in and out of the alveoli by oscillating the column of air in and out of the lung, with tidal volumes less than the dead space, a process called facilitated diffusion.

HFOV theory

Oxygen moves into the lung down a concentration gradient, as it is removed by blood in the alveoli. CO₂ cannot use the same method to escape without unacceptably high blood pCO₂ levels. Hence oscillation is used to facilitate the diffusion of gases. How it works is not known, but there are several theories. Air is pushed into the lung actively and comes out actively, slightly slower. This has the effect of making the flows laminar – with air going in down the middle of bronchi and coming out down the sides. Next at the front of a pressure wave there is mixing with the air beyond the pressure wave. Also different rates of expansion of different lung segments mean that air may flow from one segment to another during an oscillatory cycle.

Machines and HFOV

The Sensormedics device is used on PICU at SGH. This is a true oscillator in that there is a diaphragm that wobbles in and out, across the flow of gas. Other ventilators with an “oscillation” mode operate by interrupting the flow of the circuit, like ventilating very fast. In practise, the only one with enough power for a child is the Sensormedics. No device has ever been shown to improve survival or long term outcome in neonates or children. On the Sensormedics you really only have 3 knobs to play with, and FiO₂. These are mean airway pressure, power (amplitude) and frequency. Bias flow and inspiratory time are rarely altered once set.
**Which Sensormedics oscillator?**

<table>
<thead>
<tr>
<th></th>
<th>3100A</th>
<th>3100B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bias flow</td>
<td>0–40 l/min</td>
<td>0 – 60l/min</td>
</tr>
<tr>
<td>CDP adjust</td>
<td>3 – 45 cmH2O</td>
<td>7 – 55 cmH2O</td>
</tr>
<tr>
<td>Delta P</td>
<td>&gt;90 cmH2O</td>
<td>&gt;130 cmH2O</td>
</tr>
<tr>
<td>Red line balloon valve opening</td>
<td>CDP &gt; 50cmH2O</td>
<td>CDP&gt;60 cmH2O</td>
</tr>
<tr>
<td>&gt;5secs</td>
<td>CDP &lt; 20%max</td>
<td>CDP &lt; 5cmH2O</td>
</tr>
<tr>
<td>Piston</td>
<td>Must centre piston manually</td>
<td>Piston self centres</td>
</tr>
</tbody>
</table>

Recommended patient minimum bodyweight limit for the use of the 3100B is 35kg. However in patients over 20kg we use the 3100B, and it can be used on smaller patients following discussion with a consultant.

For patients under 20kg use the 3100A.

**Who is it for?**

It is best for children with alveolar or interstitial disease with a mixture of hypoxia and hypercapnia. It is not useful for airway obstruction. So ARDS, pneumonia, aspiration and drowning are useful settings. As a guide the CXR should be fairly white.

**When and how to start**

Because HFOV requires more sedation, may compress the heart, it is not used as a first line intervention. If MAP >20 in a child or MAP > 18 in an infant and still there is hypoxia with FiO₂ >70%, or CO₂ > 9 kPa HFOV is likely to be reduce barotraumas.

Start by setting the machine:
- Bias flow 20 l/min 3100A and 30 l/min 3100B (nb ball flow meter – value at centre of ball)
- Insp time 30%
- CDP (MAP) to 4 – 8 cmH₂O above MAP on BIPAP
- Power 40
- Frequency ; <2000gms 15Hz
  - 2 – 12 kg 10Hz
  - 13 – 20kg 8 Hz
  - 21 – 30 kg 7 Hz
  - >30 kg 6Hz

Connect the child to the oscillator. As soon as it is going adjust the power to get a good wobble on the chest and upper abdomen immediately.

**Oxygenation**

Oxygenation is controlled by FiO₂ and CDP. If the saturations are not improved after 10 mins, increase the CDP by 2 cmH₂O, and repeat after another 10 mins. Check an arterial gas after 10 minutes particularly to see what the CO₂ is. If there is no sign of improved oxygenation after 2 increases in MAP, get an urgent CXR – there maybe something else wrong. Otherwise you should see a gradual drop in FiO₂ over the next few hours. Get a CXR after 4-6 hours to check for overinflation.

When the FiO₂ < 40%, slowly reduce the MAP.
If the CO₂ is high:

Increase amplitude in 5 – 10 cmH₂O increments until no effect on CO₂ THEN
2) decrease rate in 1 Hz decrements (min 5Hz in large patients, 7 Hz in small patients) THEN
3) increase inspiratory time cautiously as significant increased risk of pneumothorax (33% to 36% to 39%) CONSIDER
4) change ETT to smaller size to increase the leak and increase bias flow. Remember to maintain CDP
5) REMEMBER other causes of a rise in CO₂
   a) overdistension
   b) Reduction in chest wiggle due to secretions – need to suction

There is often a drop in blood pressure when you start HFOV, due to compression of the heart and great vessels. This is usually correctable with a bolus of fluid.

**CDP Control balloon Valves**

On the ‘mean pressure’ section of the oscillator there are 2 knobs on the 3100A and one knob on the 3100B

The green knob (present on 3100A & B) controls the green balloon valve which sets CDP
The blue knob (on 3100A only) controls the blue balloon valve which is a safety valve and acts as a backup in case the green balloon valve sticks (which could generate very high pressures).
On the 3100B the blue balloon valve automatically sets at a pressure slightly higher than the CDP (set on the green balloon valve).

When setting CDP on the 3100A turn the blue knob as high as it will go. Set the CDP with the green knob controlling the green balloon valve. When this is set turn the blue knob down slowly until the CDP is no longer maintained and then turn it up by 10 degrees – the pressure on this valve will now be set slightly higher than CDP on the green valve. As this is a vital safety feature it is important to do this whenever there is a change in CDP.

**Alarm Limits**

Set min/max airway pressure alarm limits 3cmH₂O above and below CDP – remember to reset when change CDP.

**Humidification**

Good humidification is essential to prevent necrotising tracheobronchitis.
Use Fisher & Paykel humidifier.
Initial settings:
- Patient temperature 37°C (set at 37°C not 39°C as such high gas flow little temperature loss on way to patient)
- Chamber temperature –2°C to +2°C
Goal is some condensation in the expiratory limb
If no condensation in the expiratory limb: set chamber temperature to +1°C to +2°C
If excess condensation in the expiratory limb: set chamber temperature to -1°C to -2°C
Running on HFOV
The settings can be adjusted as above. Sedation may need to be increased from previous levels especially in children over 1 year old, although there is nothing wrong in the child breathing during HFOV. A daily CXR helps adjust the MAP.

Weaning from HFOV
Although technically possible to wean all the way to extubation with HFOV, most people check the compliance daily (manually) and when this is improved and the gases etc better, switch to conventional ventilation.

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May 2016