



# HIGH FREQUENCY VENTILATION IN THE ADULT PATIENT WITH ARDS

by Respiratory Care Student - Emily Hudson

High frequency ventilation (HFV) has established itself as an effective way to mechanically ventilate neonatal patients. Many studies have been performed to prove its advantages and many hospitals use it as their standard of care in the neonatal intensive care unit to treat lung conditions such as respiratory distress syndrome. Unfortunately, the same success cannot be compared to similar conditions among *adults* because HFV has simply not been studied enough under clinical conditions for physicians to feel comfortable implementing this technique on adult patients. That is not to say studies that point to HFV as an extremely successful treatment for certain adult lung conditions are not available. They certainly are; however, among the medical community, success lies in the numbers. As its popularity and use continues to grow, differences between high frequency ventilation and conventional mechanical ventilation, as well as reasons for using one or the other, should be well understood by all physicians and respiratory therapists in order to best treat critically ill patients, specifically those patients with acute respiratory distress syndrome.

Since both high frequency ventilation and conventional mechanical ventilation (CMV) use positive pressure ventilation to control the patient's minute volume, HFV, technically, only differs from CMV based on its definition: respiratory rates above 150 breaths/minute. Once frequencies reach a certain point, Hertz (Hz) becomes the unit of measurement, with 1 Hz equaling 60 cycles/minute. This characteristic becomes incredibly important when examining the type of patient which would most benefit from this seemingly outrageous setting. However, one should always first understand the basic mechanics of a machine before using it.

Since exhalation is normally a passive act, when respiratory rates are increased, there is a tendency for air trapping to occur because of decreased cycle time. With this fact in mind, when expiration becomes active and possibly equal in time to inspiration, as in high frequency oscillatory ventilation (HFOV), air trapping is greatly reduced. HFOV is just one type of high frequency ventilation and the most widely used. The

Sensor Medics 3100B ventilator is an advanced HFOV ventilator because electromagnetism is used to drive a piston back and forth creating this active inhalation and exhalation. Inspiratory time is directly related to the forward movement of the piston, while expiratory time is related to the backwards movement. Inspiratory time can be altered as a percentage of the total cycle time, usually somewhere between 30% and 50%. The distance the diaphragm is moved directly correlates with the amount of gas being pushed in and out of the patient's lungs. This is also known as the amplitude or tidal volume, and is set by the clinician.

With frequencies so high, maintaining an appropriate minute volume requires tidal volumes to be extremely small. Usually, these tidal volumes end up being less than the patient's anatomical dead space, which is especially important if the patient being ventilated has non-compliant or stiff lungs, in which case conventional mechanical ventilation is likely to cause barotrauma due to overdistension.

Mean airway pressures (P<sub>maw</sub>) produced by HFOV are normally quite high and remain constant throughout active inhalation and exhalation. This constant P<sub>maw</sub> is vital in preventing atelectasis as well as the 'inflate-deflate', 'inflate-

deflate' cycle that can severely damage alveolar membranes when sufficient surfactant is not present. This brings us back to the original point of why this type of ventilation should be used and for whom it should be implemented. There are not many adult conditions in which there is a lack of surfactant, but ARDS is one of them.

When used, high frequency ventilation is almost always seen among those adults with acute respiratory distress syndrome, or ARDS. In fact, research has shown that the outcome of ARDS patients is greatly affected by the ventilation strategy used. The reason for this however, is not because these patients have ARDS; rather, it is due to the increased likelihood of developing acute lung injury in response to the conventional mechanical ventilation implemented on those patients with ARDS. Characteristics of ARDS include protein-containing fluid that leaks into the interstitial and alveolar spaces because of some recent acute trauma or sepsis that causes the vessels and walls of the lung to become inflamed.

*Emily Hudson is an RC Student at the University of Missouri in Columbia, MO. Her paper was chosen from papers submitted to Focus for this issue. Ms. Hudson will receive a \$100 gift certificate and a gratis registration to the 2009 Focus Conference. Her school's RC Program will also receive a \$100 donation. Students are encouraged to submit their papers for the Nov/Dec issue by Nov 5th. Papers should be 900 - 1250 words and should be submitted as MS Word files to Craig Baker at BakerCT78@yahoo.com.*

This fluid results in surfactant depletion. Without surfactant covering the alveolar walls, surface tension is too great to fight the collapse and micro-atelectasis that is characteristic of the acute condition. Changing ventilation strategies to better accommodate a patient with ARDS could greatly affect their outcome.

It is not just elevated pressure that is the culprit for lung injury. Some patient's lungs are so prone to ALI that even on modes like pressure control ventilation where the pressure is limited, volumes that the patient inhales naturally are large enough to cause damage. High inspiratory pressures and large tidal volumes could lead to barotrauma in unhealthy lungs, like those of an ARDS patient. Such complications are precisely the reasons that acute lung injury is such a problem among ICU patients and why HFOV should be considered.

Sustained, high P<sub>maw</sub> is a great way to open up and keep open hard-to-recruit alveolar compartments. Oftentimes, this stinting strategy can greatly improve oxygenation since gas is being exposed to epithelium that it would normally not come into contact with under the lung's atelectatic conditions. In addition to improved alveolar recruitment, HFOV is thought to enhance the mixing of inhaled and exhaled gases as they pass through the circuit and thus improve oxygenation. There are several theories to explain this idea of a better ventilation-perfusion ratio: bulk flow, coaxial flow, Taylor dispersion, pendelluft, and augmented molecular diffusion.

Pendelluft is one theory among those studying HFOV and attempts explain why HFOV succeeds in preventing ALI in patients with varying time constants. Various units of the lung, especially those lungs of people with ARDS, have different time constants. That is, some areas are less compliant than others, and it may take less time to get gas in those parts as it does to push the gas into normal areas of the lung. One study suggests that in ARDS patients, about 10% of the lung can be made up of alveoli with "very long" time constants, greater than 8 seconds. With so much variability in just one lung, it is very difficult not to cause damage. Pendelluft simply integrates the gas between alveoli of differing compliances, and coupled with such small tidal volumes, increases oxygenation throughout the entire lung.

Longitudinal dispersion or Taylor's dispersion is another theory used to describe increased oxygenation from the use of HFOV. This idea is used in other aspects of medicine as well. Such as with intermittent positive ventilation (IPV), flow upon inspiration is direct and axial while expiratory flows travel along the outer edges of the airways and could be described as radial. These differing flow patterns can be seen in HFOV as well to better oxygenate the most distal alveoli.

High frequency ventilation among adults has been the topic of several studies; unfortunately, it is not utilized very often among practitioners because it is still a relatively new technique. Just as pressure control ventilation is rarely utilized in many healthcare institutions, doctors and other health professionals are simply not comfortable with these techniques yet. But numerous successful results of HFOV have been recorded in adult patients suffering from ARDS and more are sure to come.

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