Technology & Clinical
REPORT

Advances in pulmonary management of the critically ill infant

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Hyperinflation: How HFJV Can Help

Hyperinflation occurs when more gas gets into the lungs than is able to get back out. It is usually caused by inflammation, diagnosed by chest xray, and it can be either aggravated or alleviated by mechanical ventilation. HFJV can alleviate hyperinflation by providing ventilation with small tidal volumes, long exhalation times (I:E ratios up to 1:12), and often lower mean airway pressure (MAP).

The primary mechanical ventilation factors that affect hyperinflation are peak inspiratory pressure (PIP) or tidal volume (V_T) and I:E ratio. If the volume of gas delivered in the inspiratory time (T_I) is greater than the volume of gas that can get out during the expiratory time (T_E), lungs expand beyond their normal, functional volume. Avoidance and treatment of hyperinflation is usually accomplished by decreasing set PIP or V_T, decreasing Rate to increase the T_E, or decreasing T_I to decrease V_T and lengthen T_E.

Unfortunately, ventilator settings can't be manipulated without affecting blood gases, and they can only be reduced so far and still provide adequate patient support. Lungs are also limited in how well they may respond to various ventilation modes. So, despite our best efforts, some infants develop hyperinflation.

Here is a typical scenario: a patient on a conventional ventilator has a $PaCO_2$ of 70 mm Hg, a PaO_2 of 55 mm Hg, and an O_2 Saturation of 85% with steadily increasing F_IO_2s. The chest xray shows lungs expanded to 10-11 ribs: hyperinflation. When the PIP, V_T, T_I, or Rate are decreased, hyperinflation may or may not improve, but oxygenation will most likely suffer. If PEEP is increased to get the PaO_2 back up, $PaCO_2$ goes up as well. What is needed is a longer expiratory time, so T_I is shortened to increase the I:E Ratio; however, $PaCO_2$ rises unacceptably when this is tried. No matter what changes are made, hyperinflation persists, and blood gases remain unsatisfactory.

Patients like this often improve when they are switched to high-frequency ventilators because HFVs use very small V_Ts and short T_Is. How the patients respond to a particular HFV depends on whether the lungs are homogeneous or not.

HFOV works well for homogeneous lung disease but its limited range of I:E ratios (1:1 to 1:2) and its tendency to create gas trapping during the active expiratory phase at low MAPs, limits its effectiveness in non-homogeneous lung disease.

HFJV, on the other hand, is very effective in treating non-homogenous lung disorders like PIE. It can operate over a broad range of I:E ratios (1:1.6 to 1:12), and its passive expiratory phase allows the use of lower MAPs

without the risk of airway collapse. HFJV also has the benefit of maintaining a constant V_T as rate is lowered, because it uses a set T_I.

With HFOV, tidal volume increases as the rate decreases because T_I is a percentage of the breath cycle. Therefore, if the HFOV rate is lowered to increase T_E, hyperinflation can actually get worse because of an unintentional increase in V_T. To avoid the increase in V_T pressure amplitude must be reduced as rate is decreased.

HFJV has another advantage over HFOV – it delivers V_Ts faster than HFOV. How does this help? Think about the area of the lung where gas is being trapped: airways in that area are probably inflamed, restricted, and may even be disrupted. Restricted airways have high resistance and long time constants, it takes long, slow breaths to achieve ventilation, as is the case with asthma.

When lungs are injured and inflamed, airway resistance is high. Breaths traveling fast will be diverted away from the injury by the high resistance, allowing the injured area to rest, relax, de-gas, and heal. HFJV provides that rest by not ventilating areas with high resistance.

Many clinicians choose HFJV for patients with hyperinflation because of its wider range of I:E ratios, constant V_Ts that are independent of rate, and passive exhalation. These factors provide the best opportunity for success.

Dr. Philippe Friedlich, *et al*, cited these same factors in their success using HFJV in treating 10 patients with hypoxemia refractory to HFOV at Children's Hospital of Los Angeles (J. of Maternal-Fetal and Neonatal Medicine 2003; 13:398-402). The patients in the study were all at least a month of age with chronic lung disease and pneumonia on HFOV and 100% O_2. Within 24 hours of initiating HFJV, their mean F_IO_2 dropped to 0.54 while MAP dropped from 14 to 9 cm H_2O. Nine of the ten patients were subsequently discharged after a mean time on HFJV of 7 days. The study conclusion was: "high-frequency jet ventilation may have advantageous mechanical properties compared to those of high-frequency oscillatory ventilation that are important in the ventilatory management of critically ill preterm neonates with chronic lung disease, poor compliance, gas trapping and resultant hypoxic respiratory failure."

The experience of Dr. Friedlich and his associates is not unique. Anecdotal evidence from many Jet users supports the findings from LA Children's. In March, 2004, Dr. Richard Plavka of Charles University Hospital in Prague, Czech Republic, is presenting a pilot study of patients similar to those of Dr. Friedlich's at the European Conference on Pediatric and Neonatal Ventilation in Montreux, Switzerland. Interest in a randomized controlled study of HFJV for treatment of chronic lung disease is growing. The apparent keys to successfully using HFJV in this patient population are illustrated in the following guidelines.

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HFJV Guidelines for Lung Hyperinflation

1. Don't use any IMV breaths. Use HFJV with the conventional ventilator in CPAP mode.

2. Use lower HFJV rates. The lower the rate, the longer the exhalation time. Injured lungs have longer time constants, and the Jet ventilates very well down to 240 bpm.

3. Use adequate PEEP. Lowering PEEP with lung hyperinflation usually makes matters worse due to airway collapse, and it seldom improves oxygenation. Raising PEEP stabilizes the lungs when IMV breaths are discontinued, and it helps keep airways open during exhalation so that trapped gas can get out!

The next time you have a patient with hyperinflation unresponsive to traditional remedies on conventional ventilation or HFOV, keep this article in mind, and remember that one of our Clinical Specialists is only a phone call away at 800.800.4358.

Third Smallest Baby Survives on Jet

Michael DeSpain was born three months early, weighing just 355 grams. He was reported to be the third smallest baby to survive according to an article published in the AARC Times May 2003.

Trina Schuch, RRT, NPS, pediatric respiratory care manager, at Advocate Christ Medical Center in Oak Lawn, Illinois coordinated his respiratory care. Trina said, "Due to his extreme prematurity, Michael's lungs were very susceptible to barotrauma. To minimize the effects that conventional ventilation can have on the premature infant's lungs, he was placed on the Bunnell High-Frequency Jet Ventilator, which allowed practitioners to ventilate at the lowest possible pressures to avoid lung damage. Optimizing Michael's lung function and minimizing lung damage were at the forefront of the RCP's mind."

We would like to congratulate the entire NICU staff at Advocate Christ Medical Center for the outstanding care they provided to Michael and for their continued dedication to excellence in the care they provide all the infants treated in their NICU each year.

What's New at Bunnell

Since our last newsletter, the most important development at Bunnell is the release of the WhisperJet Patient Box. This new patient box reduces the noise produced by the pinch valve by as much as 75%. The reduction is so dramatic some clinicians have complained that it's too quiet; they can't hear the Jet running!

The WhisperJet is gradually being integrated into our rental pool, so don't be surprised if you get a rental with a patient box that looks a little different and sounds a whole lot quieter.

To inquire about getting your own WhisperJet Patient Box contact Ken Hekking, Bunnell's sales manager, at ***ken@bunl.com*** or 800.800.4358 x 13.

There are also several new additions to the Bunnell website including copies of our Operator's Manual, In-service Manual, and Quick Reference Guide. All of these documents are in PDF format and can be viewed on-line with Acrobat Reader. They can be printed one page at a time or in their entirety. They are great resources for training, testing, and troubleshooting. Take a minute and check them out at ***www.bunl.com.***

Two articles were published last summer on the Life Pulse. A retrospective review by Philippe Friedlich, MD, Children's Hospital of Los Angeles, entitled "Use of high-frequency jet ventilation in neonates with hypoxemia refractory to high-frequency oscillatory ventilation" was published in The Journal of Maternal-Fetal and Neonatal Medicine 2003; 13:398-402.

The second article, a bench evaluation, by David Platt, MS, RRT was published in the Journal of Perinatology 2003; 23:387-391, entitled "Inhaled Nitric Oxide Delivery with High-Frequency Jet Ventilation" Copies of these articles are available upon request by calling 800.800.4358.

Finally, we are proud to report that thanks to your on-going support Bunnell Incorporated posted its best year (2003) in the company's history. This was due to more hospitals using the Life Pulse and using it more often. The Life Pulse continues to be an effective clinical tool that fills a unique niche in the field of infant ventilation. ***Thanks one and all !***

Jet Papers & Studies

Bunnell is always interested in case studies and research papers. If you have a study or paper you would like to share with other clinicians, we would like to help.

We can help in the editing or proofing process. We can solicit feedback from other clinicians. We can publish articles and abstracts in our newsletter. And, we can post information on our website.

Do you have a study in mind but need help developing the protocol? The protocol is developed but support is needed in the form of equipment or supplies? Whatever support you're looking for, Bunnell can help.

If you want some assistance or if you want to discuss ideas for a research project, contact Dave Platt at 800.800.4358 ext. 15 or dplatt@bunl.com.