Technology & Clinical REPORT

Advances in pulmonary management of the critically ill infant

bunnell
INSPIRED INFANT CARE

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Why Does HFJV Work When Nothing Else Will?

Nearly every year at the HFV conferences at Snowbird or in Phoenix, someone presents a paper where the Jet successfully rescues an infant, child, or group of patients. In recent years, many of the affected patients were on HFOV before being successfully switched to HFJV. *(See Friedlich P., Subramanian N., Garg M. Marked reduction in mean airway pressure and oxygenation index using high frequency jet ventilation in neonates with severe refractory hypoxemic respiratory failure. Snowbird HFV Meeting abstracts, April 2001, on our website, www.bunl.com, under Clinical / Abstracts.)*

We respect and appreciate SensorMedics and the many oscillator users and the excellent studies they have conducted over the years. The paper noted above came from Children's Hospital of Los Angeles, one of the elite centers of HFOV expertise where Dr. Robert deLemos, beloved HFOV pioneer, trained the authors on the finer points of ventilator management from 1990 to 2000. We, like Dr. Friedlich, et al, think it is in everyone's best interests, especially those of our tiny patients, to elucidate situations where HFJV works when nothing else will.

We think one answer to this question is a matter of homogeneity and the pathophysiology of lung injury. HFO is very effective in treating homogeneous lung disorders, particularly those characterized by low lung compliance, such as RDS. We believe that RDS is the paramount indication for HFV in general, given that high frequency breaths are distributed in the lungs independent of lung compliance.

Non-homogeneous lung disorders typically comprise lung injuries that are characterized physiologically as a combination of airway resistance and lung compliance problems distributed throughout the lungs in a non-uniform pattern. PIE (pulmonary interstitial emphysema) in the premature infant is a good example. PIE dissects up airway walls creating increased airway resistance, while the surfactant deficiency of prematurity creates decreased lung compliance. Aspiration pneumonia is another example where airway inflammation increases airway resistance, which may cause restriction of alveolar expansion in other parts of the lungs due to gas trapping and lung overdistention.

What is the best strategy for ventilating lungs characterized by pulmonary overdistention, restriction of alveolar expansion, and airway

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restriction? If it is a problem of airway restriction, as is the case with asthma, then one would want to use very low ventilator rates, long inspiratory times to get the gas to the alveoli, and even longer expiratory times to enable the gas to get back out.

What if the airway restriction is upstream from the site of lung injury? In this case, which is typical in premature infants, one would want to decrease gas flow to the injured site so that it has a better chance of healing.

If it is a problem of restricted alveolar expansion, as is the case in RDS, one would want to use higher mean airway pressures to get the lungs open and smaller tidal volumes to keep from injuring alveoli, the classic prescription for a high frequency ventilator.

The problem with non-homogeneous lung disorders is that you have both pathophysiologies happening in different parts of the lungs at the same time. The prescription here is for a ventilator strategy where one can use higher mean airway pressures and small tidal volumes to combat alveolar restriction, while somehow decreasing gas flow to the areas of the lungs with damaged airways. HFJV is unique among ventilators in that its capabilities are perfectly suited for implementing this strategy.

Jet inspirations enter the lung at high velocity. Tiny tidal volumes are delivered within 0.02 seconds (20 msec). Whenever high velocity gas has a choice of going down a small diameter tube or a larger diameter tube, it will flow into the larger tube. (Remember frequency dependence of compliance from your pulmonary physiology class? The principle of preferentially ventilating the balloon at the end of the larger tube was the result of tube diameter determining where the gas goes when you try to ventilate too fast.) No ventilator uses inspirations with as high velocity as HFJV.

Squirting gas into a non-homogeneous lung at very high velocity makes the gas go where the airways are most patent. While conventionally sized tidal volumes and higher PEEP and mean airway pressure may dilate airways enough to help gas get into restricted areas, one has to ask whether that is where you want gas to go. If the lungs are injured downstream from restricted airways, you don't want gas to go that way!

PIE is much more rare today than it was back in the 1980s when a group of 14 investigators joined together to conduct an HFJV vs. rapid rate, short inspiratory-time conventional ventilation (CV) randomized controlled study in neonates.[1] Nonetheless, the results of the study were very positive: more rapid and frequent resolution of PIE with HFJV and better survival if one considered success after crossover to Jet after failure on CV.

While statistics on PIE are not available, incidence of pneumothorax in very low birth weight babies increased in the late 1990s.[2] Since air leaks in premature infants occur most commonly near the terminal bronchial[3] and then dissect into interstitial spaces or along airways and large vessels to ultimately reach the pleural space, [4] PIE and pneumothoraces are closely related lung injuries.

After nearly 20 years of clinical HFJV experience, we now know why the Jet works in certain patients where nothing else will. Matching the characteristics of HFJV with the pathophysiology of the patient leads to ventilator strategies that will help you with your more difficult cases. The table that follows may be useful as a guide.

The seven characteristics of HFJV therapy listed in the table can be selected one by one to treat and monitor complicated non-homogeneous lung disorders. For example, the premature infant with PIE should be treated with HFJV using characteristics no. 1, 2, 3, 4 and possibly 6 if the lungs are overdistended.

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Use of concomitant IMV (no. 5) in such cases should be avoided. However, in a case complicated by airway inflammation or severe atelectasis, a few IMV breaths delivered without interrupting HFJV may enable ventilation of areas of the lungs that can't be ventilated otherwise. In all cases, Servo Pressure (no. 7) will help alert you to problems and help you determine if the baby is getting better or worse.

MV tidal volumes on top of high PEEP once the atelectasis has been successfully resolved? NO! If your PEEP is high enough, you can back off the IMV breaths and avoid causing lung injury.

For more information on Jet ventilator strategies and case studies that demonstrate the flexibility of HFJV in unusual cases, visit our website, www.bunl.com under Clinical, or give us a call at 800-800-4358.

Matching HFJV Characteristics to Pulmonary Pathophysiologies

No.	HFJV Characteristic	Pulmonary Pathophysiology	Therapeutic Goal
1	High Frequency Rates	Premature surfactant-deficient lungs	Ventilate using lower airway pressure.
2	Very small tidal volumes	Premature lungs susceptible to volutrauma	Ventilate with less risk of causing lung injury.
3	Safe use of higher PEEP (because of #2)	Atelectasis	Stabilize surfactant deficient alveoli, even when treating airleak syndrome.
4	High velocity inspirations	Lungs injured downstream from airways with high resistance	Send less gas to injured areas and more gas to uninjured areas.
5	Concomitant IMV (1-10 bpm)	Atelectasis	Recruitment of collapsed, surfactant deficient alveoli.
		Airway restriction without lung injury downstream	Periodic dilation of restricted airways during HFJV changes lung time constants and afford opportunities for ventilation of areas downstream from restricted airways.
6	Extremely short I:E (up to 1:12 when rate = 240, I-time = 0.02)	Airway restriction with alveolar overdistention	Enable trapped gas more opportunity to exit during long exhalation time.
7	Servo Pressure	Changing lung compliance and airway resistance	Detect and respond to changes quickly and effectively to maintain optimal settings and avoid destabilizing conditions.

1. Keszler M, Donn SM, Bucciarelli RL, et al. Multicenter controlled trial comparing high-frequency jet ventilation and conventional mechanical ventilation in newborn infants with pulmonary interstitial emphysema. J Peds. 1991; 119: 85-93.

2. Horbar JD, Badger MS, Carpenter JH, et al. Trends in Mortality and morbidity for very low birth weight infant, 1991-1999. Peds. 2002; 110:143-151.

3. Thibeault DW. Pulmonary barotrauma: interstitial emphysema, pneumomediastinum, and pneumothorax. In: Thibeault DW, Gregory GA, eds. Neonatal pulmonary care, 2nd ed. New York: Appleton-Century-Crofts, 1986: 499-517.

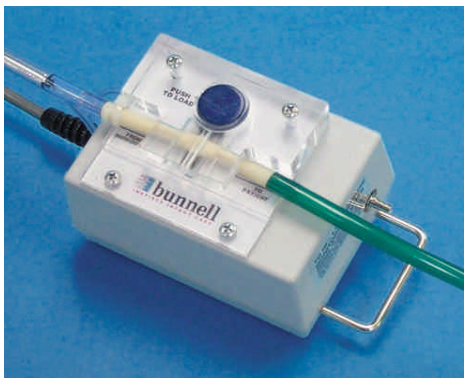
4. Macklin MT, Macklin CC. Malignant interstitial emphysema of the lung and mediastinum as an important occult complication in many respiratory diseases and other conditions: an interpretation of clinical literature in light of laboratory experiment. Medicine 1944; 23:281.

WhisperJet Approved!

The New WhisperJet Patient Box is now approved and will soon be available for purchase. This plug-in replacement for the original patient box is both quieter and more reliable. Noise in the audible range has been reduced by more than 75% (from 65 to 45 dbA).

Reliability has been improved by repositioning the pressure transducer to reduce it's potential for becoming fouled. Tubing connections have been moved to the ends of the box to avoid kinking and a handle has been attached for more secure positioning.

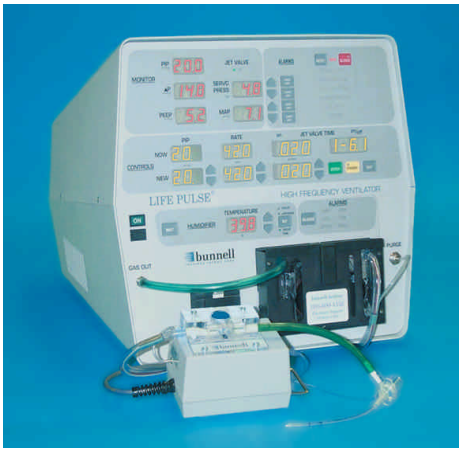
Individually these are small changes but collectively they represent a significant improvement for patients and staff. Quiet, Accurate, and Reliable, that's the new WhisperJet.



For additional information contact Ken Hekking at khekking@bunl.com or 800.800.4358 ext. 13. *Announcements have been mailed to each hospital's respiratory and neonatal departments.*

Have You Seen Our New Colors?

"Wow! It's so much smaller than ours", "We have one of those big black ones", or "'It's much prettier". These are typical reactions we hear when people see the "Jet's" new color scheme, released in 2000.



This new friendlier, more contemporary look is not only available on new Life Pulse ventilators. It is also available as an update for older Jets as well. Any Life Pulse serial number 2169 or greater can be updated by replacing the front panel and the two case halves. The cost is $1,000.00. This update is also available, at no charge, with the purchase of a two year service contract.

For more details or to make arrangements to update your Life Pulse contact Ken Hekking at 800.800.4358 ext 13 or khekking@bunl.com.

Training Anywhere, Any Time!

Did you know when you purchase a Bunnell Life Pulse it comes with a lifetime training commitment? If you have new staff or just want a refresher, Bunnell Clinical Specialists will come to your hospital and provide training at no charge.

Perhaps you have a new group of residents that just started or maybe you have a new medical director who's not that familiar with the Life Pulse. No problem! Just give us a call with some proposed dates 4-6 weeks in advance and we'll do everything we can to accommodate your schedule.

We also have PowerPoint slides available to support your in-house education and training programs. Many of the slides have speaker's notes attached so you can integrate them into existing lectures.

Our In-service Manual is another great training resource. It is available on our website in a PDF format. We are also working on a CD-ROM version and hope to have it available early next year.

To schedule training or to request PowerPoint slides contact Evan Richards at 800.800.4358 ext.37 or evan@bunl.com.

Meet Jeff Marshall

In the past few months many of you may have had the opportunity to speak with Jeff Marshall, the newest member of the Bunnell Customer Service Team. Jeff joined Bunnell in January of this year. Jeff grew up in the suburbs of Chicago and graduated from Central College in Pella, Iowa.

His interests include movies, soccer and music. Jeff's greatest disappointment in moving to Salt Lake City was that the only jazz he could find involved Karl Malone and John Stockton (Utah Jazz Basketball). Everyone at Bunnell feels fortunate to have someone as friendly and enthusiastic as Jeff on our team.

Wanted: "Jet" Clinical Specialists!

With the Life Pulse being used more than ever, requests for training have increased. Training clinicians is one of the most important services Bunnell provides. We are always looking for bright, enthusiastic Respiratory Therapists with "Jet" experience to add to our family of clinical specialists.

Clinical Specialists are used for in-service training, demos, evaluations, emergency clinical support and regional conferences. Bunnell provides extensive training and certifies clinical specialists before utilizing them in the field.

Clinical Specialists must have three or more years of experience with the Jet and the flexibility to travel. Trips are usually one to two days. Reimbursement is on a per diem basis with all expenses paid.

If you're looking for a new challenge and want to share your knowledge of the Life Pulse with other clinicians, contact Evan Richards at 800.800.4358. ext. 37 or evan@bunl.com.

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 distribute copies of papers to other clinicians upon request. 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 no problem, but you need support 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

Troubleshooting Made Easy

Troubleshooting Life Pulse alarms is an easy process if you follow a few simple steps. Is the Life Pulse running or did it put itself in Standby? How does the patient look, and what are the physiologic monitors telling you?

If the Life Pulse is running and the patient is stable, simply silence the audible alarm, take a deep breath, and start a systematic evaluation of the ventilator. If the Life Pulse is in Standby, or if the patient is deteriorating, increase support on the conventional ventilator and stabilize the patient.

The Life Pulse is designed to respond to alarms in two ways. If the problem is minor, such as fluctuating PIP, the ventilator will continue to run and support the patient at the same operating levels present prior to the alarm. It does this by locking the Servo Pressure and delivering constant tidal volumes. This response allows you to evaluate the situation, determine the cause of the alarm, correct the condition that caused the alarm while providing high-frequency therapy throughout.

On the other hand, if the problem is potentially more serious, the Life Pulse will place itself in Standby mode and activate an audible and visual alarm. In most cases, the best thing to do when these situations arise is to increase support on the conventional ventilator and stabilize the patient before troubleshooting the Life Pulse.

Is the alarm coming from the ventilator or the humidifier? Most ventilator alarms are caused by one of two things: problems with tubing, or moisture (secretions) interfering with pressure monitoring. Most humidifier alarms are related to electrical components in the circuit or a lack of water reaching the humidifier. Checking the circuit for tubing disconnections, kinks or obstructions is a simple matter. Are tubes connected to the right ports? Does the humidifier feel warm or not? Is there rainout in the clear portion of the circuit? Is there water in the water supply? Is the water supply attached to the circuit? Is the clamp on the water transfer tubing open? These conditions can be checked quickly.

If the solution to the alarm condition is not found quickly, the simplest way to resolve the problem is to call the Bunnell Hotline, 800-800-HFJV (4358). After normal business hours, you will get a call back in ten minutes or less. The hotline is staffed by clinical specialists 24/7/365. Only three people work the hotline and they all have more than 10 years of experience with the Life Pulse. They can help you quickly and efficiently solve any problem or get you a rental replacement. In addition to having technical knowledge, all of our specialists have clinical experience and they are always willing to discuss patient management issues too.

The fastest way to determine if the Life Pulse is functioning properly is to run it on a test lung. Frequently when you call the hotline, the clinical specialist will ask you to do two tests. The first thing they will have you do is connect the Life Pulse to a test lung. The test lung should consist of a 2.5 or 3.5 mm LifePort adapter connected to a 2.5 - 3.5 mm standard ET tube with a model lung on the patient end (a finger from a surgical glove or a finger cot taped in place work fine). **If you have a test lung that incorporates a Hi-Lo Jet ET (triple lumen Jet) tube, discard the Hi-Lo Jet tube and replace it with a standard tube and LifePort adapter.** The pressure monitoring tube of an old Hi-Lo ET tube can become compressed over time and result in erroneous pressure information.

The conventional ventilator is not needed for testing the Life Pulse. The 15-mm connection of the LifePort adapter is left open to the room during both test procedures. The first procedure is to run an internal test by pressing the Test button. This test checks all of the primary functions of the Life Pulse. If a problem is detected the test sequence will stop and a code will be displayed in the ON/OFF ratio display of the Control section. The clinical specialist will want to know the code (number) that appears in this display.

If this internal test is passed, the clinical specialist will have you run an operational test by pressing the Enter button. He will be interested in whether the PIP setting is reached, whether the Ready light comes on and what the monitored PEEP value is. If the set PIP is reached, the Ready light is activated and the PEEP is zero (0) ± 1 cm H_2O, the operational test has been passed. If both tests are passed, the Life Pulse is functioning normally and can be put back into service. This test sequence should only take 5 minutes to perform. (*Continued on the back of this page*)

If the alarm condition that precipitated the troubleshooting persists after the Life Pulse has passed both tests, the problem is in one of four places: the conventional ventilator, the LifePort adapter, the ET tube or the patient. Suctioning the patient and changing the LifePort adapter are easy procedures. If the conventional ventilator is having a problem it should be alarming, so you can quickly determine if it is the cause of the Life Pulse alarm. If you have checked everything else and the

alarm continues to reoccur, it must be some changing dynamic with the patient.

You can now focus all your attention on the patient and evaluate him in the same systematic way: chest rise, breathing pattern, breath sounds, transillumination, chest film, blood gases, etc.

Remember, we have a toll-free Hotline (800.800.4358) for your convenience. We are there to help you resolve problems quickly and efficiently. Our primary concern is your patient. If the solution is not obvious, don't spend time switching out equipment before you call the hotline. Call first and switch equipment only if it is necessary!

Troubleshooting Flow Chart