High Frequency Jet Ventilation: When to Switch and When to Start

Rob Graham, R.R.T./N.R.C.P.

Last month's topic was high-frequency oscillation (HFO) with volume guarantee (VG) adjunct and its implications on clinical practice in which I referenced a study by Durand et al. and gave an incorrect enrollment number. It was 500, not 512 — my mistake. I ended with a note on high-frequency jet ventilation (HFJV) being a topic for another discussion. Here it is.

Some may question the relevance of HFJV once HFO/VG becomes available in the U.S. and why a clinician may still want to use the jet. The NICU at Sunnybrook H.S.C. in Toronto where I practice was the first unit in Canada to fully embrace HFO/VG routinely. We also have at least seven jet ventilators in our ventilator inventory. I can say unequivocally there is a role for HFJV in a world of second-generation ventilators capable of HFO/VG. Further, I would submit that unless your toolbox includes a jet ventilator said toolbox is incomplete. There are things HJFV can do that HFO with or without VG simply cannot, and jet ventilation is the gentlest way to ventilate fragile lungs, i.e., those of the premature infant. (1)

"Small babies have small airways with high resistance. This resistance results in longer time constants and invariably air trapping to one degree or another."

From 2017-04-01 to 2018-03-31 our total invasive ventilation hours were 52296. The modality breakdown is as follows:

Conventional:	1920
HFO:	22512
HFJV:	27864

As one can see, even though we have a full complement of ventilators providing HFO/VG our HFJV hours are actually greater than our HFO hours. Why we so often choose HFJV over HFO/VG and when we make that choice is this month's discussion.

The majority of our intubated babies are initially ventilated on HFO/VG. However, there are some who are started on HFJV and some who are switched to HFJV, usually early in their course. What follows is a guideline as to when and why babies are started on the jet or switched to it.

First-line

A jet ventilator is kept in our admission room unless all machines are in use. HFJV is a first line mode for babies who have had prolonged premature rupture of membranes, suspected or diagnosed pulmonary hypoplasia, infants who exhibit signs of persistent pulmonary hypertension, use of Nitric Oxide (iNO), extreme prematurity and very low birth weight, meconium aspiration syndrome requiring intubation, and any infant who presents with air leak. This list is not exclusive. We are not a level four facility, but diaphragmatic hernia would also be included.

The best way to treat Pulmonary Intrastitial Emphysema (PIE) and Chornic Lung Dease (CLD) is to avoid injury in the first place. As I tell those who will listen, the jet is a ventilator, not a stem cell. Best to avoid the damage by starting or switching to HFJV early rather than waiting for the damage to be done and then trying to fix it. As with any form of therapy, the worse the patient is to begin with the poorer the outcome and the longer the course. We know that the lung is most prone to damage during recruitment, and the admission room all too often sets the stage for bad things to play out on later. Those interested in ventilation practice at Sunnybrook NICU refer to this problem . (2)

Since the original FDA approval for HFJV is for air leak it makes sense these infants are on the list, but what about other applications? In practice, the jet is very effective at eliminating CO_2, even in infants with very stiff lungs who are at high risk of air leak during the recruitment phase. Initiating HFJV on these infants starting with moderately high PEEP works well and greatly decreases the risk of air leak. Timely control of CO_2 can greatly decrease the necessity for iNO, and since the jet delivers iNO rapidly and near the area of gas exchange, I believe it is also the best way to administer this drug if this therapy becomes necessary.

"Timely control of CO_2 can greatly decrease the necessity for iNO, and since the jet delivers iNO rapidly and near the area of gas exchange I believe it is also the best way to administer this drug if this therapy becomes necessary."

Switching

What about those who end up being switched from HFO/VG to HFJV? At what point is the decision made to switch? There are many reasons, and the justification is admittedly theoretical. Having said that, our outcomes speak for themselves. Here goes.

Air Trapping

One of the most insidious problems faced by clinicians ventilating the very small, very immature infant is air trapping. Even HFJV, while being the best mitigator of air trapping by virtue of being able to generate I:E ratios of up to 1:12, is not able to completely eliminate the risk of air trapping. How is the presence of air trapping determined? Historically, using the measured PEEP on the jet and comparing to set PEEP on the conventional background ventilator has been used, but there are limitations to this from a diagnostic standpoint. As measured PEEP approaches set PEEP, we have been told to suspect air trapping. This is true however it is not foolproof. Leak around the endotracheal tube (ETT) may reduce the utility of measured PEEP. Also, there are so many time constants at play within the lung, the conducting airways, and the ETT itself it is impossible to know if air trapping is occurring regionally rather than globally and the jet cannot detect gas that is trapped on the distal side of floppy, collapsing airways; it can only provide an average indicator of air trapping as measured at the distal tip of the ET tube.

When a baby is on HFO, there are no measurements to predict from, and chest films are the standard tool of assessment. Clinically I dread chest x-rays because all too often the interpretation is "wean the MAP" after dutifully counting ribs without fully understanding what is actually happening within the patient. Given everything about micro preemies, it stands to reason that all small babies have air trapping. Unfortunately, we can't burp the babies' lungs! (Actually, we kind of can with recruitment maneuvers.) An infant whose chest x-ray shows "hyperinflation" on relatively low MAP is gas trapping, and further reduction in MAP makes matters worse. These babies are switched to HFJV when adjustments to HFO are insufficient to reduce what I will refer to as inadvertent hyperinflation. Typically ventilated at a rate of 240 BPM it is my practice to set starting PEEP at the HFO MAP. This increases MAP on the jet 1-2 cm/H_20 above HFO which is usually good because insufficient MAP is part of the problem. Because the vast majority of our ventilated babies are micro preemies, it is worth noting that 240 breaths per minute (BPM) is a standard, default rate in our NICU, although some babies do very well on rates of 300 BPM, as well. Rarely is a rate of 300 BPM exceeded. It is my hope that future versions of the jet allow rates below 240 BPM since some babies show clear signs of air trapping even at that low rate and I:E ratio of 1:12. I think this alteration may also offer more flexibility for manipulating jet inspiratory time (Ti).

Failure/maximal settings on HFO

Once HFO settings reach a certain level the mode's efficacy decreases as ventilatory efficiency decreases. As amplitude increases so do the inherent risks of airway instability and gas trapping. As a general rule, I do not allow amplitude to reach double the set MAP. As well, since our devices measure high-frequency tidal volume (HFVt), I will switch to HFJV as HFVt exceeds 2ml/kg and will not use 3 ml/kg (HFO/VG HFVt is typically 1-2 ml/kg). Because jet PIP is delivered above a set PEEP, there is no worry about ever increasing MAP to compensate for larger amplitudes and "more is always more." It stands to reason that the larger Vt becomes in HFO, the less lung protective the mode is, and jet breaths have been estimated to be less than 1ml/kg with up to 95% pressure attenuation at the distal airways.(3)

Pathology

While preventing CLD is the goal, infants who show early chronic changes on X-ray are usually switched to HFJV. This may be done prophylactically when an out-born micro preemie infant is brought in on conventional ventilation in an attempt to mitigate an impending inflammatory response. Any evidence of air leak also results in a switch because while HFO may reduce the occurrence of air leak; it has not been shown to improve it once there. (1) Infants with copious secretions may be jetted to facilitate clearance since the swirling motion of exhaled gas around the airway walls aids in bringing secretions to the trachea where it can be suctioned.

The notion of "non-homogeneous lung disease" suggests that there is homogeneous lung disease; however, studies have shown that there really is no such animal. Be that as it may, infants with unilateral hyperinflation (or collapse) may benefit from HFJV since it minimizes further inflation of the recruited lung while minimizing damage to the collapsed lung. Combined with positioning, conventional recruitment maneuvers as discussed below may greatly improve this pathology.

"Be that as it may, infants with unilateral hyperinflation (or collapse) may benefit from HFJV since it minimizes further inflation of the recruited lung while minimizing damage to the collapsed lung."

Last but not least, there is a trend towards early or immediate use of HFJV in the very small infant. As was the case with HFO, we find that most sub-25-week gestation infants end up being "jetted." There is a growing belief that using HFJV immediately on all micro-preemies is the best way to go. This application has to do with the inherent risk of air trapping these infants have due to very small airways with attending high resistance. Because of the nature of HFJV breaths, inspiratory time constants related to conducting airways and the fragility thereof are easier to deal with since the breath shoots down the centre of the airway without having to actually fill their volume first, and jet Ti can be adjusted as required to fine-tune not just for inspiratory resistance but also vary the composition of MAP. In my experience increasing jet Ti improves oxygenation/SpO_2 lability in some patients sometimes using lower PIP, part of the dance when using this machine. Clinicians are well advised to decrease rate when doing so if there is an apparent increase in air trapping when this is done. Because there is a degree of exhalation concurrent with inspiration during HFJV, the increase in displaced gas may off-set the reduction in expiratory time. And it's hard to air trap if the air can't get in. If gas trapping DOES occur, lowering jet rate can maintain an expiratory time sufficient to complement the baby's expiratory time constant.

I have not discussed settings a great deal here, and I loathe "cookie cutter" recipes for ventilation. Although there is considerable variation between my personal practice and those recommended by Bunnell, Bunnell is a good starting point for reference in terms of jet usage. (3) For instance, it is rare for me to use conventional breaths for lung recruitment; perhaps because my starting PEEP is high, I find them unnecessary. This strategy is at odds with standard Bunnell guidelines, but it works. When used, I apply gentle recruitment style breaths with a PIP of 5-6 cmH_20 above PEEP, inspiratory time of 2 seconds, rate of 10 BPM, and they are used for as short a duration as possible. A low conventional rate (say 5 BPM) may also work but I believe would take longer to accomplish the task. I do not alter jet PIP, although weaning is facilitated when the lung is properly recruited. The finer aspects of these breaths may vary between clinicians, but the general style is gaining acceptance not only within my own NICU but with other jet users as well. There are other times this is done for various reasons, but when used for unilateral collapse will usually fix the problem within 12 hours. You have to like having something fixed by the end of your shift! (Another teaser for a future paper if they'll have me!)

References:

1 *Bunnell, Bert J, Sc.D., Why, When and How to HFJV, Neonatology Today, V 13 I 8, August 2018*

2 *Ventilation at Sunnybrook NICU is initiated, driven and managed by Respiratory Therapists assigned exclusively to the NICU and who do not rotate throughout the hospital. The unit has a history of pushing the ventilation envelope, being the first in Canada to use several modes including HFO and HFO/VG using the Drager Babylog®8000 Plus and VN-500® I have been a part of the NICU team since 1989, having done my neonatal training at Toronto's Women's College Hospital (former program location) in 1988.*

3 http://www.Bunl.com/clinical

Disclosures: The author receives compensation from Bunnell Inc for teaching and training users of the LifePulse HFJV in Canada. He is not involved in sales or marketing of the device nor does he receive more than per diem compensation. Also, while the author practices within Sunnybrook H.S.C. this paper should not be construed as Sunnybrook policy per se.

NT

Rob Graham, R.R.T./N.R.C.P.
Advanced Practice Neonatal RRT Sunnybrook Health Science Centre
43 Wellesley St. East
Toronto, ON
Canada M4Y 1H1
416-967-8500
Rob Graham <rcgnrcp57@yahoo.ca>