The Best Ventilator You Can't Buy. Is There a Place for Another Jet?

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

I dedicate this column to the late Dr. Andrew (Andy) Shennan, the founder of the perinatal program at Women's College Hospital (now at Sunnybrook Health Sciences Centre). To my teacher, my mentor and the man I owe my career as it is to, thank you. You have earned your place where there are no hospitals and no NICUs, where all the babies do is laugh and giggle and sleep.

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With COVID-19 ICU admissions at record levels in several Canadian jurisdictions, this month, I will stray from the NICU to the ICU. (With full admission that adult ventilation is not my field of specialty).

High-frequency jet ventilation (HFJV) has been used in the NICU for decades. It has proven beneficial in treating varying pathologies, such as pneumothoraces, broncho-pleural fistulae, and pulmonary interstitial emphysema (PIE).

In the adult ICU, HFJV is far less commonly used. There is one commercially available jet ventilator, the Monsoon® from Acutronic®. This machine did not exist during my clinical training at Toronto General Hospital (TGH); however, several jet ventilators were in the city. These machines were rudimentary and were built by the University of Toronto. Like the LifePulse® jet ventilator from Bunnell Inc, they were used in tandem with a conventional ventilator.

I had the occasion to use HFJV once during my time at TGH. As was (and still too often is) the case with HFJV in the NICU, these devices were used as rescue therapy. There were no adult oscillators available at the time. I know of one case wherein a patient with severe ARDS was jet ventilated for a month and recovered.

As we fast-forward to the present COVID-19 pandemic, there are compelling reasons to consider HFJV in treating COVID-19 patients who require mechanical ventilation. The gentleness of HFJV and its ability to facilitate the clearance of airway secretions, as well as the ability (at least in neonates) to oxygenate at lower mean airway pressure, should be to its advantage.

There is a problem, that being the availability of jet ventilators. The Monsoon® is not in widespread use, at least in North America, and many clinicians are unfamiliar with the concept of HFJV. Reading through the operating manual of the Monsoon® gives me the impression that, while having useful adjuncts like end-tidal CO_2 monitoring, the machine is complicated when compared to the LifePulse®. What appears to be lacking is servo-control of the jet pulses.

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The driving (or servo) pressure of the LifePulse® is limited to 21 p.s.i., inspiratory time to 0.02 to 0.034 seconds, and peak inspiratory pressure (PIP) of 50 cmH_2O. With the Monsoon®, jet valve time is adjusted as a fraction of cycle time. Humidification differs between the two machines, with the Bunnell product providing temperature settings while the Monsoon® humidification system is adjusted by "power." The operating manual suggests verifying adequate humidification by bronchoscopy, suggesting to me that its system is less than ideal.

The LifePulse® is capable of ventilating paediatric patients and has been used at weights up to 26kg. (I have heard of it being used to ventilate a small adult). The Lifeport® adaptor, which replaces the 15mm endotracheal tube (ETT) connector, is limited in size to 5.5mm, too small to use with a 7mm or larger ETT. Nonetheless, there are ways to adjust the machine to provide maximum servo pressure and PIP higher than 50 cmH_2O. Doing so could conceivably provide enough power to ventilate a small adult.

The infant/paediatric version of the LifePulse® is elegant in its simplicity and ease of use. Building on its design to make an adult capable machine seems logical. It turns out doing so is not so

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simple, but, in fact, it has been done.

This begs the question: why doesn't an adult version of the LifePulse® exist? I believe there are two main reasons: The Food and Drug Administration (FDA) and a company that, given its history with the FDA, is risk-averse. Prototype machines were built, and one was used on an adult patient under compassionate grounds, but that is where this story has thus far ended. Venturing into a market in competition with another machine certainly involves risk, especially given the sparsity of studies on the use of HFJV in the ICU.

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While HFJV has been well studied and is widely used in the neonatal population, its use has been less common in the adult world. I found one study on H1N1 patients with ARDS in which the Monsoon® jet ventilator was used. Pressures used in this study were a maximum of just over 30 cmH_2O (1) which could be well within the range of a LifePulse® altered to ventilate patients larger than 26kg.

Because it is a set percentage of respiratory cycle time, Ti on the Monsoon® is longer than that of the LifePulse® and shortens with higher rates. A shorter Ti requires a higher PIP to deliver the same volume as a longer one. The higher rates of the Bunnell machine work to its advantage here as the short Ti reduces the risk of gas trapping even at rates approaching HFO. Set as real-time, Ti does not decrease as the rate increases. Comparable minute ventilation may be possible with proper adjustments.

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If I were placed in that difficult situation, my inclination would be to set Ti at 0.034 seconds and PIP at 50 cmH_2O, initially at a rate of 240 on the LifePulse® with PEEP at conventional mode MAP. If there were no improvement or deterioration occurs, I would increase the rate in 1 Hz increments to 360-420. Beyond a certain point, increasing jet rate becomes less effective, and modification is required. Bench testing may be able to approximate comparable settings between the two machines.

Given the prevalence of ARDS and its approximate mortality rate of 35 -46% (2), an effective ventilation strategy is wanting. Extracorporeal membranous oxygenation (ECMO) is the current endpoint for those failing mechanical ventilation.

The Oscillate Trial did not favour high-frequency oscillation (HFO) for the treatment of ARDS. (#) Whether it was HFO to blame for the poor outcomes of the HFO group or the design of the study itself (for instance, a 1:1 I:E ratio, "highest possible frequency," and an initial recruitment maneuver of 40cmH_2O for 40 seconds) cannot, in my opinion, be determined. The greater use of vasoactive drugs, paralysis, and "new-onset barotrauma" (3) within the HFO group begs the question of whether MAP used in the HFO group was patient-appropriate. To me, the key take-home message from the Oscillate Trial was the use of smaller tidal volumes in conventional modes in concert with higher PEEP.

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While I recognize the difficulty of conducting a clinical trial in mechanical ventilation, protocolized ventilation is, shall we say, not my cup of tea. I prefer to tailor ventilation to individual patient needs/responses within flexible guidelines. Those guidelines allow a clinician to operate beyond them when required.

Nevertheless, HFJV is fundamentally different from HFO in terms of I:E ratio, passive vs. active expiration, and the lower MAP required to achieve adequate oxygenation. (Lower MAP requirements have been demonstrated in the neonatal population but not in adults).

I believe the relative simplicity of the LifePulse®, the ability to set actual inspiratory time, and servo-controlled PIP make it a superior machine and one more likely to gain acceptance in an ICU setting. Given the enormous, tragic loss of life to COVID-19 (not to mention ARDS), it is a shame that clinicians fighting this pandemic do not have it at their disposal.

In the current tense, COVID-19 is striking ever younger (and potentially smaller) patients. At the time of writing, variants of the virus threaten the efficacy of current inoculations and the rate at which we can administer them. The virus is always one step ahead.

For decades, using HFJV to manage the most fragile and challenging NICU patients has a track record of success. Should the agonizing decision come to ventilate, a COVID-19 patient HFJV

may prove to be the best option. When a Monsoon® is not available, using the LifePulse® may be justifiable, even for some with bodyweight outside its rated operating range. When ECMO is the only other option, the nature of HFJV should make it a consideration before abandoning mechanical ventilation entirely, machine choice notwithstanding.

It is not whether we are up to the challenge; the challenge is here. Now.

Perhaps next time.

Footnote: this column strictly represents the author's opinions and in no way represents the endorsement of Bunnll Inc., Acutronic®, or anyone associated with either company.

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