New Technology, Old Problems

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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Neonatal ventilation and ventilators have come a long way since "The Bird." The availability of adjuncts such as synchronization, volume targeted ventilation, and flow graphics has afforded clinicians the ability to ventilate babies with a degree of lung protection and reduced work of breathing that we could only imagine 30 years ago. High-frequency jet ventilation as well as machines offering both conventional modes and high-frequency oscillation (HFO), and more recently, the ability to monitor and control volumes in HFO (HFO/VG) provide more options and flexibility than ever before.

While undeniably superior to ventilators of old, as sophisticated as they are, modern neonatal ventilators are not infallible; they are only as good as the information they receive. It is up to those at the bedside to determine the accuracy of that information and take corrective action when required.

Synchronized breath delivery reduces work of breathing and provides more uniform volumes, but this has introduced a problem familiar to those who have worked with these modes in the adult population: auto-triggering. The culprit here is water. When condensation builds up to the point of rain out, water gathers in the lowest part of the circuit. Bias flow produces a form of oscillation not dissimilar to bubble CPAP and, in doing so, may provide enough flow through the flow sensor to trigger the machine. This causes an inadvertent increase in respiratory rate, asynchrony, and breath stacking.

There are, of course, tell-tale signs that this is occurring. In volume control modes, this results in increased peak inspiratory pressure (PIP) as well as rate. Properly set alarm parameters may alert caregivers to the problem. However, it is not uncommon for minute volume and rate alarms to be set quite liberally above or below baseline, especially in the presence of large leaks. Appropriate setting of maximum pressure limits in volume targeted modes (≤5 cmH_2O above-average PIP or amplitude) offers the best warning of trapped water and the need for suctioning or a decrease in compliance. In the absence of alarms, other parameters offer clues that something is amiss. Maximum pressures being used consistently is one indicator, as is high respiratory rates with no apparent efforts from the baby. The pressure waveforms on machines so equipped may appear somewhat jagged or sawtoothed, particularly between breaths.

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Water accumulation in HFJV may not be as easy to spot since the conventional ventilator may not have graphics. However, the same suspect pressure waveform may appear on those that do (Figures 1,2). Water trapped in the expiratory limb of the conventional circuit may increase effective ventilation by superimposing low amplitude oscillation on top of HFJV, not unlike bubble CPAP. This water also creates resistance to gas flow which may create inadvertent PEEP, which decreases the pressure gradient of the jet breath and may decrease ventilation.

Dual heated wire ventilator circuits have greatly decreased circuit rainout and virtually eliminated "spill and fill" rounds, but there are situations where rainout can and will still occur. Low ambient temperature may be more than the heated wires can cope with. Circuits with an extension are particularly prone to water accumulating near the temperature probe at the end of the heated wire portion. The flow around the temperature probe is such that it tends to stop rainout from the unheated extension from passing

through. Accumulated water also cools the probe and may trigger a low-temperature alarm from the humidifier. This is most common if ambient temperature outside the incubator or in the incubator itself is relatively low. (Figure 3)

The temperature of modern humidifiers may not be adjustable other than "invasive" or "non-invasive" settings. Changing the setting to non-invasive when a patient is intubated is not recommended as it lowers the temperature below that required to provide 100% relative humidity at 37 degrees C. On older models increasing the circuit temperature or the pot/circuit offset will reduce circuit rainout but lowering pot temperature below 37 degrees C is not recommended. With the Bunnell jet, reducing cartridge (or water) temperature to 37 degrees while maintaining a circuit temperature of 40 degrees will reduce rainout. With any ventilator, avoiding having drafts or room ventilation from blowing over the circuit will also decrease the risk of rainout.

Figure 1: Normal HFJV pressure waveform on conventional ventilator

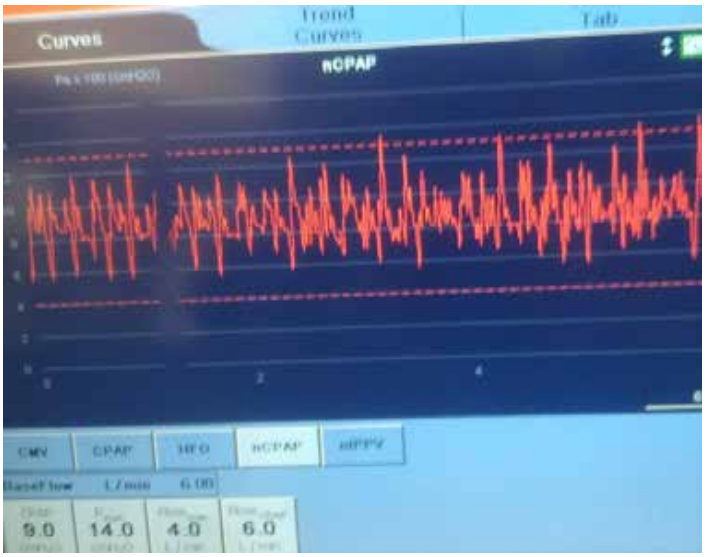

Figure 2: HFJV pressure waveform with water in circuit

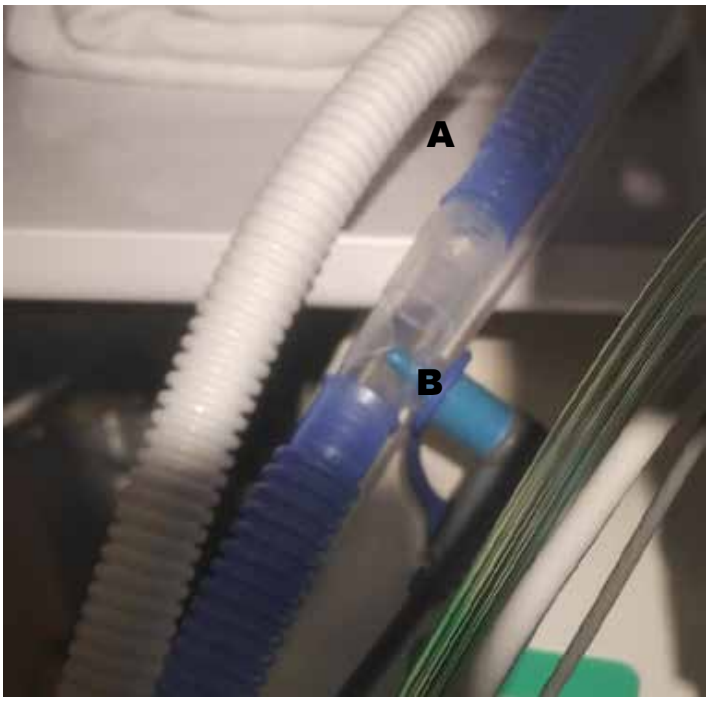

Figure 3. A: Unheated circuit extension. Removing will decrease rainout (keep if handy extra length is needed i.e. for kangaroo care). B: Junction of heated & non-heated circuit. Water accumulates here.

Since water flows downhill, gravity can be either friend or foe. Sloping the ventilator circuit downward from the baby helps prevent water accumulation in the patient wye where it can be introduced into the endotracheal tube, a potential source of ventilator-associated pneumonia. Guidelines for neuroprotective management of the micro or nano premature infant call for elevating the head of the bed 15-30 degrees. This greatly increases the likelihood of rainout reaching the baby, and baffles at the head of the bed exacerbate the problem. If the baffle incorporates a grommet, removing it may help.

Although the Bunnell jet ventilator incorporates a purge for the pressure line, it is not uncommon for the water to enter the line, particularly if positioned dependently and/or after saline instillation for suctioning. This effect dampens the signal and may cause a "loss of PIP" alarm condition. Purging the pressure line with a syringe will quickly clear the water and eliminate the alarm. (It may be necessary to hit "enter" before the machine locks in pressure again). (Figure 4)

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Water can also create problems with hot wire anemometer sensors since it cools the wires resulting in erroneous measurements. Ensuring the heated wire elements are positioned upright helps prevent this, and "messy" flow graphics may indicate this is occurring.

Figure 5: hot wire anemometer and connecting cable. A:Look for damage or discolouration (usually greenish) here as it may affect signal quality. Look for corrosion at the base of the connecting pins. B: The cable should connect such that it is at the top of the sensor.

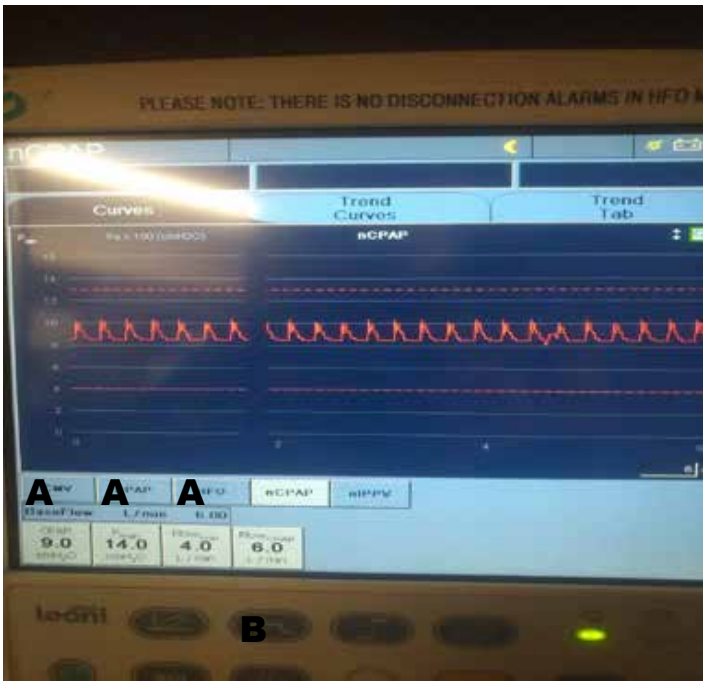

Figure 6. A: Note flow & pressure settings for manual breaths. B: Manual breath button.

Any machine relying on a flow sensor to deliver targeted volumes is only as good as the sensor's data. Loose connections or corroded contacts may interfere with the signal sent to the ventilator.

Evidence of oxidation or corrosion on either the flow sensor or cable are signs one or the other should be replaced. Often the flow graphic waveform displayed may not be as clean in appearance, or the machine may deliver higher PIP than necessary. If high

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PIP is being used consistently, this may signify a faulty signal. If pushing the flow sensor cable firmly into the flow sensor results in a flow waveform improving and/or PIP decreasing, either the flow sensor or cable or both should be replaced. It is important to note that the flow sensor may calibrate successfully in these situations. Over time, as with any plug, the snugness of the connection may lessen, providing an unreliable connection. Flow sensors and sensor cables are consumables and must be replaced regularly.

Other Considerations:

I have mentioned setting maximum pressure limits tightly enough

to promptly alert the clinician to changes. The manual breath's pressure and flow (or slope) are often not considered. It is very common for the person at the bedside to use the manual breath button to bring the baby out of bradycardia or a desaturation episode or to re-recruit after suctioning or circuit disconnection. If this pressure is too high, it can damage the lungs of a tiny (or not so tiny) baby. It is my practice to set manual pressure at 5 cmH_2O above PEEP (or MAP with HFO) and reduce the flow (or increase the slope) of these breaths to make them as gentle as possible. Should higher pressure be required, it can be adjusted. (Figure 6)

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Many ETTs are precut. The standard 2.5 mm ETT is 11 cm long. We tend to think of resistance related to diameter and having an exponential effect; this is indeed by far the most significant determinant of resistance to flow. We tend to forget that tube length also affects resistance, albeit linearly. The significance of ETT length is greater with smaller babies as it increases resistance (and any associated gas trapping) and dead space. Reducing the length of a 2.5 ETT from 11 to 9 decreases resistance by 18% and dead space by approximately 0.1 mL. When dealing with volumes of 2 mL or less, this becomes significant. Decreasing ETT length as much as is practically possible can only be beneficial.

An old driver's educational film proclaimed the most dangerous part of an automobile was the nut behind the steering wheel. As sophisticated as cars have become, the statement still holds true.

The same could be said for ventilators!

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. This article contains elements considered "off label" as well as maneuvers, which may sometimes be very effective but come with inherent risks. As with any therapy, the risk-benefit ratio must be carefully considered before they are initiated.

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