Non-Invasive Ventilation Revisited

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.

In volume 14, issue 3, March 2019, I wrote on non-invasive ventilation (NIV). In that submission, the topic of suitable candidates for NIV was discussed. The sequelae resulting from not re-intubating when reaching failure criteria (or the failure to establish those criteria) was presented. The past sixteen months have provided me the time necessary to examine first hand the results of riding the NIV bandwagon. I suspected the ride had not been as smooth as had been suggested. My observations have given me ample food for thought and caused consternation amongst my colleagues as well.

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I have previously suggested the success a facility has with NIV (as measured by chronic lung disease (CLD) outcomes), are likely to reflect how well invasive ventilation (IV) is practiced within that facility: if its clinicians are skilled at IV, then CLD outcome improvements will be less dramatic than they would be compared to those who are not as adept at IV. CLD outcomes in the unit in which I practice have been historically world-class. The adoption of NIV in our not-so-premature infants (i.e.,>25 weeks gestation (GA)) was met with little resistance. The days of intubation based strictly on GA were at that point already long past, and it made perfect sense to give these babies a chance. Things changed when NIV was used as a first-line mode for infants of less than 25 weeks GA.

If a baby is born active and breathing spontaneously, it is appropriate to use NIV to support the baby at least until vascular access is obtained; rapid sequence induction medication can then be given for intubation. It is also reasonable, in my opinion, to allow those babies, doing very well on NIV, to remain without an endotracheal tube (ETT). Here the proverbial devil is in the details; just what is "doing well"? If one's definition is simply breathing spontaneously without regard to other factors like FiO_2, bradycardia, and desaturation episodes, then one's assessment is incomplete. Evidence of the adverse effects of high FiO_2, particularly in the extremely premature lacking endogenous anti-oxidant protection, are well known. The consequences of remaining on NIV in high FiO_2 later in the infant's course are also becoming clear: smooth muscle hypertrophy and hyperreactive airways, and poorer forced exhalation at one second (FEV1).[1] It is too early to draw firm conclusions, but it would appear that rates of intraventricular hemorrhage (IVH) and retinopathy of prematurity (ROP) have also increased in step with the increased and earlier use of NIV.

There is more to this equation than simply FiO_2 and NIV vs. IV. What mode of IV also plays a part, as does the equipment used to provide that mode, particularly with high-frequency oscillation. The disadvantages of the only oscillator currently available to US clinicians have been discussed in previous columns, and there is a myriad of differences in the approach to ventilation across NICUs worldwide. In Canada, as in the rest of the world, third-generation oscillators have been used now for over ten years, and second-generation machines for 15 or more years before that. These machines are fundamentally different from those used in the United States; however, all ventilation data gets dumped into the same pot; the results may thus be negatively skewed when examining oscillation.

While some units use high-frequency oscillation (HFO) or high-frequency jet ventilation (HFJV) as a first-line mode, many units do not. Indeed, many units do not have access to jet ventilation because the machine is not widely available outside the US and Canada. This is regrettable. I have a strong bias towards the use of HFO or HFJV (depending on the patient) as a first-line ventilation mode when intubation is required, and several units with particularly good outcomes do this, including the one in which I work. There are more that do not, and ventilation practices in many units are sub-optimal. Nevertheless, data from these units are dumped into the aforementioned pot, and the result is an average value comprised of a wide range of CLD outcomes. As NIV came into vogue, many units saw their CLD outcomes improve, which in turn made the average outcomes also improve. The NIV train left the station full of clinicians of all stripes eager to improve their outcomes; after all, who does not want better outcomes?

About those outcomes…are they better, or are they worse? Yes. A year-to-year comparison does not allow for a concrete conclusion; however, the data I have observed is intriguing. In all age strata, CLD outcomes improved with one notable exception: 24 weeks GA. In this group, rates increased from approximately 30% to 58%.

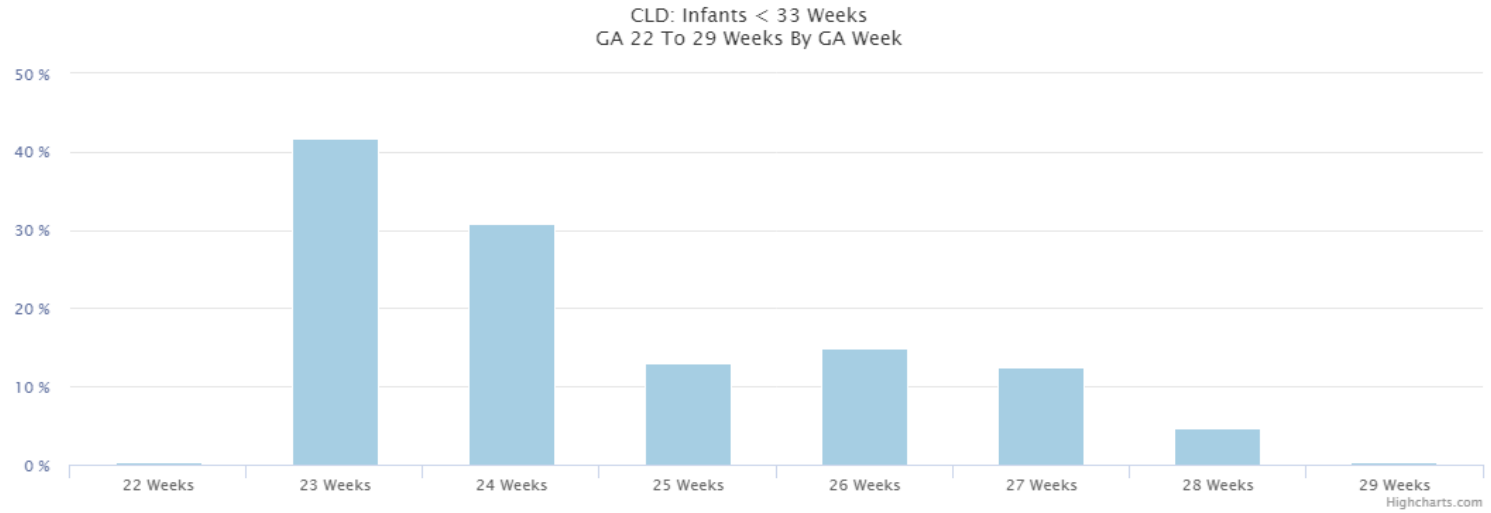

Figure 1: 2018 CLD outcomes (source blinded)

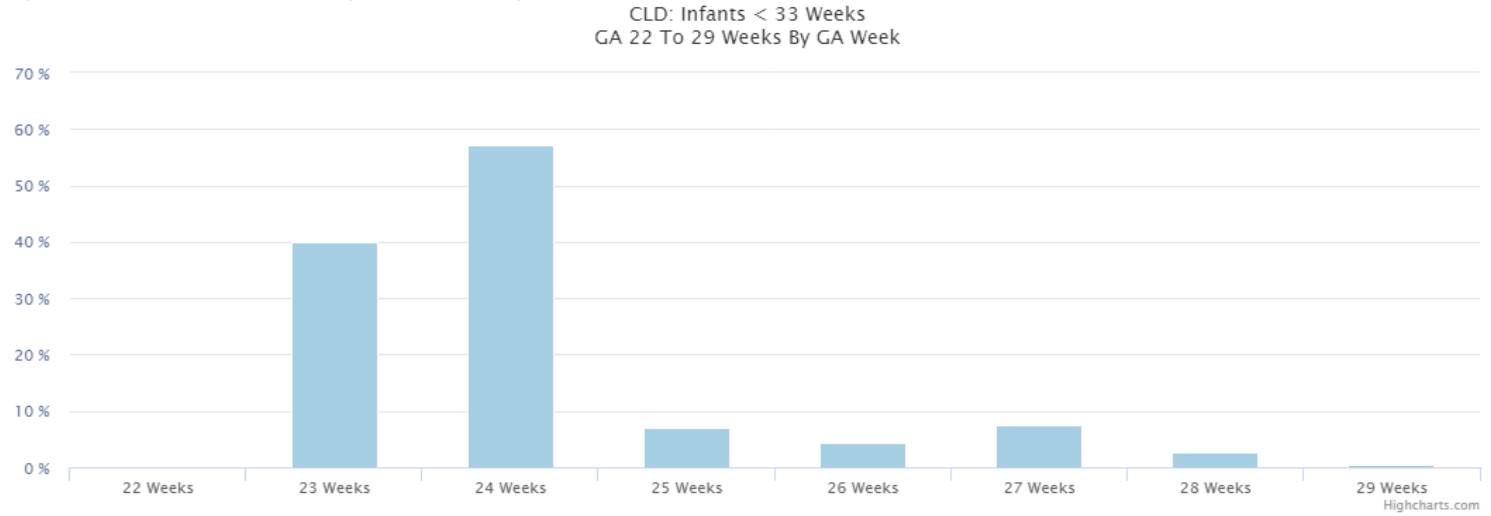

Figure 2: CLD outcomes 2019 (source blinded) Blue arrows indicate 2018 value

Why? It is almost unheard of to have a 23-week GA infant supported with NIV for any length of time. The CLD rate for these infants decreased insignificantly, while the rates in the 25-week GA group decreased from approximately 12% to 8%. This makes sense. At 25-weeks GA an infant is much more likely to tolerate NIV as the first intention, and they are also less likely to be managed with IV for an extended period. 24-week gestation infants are a much different animal. These infants are developmentally behind those at 25-weeks GA, and this must be considered when choosing respiratory support. As NIV has been used on lower and lower GA infants, the benefits have been mixed. In the ≥ 25-week GA group, the benefits seem clear: less CLD. It would appear from the limited data available to me that the increase in CLD in the 24-week GA group may be secondary to increased use of NIV on these infants, combined with earlier extubations and subsequent maintenance on NIV in high FiO_2 and pressures.

Problems with NIV

There are several ways to provide NIV, as well as modes within the realm of NIV, such as intermittent positive pressure and oscillation. Various devices exist from several manufacturers; nasal prongs, nasal masks, RAM® nasal cannulae, and others from companies such as Fisher Paykel. Each has its advantages and disadvantages, but the most egregious sequela is nasal septal damage, which follows these babies into childhood and beyond. This is most commonly related to the use of nasal prongs, although a nasal mask not carefully applied can also result in septal damage. Nasal masks are most commonly associated with skin breakdown on the bridge of the nose; in some cases, a distortion of facial features (the centre of the face being pushed in) results from having the mask applied very tightly in an attempt to maintain high pressures. Avoiding extubating from high IV support pressures can mitigate this. Adjunct barrier devices are also available, which help reduce injury **before** it happens. Alternately, "duoderm"® or similar products may be cut to size and used as a protective bar-

rier. Placing these barriers after the fact may exacerbate the injury as they may prevent them from drying out and healing.

Infants may be switched over to the RAM® canulae when nasal septal erosion or other skin breakdown is noted. Clinical experience would seem to indicate this device is less likely to result in septal damage (although it is possible) and may be used to "give the nose a break." The biggest problem with RAM® is pressure delivery. There are varying estimates of how much pressure is delivered at a given setting with this device. In clinical practice, I find increasing the set CPAP pressure by 2-3 cmH_2O seems to compensate. Accordingly, I set the pressure to a level that meets the needs of the baby. When reporting, the type of device used is stated since the team are aware of the differences between RAM® canulae and nasal prongs or masks. Should a baby require a backup rate, the RAM is not ideal, although the utility of NIV with a rate is a subject of debate. (The exception to this might be NI-high frequency jet ventilation, coined "NINJA" (see Volume 14 Issue 5).

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Alternating between nasal prongs and nasal mask helps to reduce the incidence of injury, as may gentle massaging of the baby's nose when off during routine care if tolerated. If a baby tolerates brief periods off NIV support "cycling" time off, while also contentious, may also give the nose a rest. The best predictor of nasal damage is time on NIV support, although it can occur very quickly, sometimes in a matter of hours.[2] Obviously, the earlier a baby is extubated and supported with NIV, the greater the risk of damage is. Another option is to change the NIV mode to high flow as early as possible, although as with RAM®, the pressure delivered is unknown, and flow rates are set clinically (within reason) to meet the baby's needs. Some use the "Wilkinson formula" to set high flow rates.[2] (It is worth noting that Dr. Wilkinson does not use these formulae.)

Last but not least is the problem of "CPAP belly"; as NIV pressure increases, so does the amount of air that finds its way into the stomach and bowel. As gastric/intestinal air increases, the space available for ventilation decreases. In addition, the air in the stomach may contribute to feeding intolerance and reflux, repeated X-rays, and septic workups to investigate the (perhaps obvious to the bedside caregivers) reason a baby is not doing well. Maintaining a gastric tube vented to air is *de rigueur*. The length of that tube is also important. I often see babies on continuous feeds with the extension tubing vented. The increased resistance posed by that extension makes venting it to air moot.

IVH and ROP

That premature infants will have apnea and/or bradycardia (with or without accompanying oxygen desaturation) episodes is a forgone conclusion. These events are less common when an infant's respiratory needs are fully met (i.e., IV); however, they are far more common when NIV is used. The solution? If a manual inspiration button is available, it may be used to give a gentle reminder to the baby that breathing is not optional. If that button is not available (with bubble CPAP, for instance), the only choice is gentle stimulation to trigger breathing and increase heart rate. The availability of a manual inspiration button notwithstanding, more vigorous stimulation may be required. Stimulation, particularly in the first 72 hours of life, may activate the "fight or flight" response. While this accomplishes the caregiver's goal, it also causes a spike in blood pressure and cerebral blood flow; this is a setup for a bleed. Oxygen desaturation prompts the bedside caregiver to increase FiO_2, therefore increasing saturation (SpO_2) to within an acceptable range. This acceptable range is invariably overshot before FiO_2 is returned to the baby's normal baseline. Worse, if the FiO_2 is left up (for instance, when the bedside caregiver is called to attend to another patient), re-perfusion injury or prolonged hyperoxia is the result.

Conclusion

As with any therapy, risk/benefit must be assessed, and NIV patients should be selected appropriately. I would suggest NIV not be used in babies under 25-weeks GA except under exceptional circumstances. This does not mean a baby <25-weeks GA cannot be supported with NIV temporarily while vascular access is obtained. It may also be neuro-protective to support the 25-week GA infant with carefully monitored, lung-protective NIV for the first 72 hours to decrease the amount of stimulation the infant receives during this critical period. Avoiding extubating from high support pressures and ensuring properly sized nasal prongs (they should fit snugly into the nares without putting pressure on the nasal tissue) are the best ways to mitigate nasal and facial damage.

NIV has likely saved many babies from CLD, and it has earned its place as a proven mode of respiratory support, particularly in the ≥25-week GA strata. The success of NIV is directly related to GA,

rising quickly as GA increases. Where once all infants <30 weeks GA would be intubated "for prematurity," it is now unusual to find a ≥27-week GA infant receiving IV for any length of time. With the advent of minimally invasive surfactant therapy (MIST), it is now unusual to see these infants intubated at all, and it would appear that this too may have a positive effect on CLD outcomes.

References:
1 https://www.nejm.org/doi/full/10.1056/NEJMoa1700827
2 https://pubmed.ncbi.nlm.nih.gov/19176303/
3 Wilkinson formulae for CPAP using high flow:
CPAP 5: 3.9 x weight in kg
CPAP 6: 4.8 x weight in kg
CPAP 7: 5.7 x weight in kg
CPAP 8: 6.6 x weight in kg

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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Corresponding Author

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
Email: Rob Graham <rcgnrcp57@yahoo.ca>
Telephone: 416-967-8500