Respiratory Report: Non-Invasive Nasal Jet Assisted Ventilation (NINJA): A Case Study

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 a previous column on non-invasive ventilation (NIV) I indicated there was no evidence to support these modes (with the exception of neurally activated triggering – NAVA® in NIPPV). A recent study out of China supports the use of non-invasive HFO (NIHFO) to decrease the rate of reintubation and CO_2 elimination. (1) NIHFO is a mode available to clinicians outside the United States, and it is used extensively in my own unit. Current oscillators in the U.S. are not suitable for non-invasive application.

In this column, I present a case of using the Bunnell LifePulse® high-frequency jet ventilator in a non-invasive mode which I have named and will refer to as "NINJA" (Non-Invasive Nasl Jet Assist). To the best of my knowledge, this is the first non-invasive application of true high-frequency jet ventilation.

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Overview

Maternal History and Delivery

Mom was a thirty-six-year-old gravida one para zero with a history of polycystic ovarian syndrome. This pregnancy had been complicated by gestational diabetes requiring insulin management. A cerclage procedure was performed at twenty-two weeks gestation for a shortened cervix. Magnesium sulfate was started at twenty-one plus one day gestational age with a fetal weight estimated at 490 grams. Membranes ruptured spontaneously on November 14, 2017, at 18:00 and one dose of antenatal steroids was given. Unfortunately she progressed, and footling breech presentation necessitated a caesarian section which was performed November 15, 2017, at 06:06, thus giving insufficient time for effective steroid treatment.

Resuscitation

There was a weak cry at birth, and then no spontaneous respirations, thus positive pressure ventilation (PPV) via mask and flow inflating bag commenced. The infant was orally intubated on the third attempt (the first, unable to visualize due to secretions, the second, vocal cords were closed, and the endotracheal tube would not pass, the third attempt, successful after positive pressure ventilation) at six-seven minutes of life). It is our usual practice to intubate nasally when possible. APGARS were $3^{1},5^{5},8^{10}$ and birth weight was 648 grams. At no time were chest compressions required. Arterial cord blood gas was 7.34/42 CO_2/22 HCO_3 -3 base deficit.

Initial Management

The baby was placed on high-frequency oscillation (HFO) with mean airway pressure (MAP) of 11 cmH_2O which was decreased to 10, frequency of 10, amplitude of 22 which was decreased to 16. Volume guarantee was not initially used. FiO_2 was initially 1.0 but decreased to 0.21 post-surfactant administration (bLES®) (Infrasurf® outside Canada). The baby was switched to high-frequency jet ventilation (HFJV) approximately sixteen hours later. (Those interested in the ventilatory management of this baby may refer to April's column on hyperinflation).

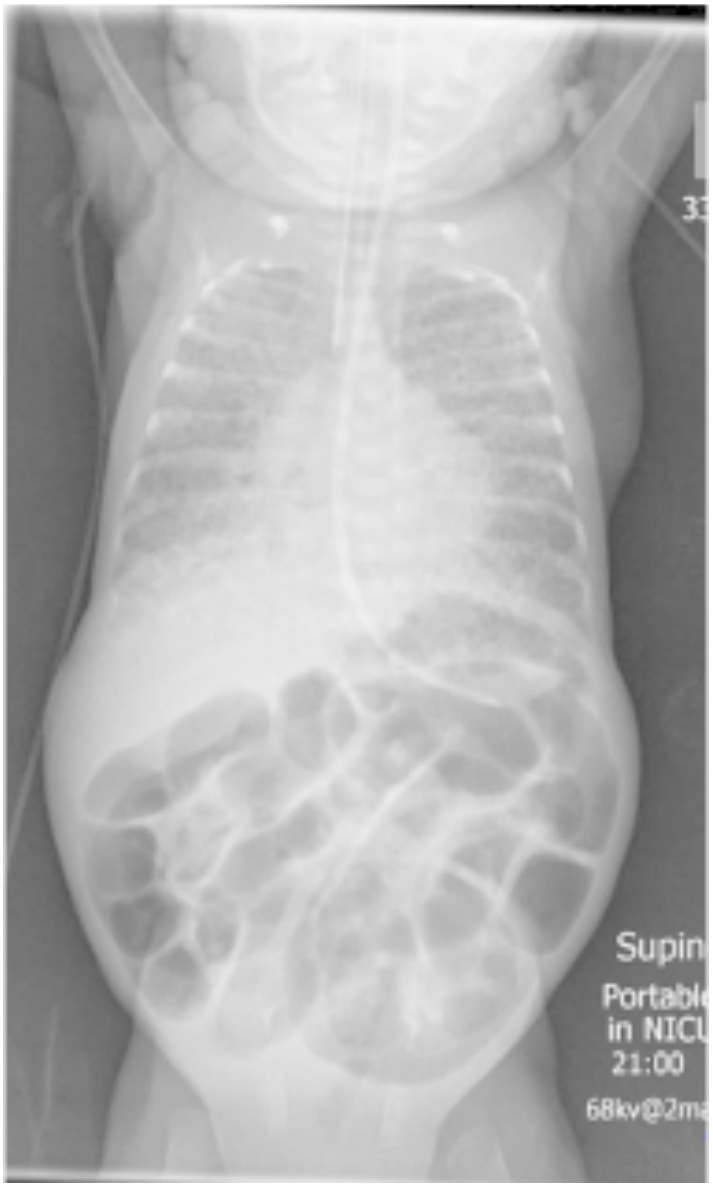

Figure 1

Course

On day 21 of life dexamethasone was started using the "DART"

protocol (2) due to high oxygen requirements and severe, evolving chronic lung disease (CLD). (See figure 1).By day 24 of life, the baby had shown a very good response to the DART protocol with decreased oxygen requirements, although the MAP was still fairly high at 16cmH_2O. This high pressure could not be reliably delivered in the team's estimation NIV using current equipment. As there was a large leak around the 2.5 ETT I suggested to the team that the positive response to steroids should be taken advantage of, a trial extubation would also allow us to upsize the ETT. Various discussions had taken place regarding the use of HFJV non-invasively, including its inclusion in an upcoming NIV study using electrical diaphragmatic impedance (EDI) to assess work of breathing. It was felt the mode would probably work and was no more "off label" than current NIV modes, but we had never actually used it on one of our babies. I felt the mode could be more able to provide higher MAP than other NI modes, and that the nature of the jet breath might facilitate CO_2 elimination similar to NIHFO as well.

In the end, a serendipitous combination of team members agreed it was worth a try. Before proceeding I insisted on setting clear failure criteria: increased FiO_2 greater than 0.2 above baseline and/or increased apneic/bradycardic/desaturation episodes above baseline. I also had been the primary respiratory therapist for this patient and had a very good relationship with the parents; hence it was agreed I could approach them for consent for this novel and hereto before untried therapy. Consent was given as was consent to present and/or publish results. Mom is a professional and had been following her baby's management very closely. Our unit provides for parental presence at all times, and she availed herself of that provision a great deal. (While caregivers may find having parents around all the time, shall we say annoying, I firmly believe that above and beyond the care and technology we as caregivers provide, it is their presence that positively impacts outcome the most, and it comes without risk of any kind.)

Method

RAM® nasal cannulae was chosen as the patient interface. A nasal pharyngeal tube (NPT) tube was also considered and could have been used, but patient comfort was a factor in favouring RAM®. The cannulae were modified to accommodate the Bunnell Life Port® adaptor as I felt there to be too much dead space and potential for dampening of the jet breath using other connections.

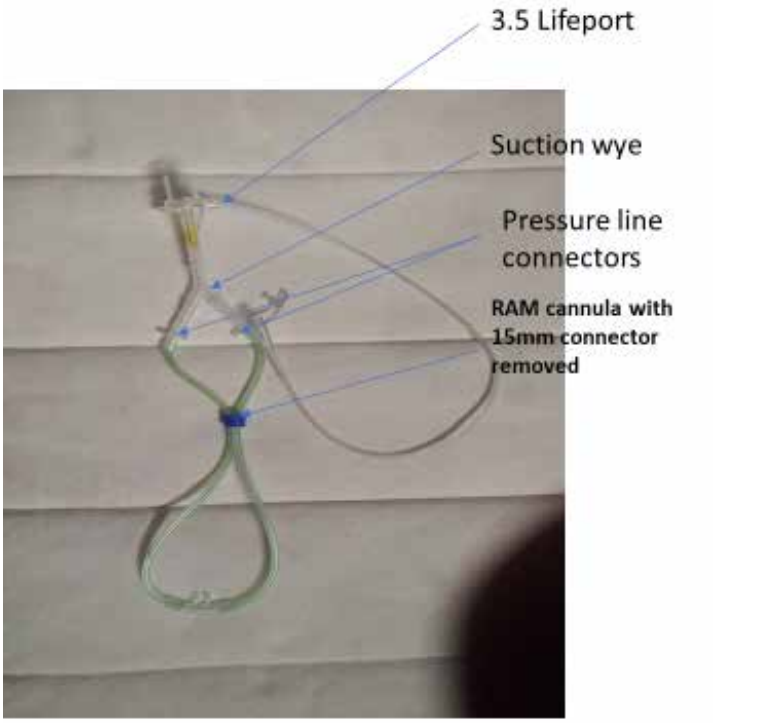

Figure 2: The set up

The set up as used is shown in figure 2.

Rapid Sequence Induction (RSI) medications were drawn up prior to extubation as a precaution and in preparation for failure. The Life Port® adaptor was connected to the jet and conventional ventilator circuit as usual, and as when used with an ETT provided consistent jet breath pressures.

Initial parameters were:

Jet rate 360, jet PIP 28cmH_2O (increased to 30), Jet inspiratory time of 0.028 seconds, PEEP of 15cmH_2O, and FiO_2 0.35. No conventional breaths were used. These settings showed a resulting MAP on the jet ventilator monitoring section was 16.3 cmH_2O. There was an initial bradycardic episode with desaturation when the ETT was removed, but the infant recovered well. (It took those at the bedside a bit longer to do so!)

The "NINJA" experience

Figure 3 shows the baby on NINJA, sleeping comfortably with no signs of respiratory distress. The team was also surprised to discover no air in the baby's stomach given the high pressures used and feeding continued via nasal gastric tube during the time on NINJA.

Failure criteria were met after about six hours. This was very gradual and uneventful, with a few bradycardic/desaturation episodes near the end. The infant appeared to be so comfortable the fellow in charge suggested we continue and simply accept higher FiO_2. I rejected that suggestion since we were already operating in uncharted waters and I did not want the baby's course to be set back by allowing further deterioration. I do not like to use high FiO_2 on very premature infants in general, and increasing oxygen requirements are a sigh of derecruitment. A blood gas done while on NINJA was similar to those done while the baby was jet ventilated.

Figure 3: "NINJA" baby! Jet and conventional circuit interface lower left

Re-intubation under RSI was quick, and a 3.0 ETT was successfully inserted nasally. Within hours of being re-intubated FiO_2 and ventilator parameters returned to pre-extubation baseline; hence we were assured this foray into the ventilatory unknown did not hinder the baby's progress. (Had we not adhered to pre-determined failure criteria that might not have been the case).

Retrospection

Later bench testing revealed the settings chosen for this baby were delivering less MAP than indicated on the jet, as best as I could tell using the equipment available to me. As well, replacing the pressure line connectors with ones the fit over the RAM® cannula and suction wye rather than inside them delivered a MAP 1 cmH_2O higher. The slight decrease in diameter causes enough resistance to decrease delivered pressure, but holding my hand in front of the nasal prongs, I could feel the pulse of the jet breaths quite well. I suspect the slightly lower MAP delivered to the baby was the primary reason for failure, and the efficacy of the jet breaths was responsible for the lack of spells until near the end. At that, higher MAP was realized than with other modes we currently utilize.

Implications for the future

I am currently tasked with drafting guidelines for "NINJA" use in our unit, and there is the possibility of testing this modality using EDI in a study proposed for the near future. While a single patient is hardly sufficient evidence to recommend the mode, our experience suggests that this may be a safe and viable modality to offer infants requiring high MAP but would otherwise be candidates for NI support.

Gastric distention commonly referred to as "CPAP belly" is a common problem with NIV. The resultant difficulty these babies sometimes have tolerating feeding may offer an opportunity to use NINJA at pressures currently thought of as high while avoiding CPAP belly, given the lack of gastric air present during NINJA with this baby.

As the Bunnell LifePulse® is available to clinicians in the U.S., it may be a way to offer a mode equivalent to NIHFO to their patients provided settings are high enough to satisfy patient needs at the nasal interface. Further bench testing with more sophisticated equipment than is available to the writer would help determine settings required to deliver corresponding pressures to the patient, but lack thereof should not, in my opinion, dissuade clinicians from "winging it" at the bedside. Bear in mind delivered pressures will increase as cannulae diameter increases, however, delivered pressures will be considerably lower than indicated by

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Epilogue

By day of life 80 (34+2 weeks corrected gestational age) the baby had been successfully extubated and was on CPAP of 6 cmH_2O via RAM® (practically nothing!) with FiO_2 0.25. Low flow oxygen was started shortly thereafter, and the baby went home on oxygen.

At discharge, clinical findings were as follows: a patent foramen ovale with small secundum atrial septal defect; a moderate to large unrestrictive ductus arteriosis; mild pulmonary hypertension and accompanying right ventricular hypertrophy with mildly decreased right ventricular systolic function; pulmonary stenosis.

The baby received home oxygen and was followed by cardiology and respirology at Sick Kids hospital in Toronto, and the oxygen was weaned off a few months later with their approval. To date, no surgical procedures have been required. There have been a few admissions to the hospital, but I believe figure 4 requires no further explanation

Figure 4. The first birthday

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References:

1. *Li et al. Respiratory Research (2019) 20:58 https://doi.org/10.1186/s12931-019-1023-0*
2. https://www.slhd.nsw.gov.au/RPA/neonatal%5Ccontent/pdf/Medications_Neomed/Dexamethasone_Neomed_v2.0.pdf

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.

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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