Clinical experience of NAVA in 40 neonatal patients
Toledo Children’s Hospital in Toledo, Ohio cared for over 4,400 patients in 2007 and is accredited by The Joint Commission. The institution hosts the largest Level III newborn intensive care unit (NICU) in the region, with 60 beds in individual units to accommodate the needs of the infant and parents, with over 700 admissions per year.

The newborn intensive care unit implemented Neurally Adjusted Ventilatory Assist – NAVA earlier this year, and staff members have been gaining experience with NAVA in neonatal patients and newborns with a variety of different conditions. Critical Care News spoke with Judith Gresky, RN, MSN, CMP, NICU Director, Diane Howard, RRT, Educational Coordinator and neonatologist Howard Stein, MD regarding their experience in implementing NAVA and Edi technology and using it on a regular basis.

Clinical experience of NAVA in 40 neonatal patients
Can you describe the size of your NICU department, average number of patients and staff?

Judith Gresky: We have 60 beds, and 100 nurses on staff as well as 50 extra staff members. We have 700 – 800 admissions per year or about 60 per month, with an average census of about 46 per week. We have a labor and delivery room here, and a transport team that provides transport to 35-39% of our patients in a 27 county area in the northwest corner of Ohio and southeast corner of Michigan.

The average length of stay for our patients is about 22-23 days. Gestational ages range from about 22-23 weeks at the earliest, to full term, and we have 8 neonatologists on staff to provide around the clock care.

Dr Howard Stein: This NICU unit has been in operation for 32 years, and Dr Krishnan, our senior partner, started the unit. We have 8 neonatologists and we provide in-hospital coverage 24 hours a day. There are also 4 neonatal nurse practitioners and residents from pediatrics and family practice programs who work with us. Our facilities and the services we provide have developed and expanded throughout the years. In our latest facility, which we completed 1 year ago, we quadrupled our space for babies and families. Most of our babies now have private rooms and we also have some twin rooms.

Which types or modes of ventilation are traditionally used in the NICU?

Diane Howard: Prior to implementing our SERVO-i ventilators in the fall of 2007, we had been ventilating our babies with the VIP Bird. While this ventilator was state of the art when introduced several years ago, it lacked the newer modes of ventilation, such as Pressure Regulated Volume Control (PRVC) and BiVent. We have used several of these different modes of ventilation on our babies but Synchronized Intermittent Mandatory Ventilation (SIMV) with Pressure Control has been most frequently used. We have used PRVC but have found it difficult due to air leaks around the endotracheal tubes. Volume Control is utilized mostly on our post-surgical gastrointestinal babies, as their bellies become distended and put pressure on the diaphragm. BiVent mode works well but is not as user friendly as SIMV Pressure Control. Since we have 8 neonatologists in our NICU, the most common mode of ventilation is SIMV(PC).

Dr Howard Stein: We have traditionally used pressure limited ventilation with SIMV. There is an occasional patient that needs volume limited ventilation. We have tried PRVC but this was not successful due to the large airleaks associated with using uncuffed endotracheal tubes. About a year ago we introduced Bivent but this has been put on hold as we have learned to use NAVA.

Can you describe the weaning process you utilize currently, for example with SIMV and how you determine appropriate time for extubation?

Diane Howard: Our usual approach to weaning ventilator parameters is to initially decrease the pressures per blood gas and chest x-ray results because barotrauma is a contributor to chronic lung disease (CLD). We wean to minimal pressures without creating atelectasis and then decrease the rate. If the baby does not have an increase in work of breathing and does not have apneic spells, the endotracheal tube is removed. Occasionally, a trial of endotracheal CPAP is ordered and if successful, the baby is extubated. We do not sedate our babies significantly in our NICU.

What generally is your extubation success rate? What is the re-intubation rate within 48 hours?

Diane Howard: Our re-intubation rate within 24-48 hours after extubation is generally low, but with neonates anytime they acquire an infection or become more apneic, they can find themselves back on the ventilator within a week or two. They are not really considered extubation failures, but have become sick again and need ventilatory support. In our older babies, the rate is low, while in 23-26 week range, 50-70% are intubated more than once, fairly typical for this gestational age.
Is surfactant therapy routinely used in this NICU?

Dr Howard Stein: Surfactant is standard of care in the NICU for certain respiratory problems. If we suspect that a premature baby has infant respiratory distress syndrome (IRDS), we treat with surfactant, usually in the delivery room, or out on transport as soon as we reach the referring hospital. We also treat term babies with surfactant; those with meconium aspiration syndrome, and some with pulmonary hemorrhage or pneumonia, to replace the inactivated endogenous surfactant. We have been using surfactant as standard therapy for at least 15 years now.

What in your opinion are the biggest challenges in regard to mechanical ventilation in neonates?

Dr Howard Stein: The major challenge we face is how to use mechanical ventilation to keep these tiny babies alive while minimizing both chronic lung disease from baro- or volutrauma and the damage associated with prolonged intubation. The main risk of baro/volutrauma is destruction of the lung architecture resulting in chronic lung disease resulting in years of respiratory problems. Prolonged intubation has multiple long term risks: palatal grooves which lead to long term speech and feeding problems, subglottic stenosis from scar tissue formation in the trachea, and damage to the vocal cords. Many of these babies can develop feeding aversions.

A unique challenge in the NICU is that we are mechanically ventilating the developing lung. Therefore we need to be very cognizant of the potential lifelong damage that can occur from excessive or prolonged mechanical ventilation in preterm infants.

Judith Gresky: Infections such as ventilator associated pneumonias are also a chronic risk; the quicker you get the baby off the ventilator, the better it is.

Can you describe your process for initial training and education when implementing NAVA?

Dr Howard Stein: We offered education within the unit, but very few people took advantage of it at that time. We distributed literature and we had the SERVO-i representatives give in-services (that were not well attended). So when the opportunity presented itself to use NAVA on a patient, we did this with very limited education. After we took the first step and successfully used NAVA on a few babies people became
interested. We then had additional SERVO-i in-services, and more people attended. After using NAVA for a month or two, the nurses and respiratory therapists came to us and asked for more education. So at that point, our nurse practitioners, Vicki Gall, Bea Troxell, Mischel Balaz and Jen Trost along with Diane Howard, two of my neonatal colleagues and myself put together a 45 minute presentation on NAVA. Then the NNPs, my neonatal colleagues, Drs Barbara Chappell and Kristie Hornick and I, gave the presentation in the NICU to the nurses and respiratory therapists who were working that day. We did this numerous times, and had everyone sign in to ensure that everyone was hearing the information at least once. By now, everyone in the unit has heard this educational session on NAVA. As familiarity with NAVA has grown, many nurses have asked me to review some of the concepts and have started to ask more thoughtful and insightful questions.

I think the level of comfort with NAVA amongst the respiratory therapists is the highest right now but many of the nurses are getting more comfortable. The neonatal nurse practitioners have become great advocates of NAVA. Some of my neonatal colleagues have been slow to use NAVA but, as their comfort level increases, they have become more likely to place a baby on NAVA.

Judith Gresky: I have to say that seeing babies that had been ventilated for quite some time being put on NAVA, and seeing them wean themselves to oxygen within hours was very impressive. This was convincing to many of our staff members here, each baby at a time.

We started at the end of May using NAVA on the first patients, but the use really accelerated in August, and now in the middle of November we have experience of over 40 patients.

Diane Howard: The first thing we did was copy all the NAVA materials that the Maquet representatives had given us and made it available to all staff working in the NICU. We placed notebooks in the work areas of the NICU as reference manuals. When Doctors Stein, Chappell, or Hornick were on service, they provided bedside education on NAVA if they initiated this mode of ventilation on a baby. In-services were held in the NICU at various times of the day but it was difficult for staff to attend. Being at the bedside and having hands-on experience with NAVA with a physician that was also learning NAVA
was the ideal way to learn. None of us were an expert, we all learned together.

**How did you initially select your patients?**

Dr Howard Stein: We selected our initial patients very carefully to learn how to use NAVA while minimizing potential risk to the patient. We chose patients who were stable on moderate to low ventilator settings and appeared to have a lot of respiratory reserve. We place the Edi catheter and watched the Edi for a prolonged time to convince ourselves that the baby had a sustained respiratory effort. Diane Howard and I then stood at the bedside continuously while the first few patients were on NAVA. I was on call in the NICU the entire first night a patient was on NAVA. As we have become more comfortable we are placing sicker babies on NAVA, and we continue to be impressed. As long as the babies have an intact respiratory drive they tolerate NAVA well.

**What is the gestational age and weight of the smallest neonate you have treated with NAVA?**

Dr Howard Stein: The birth weight and gestational age of the smallest baby is 23 weeks and 450 grams, but when we used NAVA the baby was one month old. That was really a 27 weeker, and weighed 520 grams when we started NAVA. That baby was on NAVA 5 or 6 times, failing because of apnea. After about a month on and off on NAVA, we went on NAVA and stayed there 5 days continuously and then extubated her. At that point she had been intubated about 2 months. Her FiO₂ dropped 10-15 percent right away, and peak pressures went down right away with NAVA.

**Are there some specific patient experiences that are of special interest?**

Dr Howard Stein: We had an early experience with a meconium aspiration baby who was sick enough to need mechanical ventilation. Despite being on the ventilator he had significant work of breathing manifested by retractions and tachypnea. He also was fighting the ventilator. Within 10 minutes on NAVA he had calmed down completely and the FiO₂ went to almost room air. He made great progress overnight with improved compliance and the next day we extubated him. We initiated NAVA within the first hour in this baby. We were most impressed by
the fact that work of breathing, peak pressures and FiO2 all come down, almost immediately. In this case, the respiratory rate did not increase; he was tachypneic and stayed tachypneic.

I must emphasize that we have not done any prospective studies using NAVA and that all my comments are based solely on our observations made in the course of learning how to use NAVA. We have done enough babies now to see that these observations are generally reproducible. However, I must caution anyone from over-interpreting our observations until more data is available from prospective, randomized, controlled studies.

There are a number of things we have noticed on NAVA. First, the babies ventilate on NAVA equally as well as they ventilate on conventional ventilation but they do it at much lower peak pressures (tidal volumes) with moderately higher respiratory rates (see Case studies from Symposium article). This is important because we are effectively ventilating these babies with much less baro/volutrauma than on conventional ventilation. Secondly, the babies wean themselves on NAVA. What I mean by this is that, over time, as the compliance of the lung improves, the Edi signal decreases so it takes lower peak pressures (or tidal volumes) to ventilate effectively. We do not need to wean any parameters including the NAVA level. If the NAVA level is too high, the baby will decrease the Edi signal and still allow the peak pressure to fall.

With NAVA, the baby is determining how he would like to maintain his minute ventilation. He is setting his own respiratory rate and tidal volumes. This varies breath to breath and minute to minute. At times the peak pressures are high (possibly to facilitate lung recruitment) and the respiratory rate lower. At other times the peak pressure falls and the respiratory rate increases. Although I describe our findings using peak pressures, we have seen similar patterns when we look at mean airway pressure and tidal volumes. My approach to weaning now is not to necessarily reduce the NAVA level, but to watch the trend graph, and as soon as the babies’ peak pressures are mostly between 10 and 15 and the blood gases are acceptable I will extubate the baby. One of the key things with NAVA is that you must keep looking at the baby and looking at the trends. If the Edi acutely increases and the peak pressures go up this may be an early sign that the baby needs to be suctioned or the ETT is occluded or dislodged.
Another observation we have made is that sick babies seem to have a higher respiratory rate than we have previously thought. The ability to monitor Edi as a reflection of brainstem activity is changing my thinking about what the ‘normal’ respiratory rate should be in a sick, intubated baby. Most of our babies on NAVA have ‘chosen’ to accomplish effective minute ventilation with low tidal volumes and higher rates. In the brief periods where their tidal volumes increase we see a concurrent decrease in their respiratory rate.

One of the things we have struggled with educationally with NAVA is to realize that these sick babies ‘chose’ to be tachypneic and conventional ventilation does not take tachypnea away. I think we just hide it with conventional ventilation. When we think we are synchronizing using flow triggering and we monitor Edi signals, it turns out that we are very asynchronous and are missing a lot of additional breaths that occur during flow triggered breaths. Once we place the baby on NAVA, we see their true respiratory rate, but now each of their breaths is an effective breath.

One final observation is that most babies rapidly drop their FiO₂ when placed onto NAVA. This decrease seems to be sustained as long as the patient remains on NAVA. Of course, when the babies become apneic on NAVA they do desaturate and require transient increases in their FiO₂.

Judith Gresky: I can add that nobody in their right mind would have taken an SIMV rate of 80 or 90; we simply would not have done that.

What are some of the different types of patients where you have used NAVA?

Dr Howard Stein: Most of our patients that we have placed on NAVA have had either IRDS or chronic lung disease. We have also used it in term babies with respiratory problems such as pneumothorax, chylothorax post op CCAM removal and persistent pulmonary hypertension. We have also used NAVA successfully in non pulmonary problems such as aortic stenosis pre and post balloon valvotomy, tetrology of Fallot with absent pulmonary valve, and hypoxic ischemic encephalopathy.

Are you monitoring Edi on SIMV modes or other conventional modes?

Dr Howard Stein: Yes. If we think that the baby is a NAVA candidate, we place the Edi catheter and watch the Edi signal for a few hours in the conventional mode to evaluate the babies respiratory drive. When we look at synchrony between Edi signal and ventilator breaths in SIMV, it may correlate well especially if the babies are sedated. However as soon as the babies are awake and alert, we see that they are asynchronous. Our ventilator rates seem to be too low based on the Edi signal and most of the ventilator breaths are larger than the Edi signal would predict. In addition to this we see that there are intermittent Edi signals that would predict very large breaths that are also being ignored. That is why these babies may fight the ventilator so much on conventional modes and why they appear so uncomfortable. When the babies are on NAVA each breath is different. They may take some very large breaths, and sometimes they take long slow breaths and a longer expiratory phase, allowing their lungs to deflate more. The babies are smarter than we are, when it comes to their own ventilation, even at 25 or 26 weeks, as long as they have a respiratory drive. But they don’t always have the musculature to maintain it, which is where NAVA comes in. NAVA gives the babies the ability to dictate their ventilatory needs and the ventilator then augments their natural respiratory drive. Apnea is definitely a problem, and 90% of our NAVA failures are due to apnea.

Diane Howard: We have utilized the Edi catheter on our smallest infants that do well on NAVA but are not physically mature enough to sustain adequate ventilation for long periods of time. We rest them by placing them on SIMV(PC) but monitor the Edi signal. When the infant is rested and the Edi signal is good, we exercise their respiratory muscles for short periods, slowly increasing the time on NAVA. We have been able to successfully extubate extremely small infants using this method. We also ask that the Edi catheter remain in place for 24 hours after an infant is extubated so the Edi signal can be monitored. In this way we know if the infant is tiring and needs reintubation.

In terms of experience so far, what do you perceive as the benefits of NAVA, compared to other modes of ventilation in neonates?

Dr Howard Stein: It is far too early yet,
to establish endpoints of fewer days on ventilator or less chronic lung disease. We still need randomized controlled trials to establish this. Our observations at this point after more than 40 neonates are that babies can regulate their own pressures (tidal volume). They maintain their minute ventilation with lower pressures (tidal volumes) and higher rates as we go from conventional ventilation to NAVA. If babies are under-ventilated they are able to take bigger breaths than we were giving with SIMV, and as soon as they have recruited themselves sufficiently, the pressures subsequently go down. The second major benefit is the autoweaning aspect; as the babies compliance improves, we see a drop in pressures.

Diane Howard: The babies look so much more comfortable, they are quiet. Some of the staff were initially concerned about the increased respiratory rate, and they called me to bedside. I would say “The baby looks great – resting peacefully, the saturations are good, and the high respiratory rate is what the baby wants”. In the meconium case, the baby looked so poorly when it was on SIMV, the baby might have been ventilated an additional 2 or 3 days with more sedation and increased pressures in the conventional mode.

Has the experience of NAVA so far led to any changes in ventilatory settings, such as respiratory rates and trigger levels, in conventional modes?

Dr Howard Stein: I now try to look at every baby as a potential NAVA candidate unless they have exceptions such as frequent apnea. If the baby is having apnea and the backup rate of 30 is not enough to maintain them, we then switch them back to SIMV for 3 or 4 hours until we see that their Edi is stable again and then we try them back on NAVA. I think this is normal physiology in these small patients – you have breathing periods and non-breathing periods in fetuses, which is what these patients essentially are. The post-op gastrointestinal babies would be ideal candidates for NAVA once the problem of using the catheters for suctioning is improved. For the babies with frequent apnea, the ideal mode would be one that switches back and forth between NAVA and a mode with a higher rate than currently available.

What is your opinion regarding the advantage of Edi signals as a completely new parameter in ventilation?

Dr Howard Stein: I think that the Edi signals may become very helpful – now that we have the capacity to monitor brainstem activity I anticipate that we will gain a lot of insight into respiratory function in the neonate. The SERVO-i now has the capability to monitor Edi in the standby mode so we can also monitor extubated patients. In our post-extubated babies that have apnea, the Edi signal has been a great tool for looking at obstructive versus central apnea. If they have obstructive apnea, the Edi signal goes up since they are demanding bigger breaths due to the obstruction, whereas in central apnea the Edi signal drops to 0. The Edi signal may also have a use in pneumograms. Our current pneumogram technology includes heart rates, saturations, respiratory rate and airflow.
with a thermistor so adding Edi signal to that would be wonderful, because we can also evaluate central drive.

Our hope is to start doing prospective studies in neonates. Our first goal was to learn how to use NAVA so we were not evaluating a therapy during the learning curve, and then to start some studies. We are almost at that point.

Diane Howard: We would love to see the Edi signals on every ventilated baby, not just on the NAVA candidates. Sometimes we see the infants fail, and without Edi it is difficult to know why.

**Have you observed tonic activity of the diaphragm in neonates by means of Edi monitoring?**

Dr Howard Stein: We have started to look at the Edi minimum, which is tonic activity of the diaphragm. We use that to set up our PEEP. We find that if the Edi minimum is very high, it is the baby’s brain stem saying that it is generating a much higher tonic activity and needs more PEEP. We will provide a little more PEEP, and watch the Edi. On the other hand, if the Edi minimum is 0 to 1, we think we are over distending the diaphragm, and the brain stem does not feel the need to do anything, then we will consider decreasing the PEEP.

**What according to your experience so far, are the most important aspects for ICU staff to learn, prior to initiating NAVA ventilation therapy?**

Diane Howard: Before initiating NAVA ventilation, staff must understand the concepts of how NAVA works and that it is a spontaneous mode of ventilation. Staff must realize that there needs be a signal from the brain to the diaphragm to initiate a breath or NAVA may not work. Babies that have apnea of prematurity or hypoxic brain injury may not do well in the NAVA mode of ventilation. Since NAVA is a spontaneous mode of ventilation, the baby will set the tidal volume and respiratory rate they need to maintain adequate ventilation. We should not be alarmed if the infant appears tachypneic as long as the infant is comfortable. NAVA is a dynamic mode of ventilation that requires good assessment skills and the patience to allow the infant to breathe as they want.

**Dr Howard Stein:** In the initial phases, there was a lot of confusion about the new terminology, such as NAVA level, Edi signal and so on, and so there was a focus on the new terminology, rather than the basics of how NAVA works. When we were educating small groups at a time in the NICU, we would teach that Edi minimum is a fancy word for tonic activity and related to PEEP, and Edi maximum is related to peak pressure. This helped our colleagues to understand the methodology. We emphasized the things that changed from conventional ventilation was the trigger to initiate the breath and the parameter used to determine the peak pressure. The basic concept of ventilation is essentially the same but the control is given to the baby.

We have slowly made progress. Diane and I have spent a lot of time educating behind the scenes, but it is really our nurses, therapists and our nurse practitioners that have helped us make progress. They are the ones at the bedside, and who have learned to troubleshoot signals and alarms. The respiratory therapists have done an incredible job supporting our efforts. Any nurse that has not had a baby on NAVA sees “this is not really that different”. Any nurse that has had even only one baby on NAVA rapidly sees “is that all there is to it?” They saw that it was really simple to use. Secondly, it would have been very reassuring to have an experienced neonatologist or respiratory therapist used to NAVA, come to our unit, stand with us as we placed our first baby on NAVA, tell us about the signals we were seeing and how to adjust the ventilator.

**What in your opinion are the most interesting areas of NAVA research in the future?**

Dr Howard Stein: From a purely scientific standpoint, I think that NAVA is going to give us insight into respiratory physiology, that we never had available before, since we couldn’t access the brain stem. The neonatal patient is respiratory physiology at its purest, and you can see development of the respiratory drive from 23 weeks and up.

Non-invasive NAVA would be an awesome development. I am very excited about this – NAVA is already revolutionary in that air leaks are no longer an issue but if we can successfully ventilate babies without putting endotracheal tubes in, it could make a major impact improving respiratory outcomes in the NICU.
Howard Stein, MD, received a BSc degree in Biomedical Engineering at the University of California, San Diego in 1981. His postgraduate studies in Applied Human Physiology were conducted at Hahnemann University in Philadelphia, Pennsylvania in 1982, and he obtained his Medical Degree at the same university in 1986.

Dr. Stein was Pediatric Resident at the Milton S. Hershey Medical Center at Pennsylvania State University from 1986-1989, and Neonatology Fellow at Harbor-UCLA Medical Center in Torrance, California from 1989-1992. He was Visiting Associate Professor in the Division of Neonatology at the same institution from 1992-1993, followed positions at Georgetown University Children’s Medical Center in Washington DC, as Associate Department of Pediatrics from 1993-1995 and Pediatric Cardiology Fellow from 1993-1995. Howard Stein served as Neonatologist and Pediatric Cardiologist at Prince George’s Medical Center in Cheverly, Maryland from 1995-1996, followed by positions at Toledo Children’s Hospital as Pediatric Cardiologist (1996-2004), and Pediatric Intensivist (2006-2008). Howard Stein, MD has won numerous awards and co-authored numerous original publications.

Diane Howard, BEd, RRT, NPS, AE-C, received her initial B.Ed University degree in 1973 and her Associate Degree in Respiratory Therapy Technology from the University of Toledo Community College in 1982. As Certified Respiratory Therapist she was employed at Toledo Hospital in 1982 as a staff therapist, and advanced to transport therapist for the NICU/PICU at Toledo Children’s Hospital in 1985. In 1986, Diane Howard became a Registered Respiratory Therapist. She became Education Specialist for the Children’s Pulmonary Center of St. Vincent Mercy Medical Center 1997. Diane Howard is currently Education Coordinator in Respiratory Therapy for Toledo Children’s Hospital, a position she has held since 2004.

References


