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and Julie Mitchell, RRT, of the University of Alberta Hospital in Edmonton, Canada



Kevin Coghlan, RRT and Dr Craig Guenther discuss Edi trends of a lung transplant patient in the CVICU of the University of Alberta Hospital in Edmonton.

Deepening knowledge and experience of new ventilation therapies

Intensive care staff members and caregivers around the world are usually familiar with any number of modes of ventilation. Many of these were introduced in the past two decades, and as we all know, some of these modes are unique and others may be quite similar. Generational shifts in developing new types of ventilation therapies, however, are quite rare and may influence standards of critical care for decades to come.

The new generation of ventilation therapy called Neurally Adjusted Ventilatory Assist, or NAVA, became commercially available for the first time about one year ago, in late 2007. Since then, NAVA has been introduced and implemented in intensive care departments in over 25 countries around the world. Some of these first intensive care units to experience NAVA have now been collecting therapeutic experience and familiarity to new levels of application knowledge; larger numbers of more specific patient categories, increased understanding of the use of bedside Edi monitoring to observe sedation levels and washout, and the opportunities of Edi monitoring to avoid diaphragm disuse atrophy. The first language specific scientific review articles about NAVA have also been published recently: F Suarez-Sipmann et al in Spanish in *Med Intensiva* 2008; 32(8): 398-403 and M Quintel et al in German in *Anaesthesist* 2008; 57(10): 998-1005.

The new levels of clinical experience of NAVA and the opportunities of Edi monitoring in specific patient categories, such as spinal cord injury patients and neonatal patient categories, and in expanding patient numbers is the

focus of this issue of Critical Care News. In addition to NAVA, we also report about the developing standards of neonatal intensive care in the rapidly developing People's Republic of China, the increasing use of Heliox

in ventilation therapy in intensive care and first impressions of a new Heliox ventilator application, as well as to focus about the need for quality in ventilation in anesthesia as well as critical care.

Institutional experience of NAVA in neuro and cardiovascular intensive care patients

The University Hospital of Alberta in Edmonton, Canada has been using NAVA for over one year now in the Neuro Intensive Care Department as well as the Cardiovascular Intensive Care unit. Dr Kutsogiannis and Darryl Ewanchuk have had experience with NAVA in a number of spinal cord injury patients, who are particularly interesting as these patients belong to the category of the longest ICU stayers in North America, and are typically not deeply sedated. The Emergency Room team within the hospital are now inserting Edi catheters in spinal cord injury patients, prior to sending them up to the neuro ICU. The Cardiovascular Intensive Care Unit of the University Hospital of Alberta has also been using NAVA for over one year. Dr Craig Guenther and Kevin Coghlan in the CVICU are especially interested in opportunities for NAVA and Edi monitoring in delirium patients, during night time in the ICU. Next up at the University Hospital of Alberta for NAVA will be the Stollery Children's Hospital within the University Hospital system. Julie Mitchell, RRT, Edmonton shares her experiences of educating about NAVA, and the future plan for the implementation in the PICU.

Akron Children's Hospital symposium report – neonatal and pediatric ventilation: emerging trends and challenges

Over 120 neonatologists and caregivers in neonatal and pediatric intensive care gathered at the Akron Children's Hospital for a one day symposium hosted by representatives from the NICU, PICU and respiratory therapy departments. NAVA was one of the most topical subjects during the day, with presentations by members of the impressive lecture faculty including Mark Heulitt, MD of Arkansas Children's Hospital, Jennifer Beck, PhD of St Michael's Hospital in Toronto, Maureen Reilly, RRT of Sunnybrook in Toronto, and neonatologist Howard Stein, MD of Toledo Children's Hospital, who reported on the rapidly expanding experience of NAVA in neonates at his institution.

Clinical experience of NAVA in 40 neonatal patients

The neonatal intensive care unit of Toledo Children's Hospital is one of the largest facilities in their region of Ohio. Neonatologist Howard Stein, MD, Educational Coordinator Diane Howard, RRT and Judith Gretskey, RN and colleagues have been implementing NAVA and Edi monitoring in their unit. Within a few months, they had gained experience in over 40 neonatal patients. They share these experiences and the challenges of introducing a new ventilation therapy such as NAVA in patients with developing lungs. They also describe the benefits they perceive so far with Edi monitoring in the smallest of patients, of whom Dr Stein describes as "the neonatal patient is respiratory physiology at its purest", and where he tries to look at every baby as a potential NAVA candidate.

Research and establishing standards of care and training in neonatal intensive care in China

The Fudan University Children's Hospital in Shanghai has expanded rapidly in terms of research, structure, staffing and standards in recent years, mirroring the rapid expansion of many other aspects of society in the People's Republic of China. Dr Bo Sun, MD, PhD, Head of Laboratory for Research for intensive care at that institution, and NICU staff members of the Children's Hospital discuss some of the challenges and the opportunities related to this recent rapid expansion.

First impressions of the use of a new Heliox ventilator solution

The use of Heliox has been documented over a number of years in specific patient categories, such as severe asthmatics. There is growing interest about the potential of Heliox in a number of other clinical situations in the intensive care unit. Dr Ian White and staff members of the general Intensive Care Unit of St. Peter's Hospital in Chertsey, Surrey have been working with clinical application of Heliox in intensive care patients for over four years. They will very soon be one of the first intensive care units in Europe



Dr Ian White has been using Heliox for a number of years.

and globally to utilize Heliox directly piped in to the patient bedside in the ICU. Dr White and his ICU colleagues have recently had the Heliox application installed on their SERVO-i ventilator fleet, and he shares their first clinical impressions from patient treatments.

The need for high ventilatory performance in anesthesia – perspectives from two clinicians in anesthesiology

The final feature of this issue highlights these perspectives from two highly specialized clinicians: Xavier Capdevila, MD, PhD, anesthesiologist, intensivist and university Professor from the University Hospital of Montpellier, France and Per-Arne Lönnqvist, MD, PhD, anesthesiologist, intensivist and Professor in Pediatric Anesthesiology at Astrid Lindgren Children's Hospital in Sweden share their thoughts on the quality of ventilation and ventilatory parameters in a wide range of anesthesia patient categories. ■



Darryl Ewanchuk, RRT and Dr Jim Kutsogiannis with ventilation patient in the neuro ICU.

Institutional experience of NAVA in neuro and cardiovascular intensive care patients

The University of Alberta Hospital in Edmonton is one of Canada's leading clinical, research and teaching hospitals, treating more than 700,000 patients annually within the region.

In addition to a wide range of diagnostic and treatment services, the hospital provides specialized services within cardiac science, neuroscience, surgery, medicine, critical care and emergency and trauma care.

The institution was one of the first to implement and utilize NAVA – Neurally Adjusted Ventilatory Assist as this ventilation technology became available in the beginning of 2008. Two specialty critical care units have been gaining experience in specific patient categories for the past 10 months; the Cardiovascular ICU and the Neuro ICU, and the technology is in line to be implemented at the pediatric and neonatal ICU at Stollery Children's Hospital within the institution.

Use of NAVA in neuro intensive care patients

Critical Care News met with staff members of the Neuro ICU and Cardiovascular ICU to hear about their experiences with the clinical application of NAVA in specific patient categories, and heard about plans for educating and evaluating the use of NAVA in the neonatal/pediatric ICU.

The Neuro Intensive Care Unit of the Neuroscience Department of the University Hospital of Alberta, in Edmonton cares for approximately 700-900 patients on an annual basis, with 11 beds within the unit. The unit is dedicated and is one of only 2 neuroscience units in Canada, staffed by 10-15 neurosurgeons, 7 intensive care physicians and 8 respiratory therapists.

Dr Jim Kutsogiannis of the Neuro ICU described the various patient categories that are admitted to the unit. “We see traumatic brain injury and subarachnoid hemorrhage, brain tumors and spinal cord injuries as our major patient groups. We do some neurology, but it only accounts for about 10% of our total admissions. We care for predominantly neurosurgery patients, but we are also referred patients with severe stroke and neuromuscular disorders.”

Darryl Ewanchuk, RRT outlined the various ventilation therapies that are most frequently used on the unit. “We are traditionally using Pressure Regulated Volume Control (PRVC) and Volume Control, and when the patient is suitable for supportive modes we use Pressure Support and on occasion APRV. We typically use conventional ventilatory strategies for the majority of our patients, and when it comes to difficult patients we like to dig into our toolbox and pull out other alternatives.”

The average length of stay for patients in the Neuro ICU is generally around 5 days, but categories such as elective surgeries generally move through the unit more quickly, and spinal cord patients are treated in the ICU for an average of 1- 2 months. Dr Kutsogiannis comments,



Darryl Ewanchuk, RRT shares his experiences with NAVA in spinal cord injury patients.

“Spinal injury patients are also the longest length of stay category by diagnostic code in the USA as well, so weaning these patients is a challenge. There is a paucity of published literature regarding weaning and modes of ventilation in spinal cord injury.”

Experience of NAVA in spinal cord injury patients

The staff members of the Neuro Intensive Care Unit received education and training on NAVA in the beginning of the year, and initially tried NAVA on a few patients that were ready to wean,

to gain experience where they were reasonably sure to achieve success. The use of NAVA was avoided in severe head injury cases, due to the depth of sedation in these patients, but use of NAVA has focused on the difficult to wean patient categories, such as spinal cord injuries and longer-stay patients.

Experience with NAVA was ramped up and intensified during the summer trauma season, which typically starts with a long weekend in May. Darryl Ewanchuk explains, “We have had 20 quadriplegic admissions this year, and from there we ran NAVA on

10 patients with spinal cord injuries. Much of our hands-on knowledge was gained in the latter part of the summer, when Dr Kutsogiannis and I started discussing the possibility of structuring some study-based protocols."

Dr Kutsogiannis clarifies, "I am an epidemiologist as well as an intensive care physician, and the studies I do are ones where we try out a method on a subgroup of patients, to get a feel for what is achievable and develop a protocol from this base. I think we are at a stage now where we have sufficient exposure with these patients that we can develop a protocol for how to wean these patients from start to finish. It will require some modification, but based on our experience over a few decades here with our dedicated neurosciences ICU, and our respiratory therapists that specialize in the spinal cord patient category, it is manageable."

"We feel that these spinal cord injury patients are a population of patients that is ideal for NAVA, as very few of the spinal cord patients have severe head injuries. They are awake and their brains work, but have neuromuscular weakness from their spinal cord injury. Their diaphragms are mainly preserved, so what they need is augmentation of their natural relay between the brain and the diaphragm. They are a "clean" patient population in that they are reproducible; they do not have any other disease factors. Physiologically it makes sense to utilize NAVA in this patient population. This has also been borne out in our experience to date where we have had success with NAVA so far."

NAVA from start to finish

Darryl Ewanchuk and fellow respiratory therapists have been educating their colleagues in the emergency room about the function and placement of the Edi catheter. He summarizes the situation: "In a crisis situation after intubation in the ER, we have educated how the Edi catheter should be inserted, so that everything is in place in the patients when they arrive to our unit a few hours later. This enables us to monitor their Edi status as soon as we receive the



Dr Jim Kutsogiannis is interested in studying NAVA in depth in spinal injury patients, as they are typically the longest staying patient category in hospital.

patients. Spinal cord injury patients have so much to deal with anyway with these types of injuries, they are often young and their whole world has changed, so we are adverse to extra interventions when they are awake in our unit."

Dr Kutsogiannis adds "Our colleagues in the ER contact me when they receive patients with spinal injuries not resulting in neurological deficit, for example spinal fracture but the spine is intact, and ask me if the Edi catheter should be placed in these patients. It is a good cooperation between the ER and the ICU that assists us in implementing NAVA early in the patient care process. We had two particular patients at the end of the summer that were treated with NAVA concurrently. We were fortunate that from the time the patients were admitted right up to the time they were transferred out of the ICU, they were solely ventilated on NAVA from beginning to end. We have met with some hurdles along the way, it requires bedside

focus, troubleshooting and learning to understand the Edi signal in relation to recovering neuromuscular condition of the diaphragm. One needs to try it out on several patients and observe it systematically. These patients that were on NAVA from start to finish required it for approximately two weeks."

Spinal cord injury patients were defined as an interesting category by the staff members to gain experience with NAVA, as they do not require a great deal of sedation and initially have healthy lungs. They may develop pneumonia during the course of their stay in the ICU, but they generally are not ARDS patients. The spinal cord patients often receive bronchodilators, anti-mucolytic therapies and antispasm drugs for muscle spasms. Neuropathic pain is dealt with by means of certain analgesics, and sleeping aids are also administered, but these patients usually do not receive much medication in comparison to general ICU patients, according to Dr Kutsogiannis.



Darryl Ewanchuk and Dr Kutsogiannis have educated ER colleagues about the use of NAVA in spinal cord injuries, so that the Edi catheter can be placed as soon as possible after patient admission.

Avoiding rapid disuse atrophy

In terms of titrating the NAVA level in spinal cord injury patients, there are three parameters generally used. Dr Kutsogiannis explains: "Work of breathing, rapid-shallow breathing index and another index we are developing are used to titrate the NAVA level. The latter parameter incorporates respiratory rate and inspiratory time. During the day we will allow the patient to work more, and at night we are more restrictive, meaning more assist and unloading from a higher delivered NAVA level. What is critical is measuring work of breathing, because we do know from esophageal balloons and traditional respiratory physiology that beyond a certain level of work of breathing it is not possible to sustain breathing. Dr Christer Sinderby and I have had discussions regarding this, and we will incorporate parameters in our protocol in these patients to look at NAVA compared to conventional mechanical ventilation.

We have started to systematically collect information every hour, to observe the ranges in these parameters in order to plan for our protocol."

Darryl Ewanchuk agrees. "There was a study published in the New England Journal recently about rapid disuse atrophy, and in recent years we have really shifted our whole philosophy. When I first started here, our spinal cord patients came in through the emergency department and would struggle in a trauma unit with pneumonia and other complications, and we would see them in a crisis situation. Today, interventions are occurring earlier in the ER, they are getting intubated and put on partially supported modes of ventilation whenever possible, to avoid atrophy. This is why I think NAVA will give us the potential to shorten our weaning times and lengths of stay for these patients, compared to supported modes of ventilation. There is a big shift in a consistent pattern in how we deal with these patients, a more systematic approach."

Edi signal monitoring is also used as a tool to determine the level of support needed. There has been some experience in using the Edi signal and tracing as a diagnostic parameter in conventional ventilation modes, according to Darryl Ewanchuk. In regard to spinal cord injury patients on NAVA, data is downloaded every morning, in order to see and compare patterns at night and in daytime. Dr Kutsogiannis states, "We are using these tools based on sound respiratory physiology, but I think this will be an area of research for us in the future. We know that these patients need to be breathing to some extent, in order to strengthen their diaphragm and avoid disuse atrophy. At the same time, we know if they breathe on their own for too much, they may decompensate and it may take a long time to get them back to where they were. It is a delicate balance, as training for a marathon, which may be a good analogy to describe the situation."



Darryl Ewanchuk is interested in the potential of NAVA to avoid diaphragm disuse atrophy.

Training and educational effort

All of the staff members within the Neuro Intensive Care Unit have had various levels of training from the start of the implementation of the modality within the unit. Dr Kutsogiannis has been spearheading this modality with his ICU physician colleagues and distributing literature and information. The nursing acceptance of NAVA is critical as well and there is a learning curve in this respect, as something new may be a subject of resistance which requires a lot of education and reassurance for a positive implementation, according to Dr Kutsogiannis.

An educational package has been provided to respiratory therapists and nursing staff members, according to Darryl Ewanchuk, and since the spinal cord injury patients are seasonal, a roll-out of education sessions for nurses is planned in the early spring. He also agrees that education and reassurance are important factors, and states, "There has been some doubt with some of

my colleagues, but one of them was involved with a spinal cord patient that was ventilated with NAVA from start to finish, and at the end of the case she told me that she wouldn't have believed it if she had not seen it herself."

"Bedside experience of observation of the patient and the Edi signal is critical. We need to integrate respiratory physiology with what we learn with NAVA at the bedside in order to go forward, and in some cases re-learn old knowledge. The fact that we have put some of these spinal cord patients on NAVA upfront is really remarkable, considering that we do not often put these patients on Pressure Support from the beginning. NAVA gives us the opportunity to augment these patients own drive to breathe enough to recover more quickly."

Within the Neuro ICU, the respiratory therapists are responsible for placement and verification of the Edi catheter. In an early case with a patient with Guillain-Barre syndrome, it was not possible to obtain an Edi signal, since there was so

little electrical activity of the diaphragm. This was also a learning experience for the respiratory therapists, as Darryl Ewanchuk explains, "We decided to leave in the Edi catheter, and as the patient improved, we found that the Edi signals started to appear and develop. I came in the morning and a colleague told me we were getting Edi signals, which were amazing. This patient was switched to a t-piece trial very quickly after that and was soon off the ventilator."

Dr Kutsogiannis agrees that NAVA offers new learning opportunities. "We had a meeting recently with resident education, in terms of studies and trials, and I think we may have been at risk of losing basic physiology with some of the residents. Things like work of breathing is fundamental in terms of respiratory physiology, but we seem to tend to be bogged down in logistics, such as weaning protocols and other operative issues, where it is easy to lose the fundamentals of basic physiology and anatomy. The New England Journal study of rapid disuse atrophy earlier this year



Darryl Ewanchuk and Dr Jim Kutsogiannis are also interested in studying NAVA in other patient categories that may be prone to muscular fatigue.

highlights this point; we need awareness of diaphragmatic issues in order to build sound clinical applications. We need to consider why asynchrony may occur in mechanically ventilated patients.”

Future use of NAVA in the Neuro ICU

In the process of developing guidelines for conditioning and weaning of spinal cord injury patients with NAVA, Dr Kutsogiannis mentions that a randomized trial comparing traditional mechanical ventilation with NAVA in spinal cord patients is planned. “I think our endpoint will be length of stay and ventilator-free days, but we have not yet started our calculations. Interventions and complications are also interesting endpoints, since these are the longest staying patients in the hospital, to determine improving patient care.”

“Secondly, looking at economics worldwide in regard to spinal injury patients and implications for costs in hospitals is an important factor. If

we can shorten their length of ICU and hospital stay in rehabilitation, this would be a big benefit for these patients as well as the institutions caring for them” says Dr Kutsogiannis.

In terms of additional research and areas of use for NAVA in the future, Dr Kutsogiannis mentions other patient categories, including COPD, and Edi monitoring in head injury patients and difficult to wean patients. “Chronic COPD patients spend a lot of time in the ICU after their initial situation is dealt with, they have neuromuscular fatigue and their lung function is weakened. They spend a lot of time in the ICU in the weaning process, and this is another opportunity for NAVA I see. They are also awake and alert patients, and need to regain strength to come off the ventilator.”

Dr Kutsogiannis is interested in Edi monitoring of head injury patients in future, in order to monitor signal patterns in severe injuries and to determine the point that they start to recover.

“There are sedation levels and brain function, and we have implemented continuous EEG monitoring here, so I would like to look at continuous EEG monitoring and the relationship with Edi signals in these patients as they start to normalize, to determine if this happens synchronously or not.” In terms of other difficult to wean patients, he is interested in knowing if the conventionally mechanically ventilated patients are being ventilated optimally. He would like to study Edi signals in these patients to determine if they are being oversedated, or if there is a need to change the parameters of the conventional modes being used.

Dr Kutsogiannis summarizes future challenges by stating that “In pioneering new methods and modalities, the biggest obstacles are often ourselves. People may be resistant to change, but that does not advance medical care”.

Use of NAVA in cardiovascular ICU patients

The University of Alberta Hospital in Edmonton is one of the largest transplant centers in Western Canada, with approximately 25 heart transplants and 33 heart-lung transplants conducted annually. With over 14,000 open heart surgeries per year, the institution is planning to open the Mazankowski Alberta Heart Institute in 2009, one of the largest centers of its kind in North America, with some of the most advanced technology in the world.

The Cardiovascular Intensive Care Unit provides care to patients pre and post open-heart and transplant surgery, and contains over 20 beds. In addition to 10 surgeons, there are 8 intensive care physicians on staff, and over 25 respiratory therapists and 95 nurses within the unit, as well as pulmonologists and physiotherapists on the interdisciplinary team. Average weaning time for ventilated patients may range from 8 hours for CABG (coronary arterial

bypass graft) patients to 4.7 days in more complex cases such as lung transplants. Staff members within the unit started experiencing use of NAVA in January 2008, and intensive care physician **Dr Craig Guenther** states, "I read the original research article in Nature Medicine in years past, and when we saw that NAVA became available, we regarded it as a weaning modality, for our patients that are here for 4-6 days and are difficult to wean. Long-term ventilation in the global literature is about 96 hours, so this is something we are very interested in influencing if we can." Respiratory Therapist **Kevin Coghlan, RRT** agrees "The intensive care group is very progressive and tend to listen to new ideas and new aspects of ventilation. I kept discussing the idea of NAVA and as we learned more, I was fortunate to attend a symposium in New York in 2006, and after that it seemed very clear that we should be investigating this possibility.

Using NAVA in failure-to-wean patients

NAVA has been run in a wide variety of critical care patients in the Cardiovascular ICU, including COPD, lung transplant and delirium patients, and other patients that may be experiencing dyssynchrony. Kevin Coghlan states "We have used NAVA on delirious patients, and we tend to get a bit of that with the elderly and anesthetics, and NAVA works well for those types of patients. We have also used NAVA on lung transplant cases and we have been able to diagnose a diaphragmatic paralysis with the Edi catheter in one case." Dr Craig Guenther adds "The diaphragmatic paralysis patient was an interesting case, as we were trying to learn the technology. We were having difficulties in weaning this patient, and trying to figure out rational reasons for these difficulties. It was pretty apparent when switching over to NAVA that he was having difficulties in triggering despite the fact



Kevin Coghlan, RRT and Dr Craig Guenther observe Edi monitoring trends of a lung transplant patient.

that we knew that the Edi catheter was in the right spot. We did not see any diaphragm activity going on, which led us to believe that there was phrenic nerve involvement. That led to a bilateral ultrasound investigation that confirmed the paralysis.” Kevin Coghlan agrees: “The diaphragmatic paralysis case was interesting, he was only 3 days out and the surgeon decided to plicate the diaphragm very quickly. In doing that, I think the patient was spared from a long wean, and avoided problems with consistent collapse. But we also utilize Edi monitoring to understand other modes of ventilation, as we had with a 26 year old lung transplant patient today. You can adapt it and learn from it.”

NAVA in delirium patients

Dr Guenther states that one of the aspects he is most impressed with regarding NAVA is related to the issues of dyssynchrony in spontaneously breathing patients and night resting possibilities. “One of our hypotheses is to determine if you can actually provide the patient with REM sleep with greater episodes

at night, and would this technology provide this? As you enter into the unit, it is busy and the patients are agitated, so they are usually put on a rate at night. When we have switched to NAVA, we realize that their respiratory rate is 45, but no REM sleep is being seen on the EEG. We have a delirium project that is planned for the near future to further investigate these possibilities with our new information system, that is similar to the one Johns Hopkins Hospital is using.”

“The Edi signals absolutely give us new dimensions to see things we would not have seen before. We have to take it to the next level, which is defining an intervention path that affects these factors, requiring science and documentation, but it is very interesting to see so far. We are all interested in delirium, we are all getting older patient populations wherever we are in the world, as our 82 year old mothers are having surgeries that they have never had before. The one thing in cardiac surgical literature that is very clear is that delirium after bypass surgery is a very great mortality-related phenomenon.” Any aspect of care, such as ventilation,

that can affect delirium, is very valuable according to Dr Guenther.

Monitoring of the Edi signal

Kevin Coghlan finds it fascinating to monitor Edi signals of conventional modes, such as PRVC and Pressure Support, prior to switching to NAVA. He describes, “We can learn so much about everything that we thought we knew, only to discover that we need to learn more. We are re-learning. The Edi catheter allows us to see that work of breathing is twice or three times what it should be in some cases, and allows us to study screens and trends. We really have to start thinking about other modes and why they have not been optimal, and what little adjustments we need to make or titrate. We typically have patients on PRVC, and as they rewarm and hemodynamics are in balance, we move to Pressure Support. We really have opened our eyes in regard to Pressure Support and the parameters we set, when we have observed the Edi signals and seen the whole process.”



Dr Craig Guenther and Kevin Coghlan, RRT, are interested in studying Edi signals of delirium patients and with regard to their REM sleeping patterns.

In terms of titration of the NAVA level, the staff members generally start with the NAVA preview, and the NAVA level is titrated up or down, based on the respiratory rate and minute ventilation of each particular patient, according to Kevin Coghlan. "Typically we titrate very slowly, in increments of 0.1 or 0.2 and observe how the patient is doing in the process as a graduated response."

"What really struck me with NAVA is that it challenges respiratory therapists to think about what is going on in the patient, and the therapist-patient-ventilator interaction. It is very much Back to Basics physiology. For a lot of these patients it can be difficult, lung transplant cases may have 5 chest tubes in place, and their thoracic compliance is quite different to other patients, which means you must ask yourself – which work load does that mean for these patients? In addition to NAVA, Edi monitoring would be great to have on all ventilators."

Esophageal ECG monitoring, and different pacing devices

The staff members have had early experiences with interference of the Edi catheter with specific pacing devices, and also with details provided by esophageal ECG monitoring. Dr Guenther explains "Sometimes rhythm disturbances may occur to post-op cardiac patients. We had a NAVA patient in atrial fibrillation on a pacemaker, and the esophageal ECG picked up the fibrillation which the ordinary surface ECG leads did not. There were clearly atrial dysrhythmias that were not picked up by the surface electrodes".

As more patients are coming out of surgery with pacemakers, and as the different models of pacing devices are increasing, there is an interest to study the technology to determine how much interference can be attributed to the Edi catheter in specific types of pacing devices. Kevin Coghlan clarifies: "We had two patients with left ventricular assist devices, and one in particular was very interesting, with a pacing spec appearing as a big square wave on the Edi electrodes. That was an internal pacemaker, versus the external pacemaker that had a



Kevin Coghlan, RRT feels that NAVA offers educational opportunities in basic physiology, especially for hard-to-wean patients.

slightly different waveform showing up on the Edi signal. We have had two different pacemakers showing different disturbance patterns on the Edi signal".

Dr Guenther concurs, "We are interested in this, since it helps us to understand. We are learning the benefits of NAVA and the physiology of breathing, and we would like to validate from a research perspective by doing more pacemaker patients in terms of the different pacemaker technologies. We want to define what interferes and what does not, in order to optimize the use of the technology".

NAVA in future research areas

Dr Guenther believes that delirium patients will continue to be the primary area of interest for NAVA research within the unit, as they struggle to get their patients to sleep in a more restful manner. "NAVA will be a huge player in getting people to understand

what is happening with the delirium patient, and valuable in understanding the weaning process. Getting a more optimal ventilation method at nighttime is a significant factor and we need to know how we can better support these patients. That is the most important aspect to me, understanding the difficult to wean patient and making inroads in what is going on during nighttime."

"You could never have tracked this, nor assessed this information with any other ventilation modality. This provides us with the means to learn, but we need to educate others as well. NAVA and Edi monitoring allows you to take information that you would not be supplied with otherwise, in order to see how Mrs Jones is doing at bedside at 2.30 in the morning. Delirium is not going to disappear, and the patients are not getting any younger. We need to understand modalities and rest at nighttime, and we need to use technology to help us. "

The educational plan for NAVA in the pediatric/neonatal ICU

After the introduction of NAVA in the Neuro ICU and the Cardiovascular ICU of the University of Alberta earlier this year, the next unit to be introduced to NAVA will be the pediatric/neonatal intensive care unit of the institutional children's hospital, the Stollery Children's Hospital.

Respiratory Therapist Julie Mitchell, RRT and RT Educator will be initiating this educational effort. As staff educator for all respiratory therapists within the institution, she has been responsible to coordinate training of staff with vendors. She defines her responsibility in this respect, "Basically I work in initiation of all educational requirements any time a vendor offers a new product or technology that we purchase to implement in our working day. When the vendors leave, I act as a coordinator for all staff questions."

With a staff of about 200 respiratory therapists at the University of Alberta and Stollery Children's Hospital, Julie Mitchell is not only the sole clinical educator but is also a general resource for the respiratory therapy staff members, including general education and policy and procedures as well.

NAVA educational effort

There was a structured plan in introducing NAVA to the two intensive care units previously in the year. The manufacturer representative was on site for the first weeks to help implement the start-up process. Julie Mitchell describes the process: "The first sessions were set up with a full week of education, with no implementation at that point. After that point, inservicing was set up with the schedule for all respiratory therapists, nurses and physicians within the intensive care units. We did have concurrent sessions for nurses, respiratory therapists and physicians that were invited to come morning and afternoon and at nighttime for night staff as well."



Julie Mitchell, RRT, is staff educator for all 200 respiratory therapists at the University of Alberta and Stollery Children's Hospital in Edmonton.



The pediatric and neonatal intensive care units of Stollery Children's Hospital are the next units in line for introduction of NAVA at the University of Alberta Hospital in Edmonton.

The second week consisted of implementation, finding appropriate patients, placing the Edi catheter and observing Edi signals at bedside, followed by running NAVA and observing and following up on patients. In the third week, the intensive care units were running the patients on NAVA themselves, with the representative available as a resource for questions.

Julie Mitchell coordinated follow-up sessions about 6 months after the introduction. "In the follow-up session, we gathered information about what we had learned and how we were troubleshooting. I prepared a summary after those sessions in how to use and troubleshoot NAVA. This summary, together with power point presentations and the user manual have been collected in a shared space in our computer system for the respiratory therapists. This will allow the staff members to access the information, together with policies and procedures when needed."

Neonatal/pediatric start-up

When the physicians have confirmed the start-up date, Julie Mitchell will prepare educational materials as well as modules

and Edi catheters for the introduction. "The process will follow the same cycle: education during the first week and implementation during the second week. We will start out with Edi monitoring

focus, and go on to NAVA from there. We hope to give the staff members the same information as we did in the earlier educational sessions, but with more of a pediatric/neonatal focus. ■



The University of Alberta Hospital in Edmonton is one of Canada's leading clinical, research and teaching hospitals.

Biography

Jim Kutsogiannis, MD, MHS, FRCPC obtained his medical degree at Queen's University, Kingston Ontario, Canada, and completed a residency in Internal Medicine from the University of Western Ontario, Canada, followed by a fellowship in Critical Care Medicine at the University of Alberta, Canada. Thereafter, Jim Kutsogiannis completed research training in clinical epidemiology from the Johns Hopkins School of Public Health, in the USA. Jim Kutsogiannis is currently an Associate Professor of Critical Care Medicine at the University of Alberta, the co-director of the Neurosciences ICU and the Director of the Human Organ Procurement Program for Northern Alberta. Dr Kutsogiannis

has a research focus in critical care nephrology and neurocritical care.

Darryl Ewanchuk, RRT studied initially as Bachelor of Science at the University of Alberta, Edmonton, Alberta Canada in 1988. He received his Respiratory Therapy degree from the Northern Alberta Institute for Technology in Edmonton, Alberta, Canada in 1990. He started as Clinical Respiratory Therapist at the University of Alberta and Stollery Children's Hospitals from 1990-1994. He thereafter took a position as Clinical Respiratory Therapist at the King Faisal Specialist Hospital and Research Center in Riyadh, Saudi Arabia from 1994 to 1996. After serving as Clinical Respiratory Therapist at the University of

Alberta and Stollery Children's Hospitals from 1996-2004, Darryl Ewanchuk became Respiratory Therapy Supervisor Neurosciences at the same institution in 2004. Darryl Ewanchuk is currently serving as Respiratory Therapy Supervisor, Neurosciences/ENT/Surgery at the University of Alberta and Stollery Children's Hospitals, a position he has held since 2006.

Craig Guenther, MD, BSc Pharmacy, CCFP, FRCPC obtained his undergraduate degrees of BSc, MD and LMCC at the University of Alberta in Edmonton from 1976 to 1982. He completed his residency in Surgery (orthopedics) at Dalhousie University, Halifax, Nova Scotia from 1984-1985, and

residency in Anesthesia at Foothills Hospital at the University of Calgary in Calgary, Alberta from 1989-1991. Craig Guenther conducted his Clinical Research Fellowship at the Ottawa Heart Institute in Ottawa, Ontario in Cardiovascular Anesthesia and Critical Care from 1991-1992. His echocardiography training took place at Calgary General Hospital in 1996, and he obtained his Society of Cardiovascular Anesthesiologists (SCA) and Perioperative Transesophageal Echocardiography Examination (PTEeXAM) in 1998. Craig Guenther is currently Clinical Associate Professor at the Department of Anesthesia and Pain Medicine at the University of Alberta Hospital. Dr Guenther has a research focus in analgesia and sedation in the ICU and transfusion and coagulation in cardiovascular surgical patients as well as renal replacement therapy and dialysis in post-op cardiac surgical patients.

Kevin Coghlan, RRT received his degree from the Northern Alberta Institute of Technology in 1988. He has been Supervisor and Program Specialist for the Cardiovascular Intensive Care Unit of the University of Alberta Hospital in Edmonton since 1992. Kevin Coghlan RRT is currently taking an 8 month temporary assignment covering Pulmonary, Coronary and Emergency Care within the University of Alberta Hospital in Edmonton.

Julie Mitchell, RRT, received her Bachelors of Science Degree in 1995 at the University of Ottawa in Ontario, and her degree in Respiratory Therapy at Fanshawe College of London, Ontario in 1991. She worked as Respiratory Therapist from 1999-2006 at the University of Alberta Hospital in Edmonton. Julie Mitchell currently is Clinical Educator, Respiratory Therapy for the University of Alberta Hospital and Stollery Children's Hospital in Edmonton, a position she has held since 2006.

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Guest speaker Jennifer Beck, PhD, John Pope MD of Akron Children's Hospital PICU, guest speaker Maureen Reilly, RRT and Anand D Kantak, MD, Director Neonatology at Akron Children's Hospital

Neonatal and Pediatric Ventilation: Emerging Trends and Challenges

A Symposium Summary Report from Akron Children's Hospital

Over 120 neonatologists, respiratory therapists and nurses from the states of Ohio and Michigan attended a one day symposium with focus on respiratory management of neonatal patients and pediatric patients, organized by Kim Firestone, RRT and Neonatal Outreach Educator, and Diane Dunn, RRT, Respiratory Care Educator of Akron Children's Hospital, Ohio, USA. The impressive Faculty of Speakers included Professor Mark Heulitt, MD, Little Rock Children's Hospital, Arkansas; Jennifer Beck, PhD, of Keenan Research Centre in the Li Ka Shing Knowledge Institute of St. Michael's Hospital, Toronto, Canada; Maureen Reilly, RRT, Sunnybrook Health Sciences Center, Toronto, Canada; and Howard M Stein, MD, Neonatologist at Toledo Children's Hospital in Ohio.

The highlights of the symposium included response time and work of breathing in neonatal and pediatric patients, the concept and physiological basis of NAVA, neonatal ventilation techniques and strategies, and NAVA neonatal clinical experience of 40 patients from Toledo Children's Hospital.



Kim Firestone, BS, RRT and Neonatal Outreach Educator of Akron Children's Hospital, was responsible for organizing the symposium.



Professor Mark Heulitt, MD of Little Rock Children's Hospital in Arkansas, lectured on the subjects of ventilation response time and work of breathing.

Anand D Kantak, MD, Director of Neonatology and **John Pope, MD** of the Pediatric Critical Care Department of Akron Children's Hospital opened the symposium for the participating physicians, respiratory therapists and nurses. The objectives of the symposium included learning opportunities to change strategies, including other approaches to minimizing ventilator-associated diseases, in getting the patients off the ventilators as soon as possible, and to address the significant difficulties of patient-ventilator asynchrony.

Response Time and Work of Breathing – Professor Mark J Heulitt, MD, Arkansas Children's Hospital

Dr Heulitt reviewed the physiologic principles of positive pressure mechanical ventilation. He also reviewed the physiologic components for the measurement of work of breathing, with the definition that work is performed when a force moves its point of application, or $\text{work} = \text{force} \times \text{distance moved}$. In a ventilation perspective, he summarized that work is equal to the mean pressure \times change in volume, or mean volume \times change in pressure.

Dr Heulitt illustrated the need to understand ventilator design, effects of triggering and response times in order to understand how components may affect breath delivery by means of examples from the laboratory and recent research (Heulitt et al, Respiratory Care 2007).

He emphasized the understanding of the response of the ventilator, and how the ventilator and patient interact in addressing patient ventilator synchrony. In traditional pneumatic mechanical ventilation, the response of the ventilator to patient effort should take into consideration ventilator factors, such as triggering variable, variables that control gas delivery and cycle-off criteria. Patient related factors include mechanics of the respiratory system and characteristics of the Pmus waveform.

Dr Heulitt briefly described Proportional Assist Ventilation – PAV by stating that the amount of ventilatory support applied by PAV is determined by inspired volume, inspiratory flow rate, thorax compliance, lung compliance and total resistance from the ET tube and lungs. He went on to describe the NAVA concept and aspects of neuro-ventilatory coupling, and explained regulation of the breath

with NAVA in relation to the Edi signal and Edi curve. Dr Heulitt showed a video example of an infant patient breathing first on Pressure Support, and then the same infant switched to NAVA with more comfort and lower FiO_2 and peak inspiratory pressure (PIP) levels.

Dr Heulitt explained that experience of NAVA in neonates at his institution was limited at this point, but presented screens and trend graphs of two infants on NAVA, one weighing 910 grams and another weighing 1009 grams.

Dr Heulitt concluded his presentation by describing the benefits of Edi monitoring as a new parameter at bedside, and showed examples of Edi monitoring of infants in PRVC and Volume Support modes. He concluded his presentation by stating that response time and trigger delay can have an impact on patient synchrony with the ventilator, that trigger delay is directly related to patient drive, and that work of breathing can vary significantly depending upon the patient, ventilator and clinician treatment decisions. He stated that the potential of future modes to address these issues needs to be studied further.



Maureen Reilly, RRT and Jennifer Beck, PhD, who spoke on the topic of Neurally Adjusted Ventilatory Assist - NAVA.

Mechanical ventilation and the extremely low birth weight infant – An RRT perspective: Maureen Reilly, RRT, Sunnybrook Health Sciences Center, Toronto, Ontario, Canada.

Maureen Reilly described the Sunnybrook Hospital NICU as a 41 bed unit, with 250-300 extremely low birth weight infants admitted annually. The hospital collaborates with the Hospital for Sick Children transport team in Toronto, and is a teaching hospital with integrated neonatal-perinatal fellowship program. The neonatal respiratory department uses Babylog and oscillator, Bunnell Jet, infant flow CPAP and SiPAP, and nitric oxide in their ventilation therapy.

The hospital participates in the Vermont

Oxford Network of over 800 neonatal intensive care units, which provides statistics and ratios in terms of morbidity and mortality, and observed values in regard to specific conditions such as pneumothorax and chronic lung disease.

Maureen Reilly described some of the recent research such as implementation of a respiratory therapist driven protocol for neonatal ventilation and impact on premature population (Hermeto et al) and CPAP as summarized in the COIN study by Morley et al in NEJM 2008. She also summarized the use of surfactant in terms of effect on neonatal mortality in regard to prophylactic versus selective surfactant in a meta-analysis of 7 published studies by Soll et al in 2001. Maureen Reilly summarized literature

in regard to subjects such as HFO and permissive hypercapnia. She concluded by defining what she perceived as the trend of the future, to avoid intubation or to extubate as soon as possible.

Neurally Adjusted Ventilatory Assist – NAVA, Jennifer Beck, PhD, St. Michael's Hospital, University of Toronto, Canada.

Jennifer Beck started her presentation by defining Edi as neural respiratory output, and describing how Edi is measured. She showed examples of Edi waveforms and videos of increasing phasic Edi with added resistance as well as increasing tonic Edi with derecruitment. She outlined the increase



Discussions between sessions: John Pope, MD, Anand D Kantak, MD, Jennifer Beck, PhD, Howard Stein, MD, Alberto Marra and Maureen Reilly, RRT.

of tonic Edi by removal of PEEP from her study on intubated term infants.

Jennifer Beck continued by describing what NAVA is from a concept basis, the features of NAVA as provided in a screen with Pvent, flow, volume and Edi, with waveform segments displaying trigger, assist, cycle-off and PEEP. She discussed different methods of adjusting the NAVA level.

She summarized some of the opportunities to monitor and improve patient-ventilator interaction with NAVA by a series of 4 screens with Edi waveforms of babies that the audience should guess whether the infants were breathing or not. She

presented research that has been recently submitted for publication on patient-ventilator interaction in infants (Bordessoule, Jouvett, Momeau, Beck 2008), with comparisons between Babylog and NAVA, indicating early cycle off with Babylog up to 50% in monitoring peak Edi/breath, and indicating that NAVA responds to respiratory drive (Beck et al 2008 Clin in Chest Med).

Jennifer Beck also presented how NAVA may provide protective ventilation in neonates by showing the physiological response to NAVA level titration, and that NAVA allows the patient to limit tidal volumes and airway pressures. She also referred to the recently published study by Lukas Brander (Chest 2008)

indicating spontaneously chosen VT and lung compliance during NAVA. She also presented how NAVA responds to changes in respiratory demand and drive in preterm infants. Finally, she presented how, with NAVA, synchrony is not affected by leaks, as well as the potential of non-invasive NAVA in the future.

Jennifer Beck concluded by stating what we know so far about NAVA; in terms of improving patient ventilator interaction, that it may provide protective ventilation; that it adapts to altered respiratory drive, improves success of non-invasive ventilation and allows for on-line monitoring of respiratory drive.



Neonatologist Howard Stein, MD shared his experiences with NAVA in over 40 neonatal patients at Toledo Children's Hospital, in Toledo, Ohio. (An in-depth interview with Dr Stein and colleagues on NAVA in neonates can be found in this issue of Critical Care News.)

NAVA in the Neonatal Intensive Care Unit – Toledo Children's Hospital Experience, Howard Stein, MD, Neonatologist

Dr Stein introduced his presentation by stating that NAVA had been in use in the NICU since May, 2008, and that they have 40 neonatal patient cases that have been treated with NAVA at this point (November 2008). The birth weights of these infants have been between 440 – 3930 grams, and gestational age has ranged from 22 to 40 weeks, however the average patient has usually been between 30 and 32 weeks. Time on NAVA has been between 15 minutes to 20 days, and patient age at NAVA use has ranged between 1 hour and 15 weeks.

Patient categories presented by Dr Stein included 24 neonates with respiratory distress syndrome, of which 20 were extubated from NAVA: 8 extubated after 1 day of NAVA, 8 extubated after 2

days, 3 extubated after 3 days of NAVA and 1 extubated after 4 days. Four of these RDS neonates required other ventilatory support prior to extubation, due to recurrent apnea or development of chronic lung disease. 6 of the RDS patients had been treated with surfactant while on NAVA, and 17 had been treated with surfactant prior to NAVA. Dr Stein also presented experience with the chronic lung disease category, of which 10 patients had been treated with NAVA. Of these CLD patients, 3 were extubated directly from NAVA, 1 after 1 day of NAVA, 1 after 10 days of NAVA, 1 after 20 days of NAVA.

One neonatal patient was treated for meconium aspiration syndrome, and was successfully extubated after one day on NAVA. Dr Stein stated that some of the patients also had miscellaneous associated conditions while on NAVA: 4 had pneumothoracies, 1 patient had non-ketotic hyperglycemia, 1 patient at

28 weeks had gastroschisis, one patient that was 3 months post removal of intrathoracic teratoma with CLD. Dr Stein went on to pose a series of questions, and relayed his experience in each area.

In answer to the question if the NAVA Edi catheter could be placed correctly in premature infants, Dr Stein displayed an example of a screen of a 28 week old infant with RDS and correct Edi catheter positioning of leads.

Many clinicians are wondering if Synchronized Intermittent Mandatory Ventilation - Pressure Control (SIMV PC) is really synchronized in premature infants. Dr Stein presented a screen with Edi signals showing evidence of flow triggering in a 1 day old 28 week infant on SIMV (PC), as well as lack of synchrony in all flow triggered breaths in a 3 week old 26 week infant with chronic lung disease on SIMV.

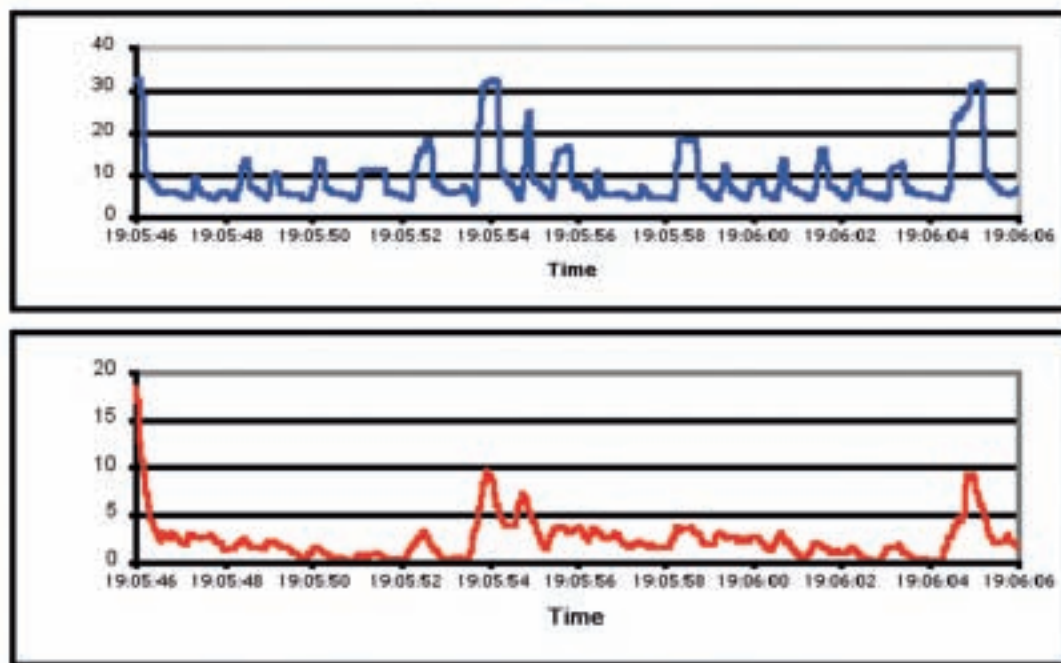
Dr Stein discussed the challenges of defining if central apnea is truly "central" in origin. In addressing this issue, a screen was displayed of a 1 month old 23 week infant on SIMV (PC) where the Edi signal showed true central apnea.

In response to the question if premature infants have intact respiratory drives, Dr Stein exhibited the Edi curve showing respiratory drive in the same 1 month old 23 week infant as above, 20 minutes after the SIMV (PC) central apnea capture.

Is the respiratory drive of a neonate mature enough to regulate respiration effectively? Will NAVA work in neonates?

Dr Stein revealed a screen showing the same 1 month old 23 week infant, previously on SIMV (PC) being effectively ventilated with NAVA. He also displayed screens of NAVA working effectively in a 1 day old 28 week infant with RDS as well as NAVA in a full-term infant with meconium aspiration syndrome. He also displayed NAVA in a breath-to-breath variation in a neonatal patient. Dr Stein proceeded to present four individual neonatal cases with NAVA. In the first NAVA case, a baby born at

NAVA in a neonate – breath to breath variation in peak pressure, IT and respiratory rate (average 63 breaths per minute) over 20 seconds.



Perfect synchronization between EDI and PIP

Data presented by Dr Howard Stein of Toledo Children's Hospital

30 weeks gestation at a birth weight of 1440 grams was reviewed. NAVA was started at NAVA level 2.5 $\mu\text{v}/\text{cm H}_2\text{O}$ and surfactant was given within one hour. The baby was monitored, and trends revealed that Edi peak and min remained high for about 40 minutes after surfactant administration. Dr Stein believed this could indicate alveolar recruitment. The baby was extubated on the first day of life.

The second NAVA case involved an infant at 32 weeks gestation, one of three triplets with a birth weight of 2140 grams. The baby had RDS and was treated with surfactant, but developed bilateral pneumothoraces and pulmonary hypertension requiring NO and Dopamine. The baby was first ventilated on SIMV and was later placed on NAVA at a level of 5 $\mu\text{v}/\text{cm H}_2\text{O}$. After one hour of NAVA, blood gas revealed pH 7.32, PCO_2 of 52 and BE +1. The blood gas at three hours showed pH 7.37, PCO_2 of 49 and +3. While on NAVA, the pneumothoraces were resolved, however there was pseudomonas growth in the endotracheal

tube and chest tube sites. This patient was extubated after 7 days on NAVA.

The third NAVA case presented an infant at 33 weeks gestation, born under C-section under general anesthesia for PIH at a birth weight of 2160 grams. The baby was intubated in the delivery room for respiratory depression, and was started on NAVA at 12 hours of life. The baby was treated with a second dose of surfactant and weaned from NAVA to CPAP but failed to wean on CPAP on the second day of life, but was extubated on day 3.

In the fourth NAVA case presentation, a 27 week old 820 gram surviving twin was treated with surfactant for RDS on first day of life and NAVA was tried at 9 days of life. The baby was extubated after 3 days on NAVA.

In summarizing his presentation, Dr Stein stated that in general observation of their neonatal patients, they find that peak inspiratory pressures (PIP) decreases

when the patient is on NAVA, blood gases improve and that NAVA allows neonates to wean their own PIP over time. He concluded that neonates do have the capacity to ventilate themselves effectively using NAVA, and that patient selection is important – not all neonates are candidates for NAVA (for example neonates with abdominal surgery). He stated that neonates are able to ventilate on NAVA effectively with lower PIP than conventional ventilation.

Dr Stein also summarized that NAVA can be used effectively with administration of surfactant and nitric oxide, and in the presence of pneumothoraces, and that in the number of patients they have observed so far, there were no significant complications or side effects noted with NAVA.

(An in-depth interview with Dr Howard Stein and colleagues from Toledo Children's Hospital regarding their experience of NAVA in neonates follows in this issue of Critical Care News.)



Cindy Zimmer, RN and neonatologist Howard Stein, MD with NAVA neonatal patient

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.



Diane Howard, RRT, NPS, Education Coordinator for Respiratory Therapy at Toledo Children's Hospital



Judith Gresky, RN, MSN, CMP and NICU Director at Toledo Children's Hospital.

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.



Dr Howard Stein and colleagues wanted to become very familiar with NAVA, prior to starting any clinical trials.

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.

Neurally Adjusted Ventilatory Assist

How did you become familiar with the concept of NAVA?

Dr Howard Stein: Once we knew we were going to replace all our ventilators we evaluated a number of the ventilators that were available. Each company brought in their ventilator, in-serviced us

and then we put babies on each type of ventilator. The hospital was interested in a versatile ventilator that would work on our preemies and our term babies in the NICU but could also be used in the PICU for children and adult size patients. After trying multiple ventilators we felt that the SERVO-i was the most user-friendly, and the easiest to learn.

In addition, we had heard about NAVA and were aware that the SERVO-i was the only ventilator that could provide this type of ventilation. We were unaware at the time how little was known about NAVA in the neonate. We assumed that NAVA had been studied extensively in these patients. When our NAVA module arrived and we went to review the studies, we were surprised at the very limited amount of data regarding the use of NAVA in neonates. This made the initiation of NAVA in the NICU a challenge. Because it was new and neonatal data was so scarce, there was initial resistance from my colleagues to the use of NAVA. Earlier in 2008 I had met both Dr. Sinderby and Dr. Beck at different meetings and heard them speak about NAVA. I felt the concept was sound and made sense. I then reviewed all the literature I could find and submitted a proposal to our IRB (Institutional Review Board). Because NAVA was FDA approved in neonates we did not need IRB permission or parental consent to use NAVA but we did need IRB consent to collect and track the data (in a de-identified form). My next goal was to educate my colleagues and the NICU staff with the information that was available.

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



NAVA in a 1 day old 28 week infant with RDS.

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



Cindy Zimmel with Educational Coordinator Diane Howard, RRT. Diane Howard has been involved in the educational effort for NAVA since implementation in the NICU.

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 FiO_2 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 FiO_2 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



Parents with neonatal patient who experienced IRDS. The patient was successfully extubated after one day on NAVA.

the fact that work of breathing, peak pressures and FiO_2 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.



Dr Howard Stein has been presenting his experience with NAVA at a number of scientific meetings and symposia within the United States.

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 FiO_2 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 FiO_2 .

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, tetralogy 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,



Dr Howard Stein with staff members John LaPlante, RRT, NPS, Unit Clerk Jodi Conkle and Diane Howard, RRT.

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 to 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 is obviously nervous. Any nurse that has had even only one baby on NAVA rapidly sees "this is not really that different".

Judith Gresky: I don't think we would have reached the number of 40 patients in a short period of a few months time if we did not see successes. The mere fact that NAVA is working on the patients compels us to find new candidates all the time.

What is your process for Edi catheter insertion and placement confirmation, and use as a feeding tube?

Diane Howard: In our NICU, the nurses insert the Edi catheter after the respiratory therapist has determined the correct size Edi catheter for the patient and the insertion depth. As the Edi catheter is inserted by the RN, the RT views the ventilator screen and can

determine if the Edi catheter needs to be inserted further or pulled back. The Edi catheter can be inserted orally or nasally and it is usually at the discretion of the RT which method is used. We secure the catheter with Tegaderm so that it does not gravitate in or out and maintains proper placement. The Edi catheter is used for lavage feedings if applicable. We have noted that it is common for the Edi signal to be decreased during a feed, so we may change to SIMV(PC) during the feed, monitor the signal, and return to NAVA mode when the Edi signal returns.

How would you recommend other NICU departments to start with NAVA, in order to gain experience?

Dr Howard Stein: I think two things would be helpful. First, it would be useful to see NAVA used at another unit. We recently hosted a group from Michigan and showed them a baby on NAVA, and within five minutes they said "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. ■

Biography

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.

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Neonatologist Dr Wenjin Shi with patient in the neonatal intensive care unit of Fudan University Children's Hospital.

Research and establishing standards of care and training for neonatal intensive care in China

The People's Republic of China has undergone a rapid and major expansion during the past twenty years in many sectors of society, as illustrated in a growth rate of over 10 percentage points within the country which is more than the growth rate of the entire world. By opening itself to other economies, China is also optimizing the world industrial structure in terms of investment and growth.

This rapid development and growth in recent years is also mirrored in the Neonatal Research and Intensive Care Departments of the Shanghai Children's Hospital of Fudan University Hospital. As a comprehensive multi-disciplinary research university hospital, they have also in recent years established a National Neonatal Training Program to serve the People's Republic of China, in joint venture with the Canadian Neonatal Network™. Critical Care News met with Dr Bo Sun, MD, PhD, Head of Laboratory of Pediatric Respiratory and Intensive Care Medicine at Shanghai Children's Hospital of Fudan University, and with staff members of the Neonatal Intensive Care Unit of Shanghai Children's Hospital to hear about the development and progress that has been made in recent years.

Bo Sun, MD, PhD, has worked for many years as head of Laboratory of Pediatric and Respiratory and Intensive Care Medicine at Shanghai Children's Hospital of Fudan University. He has also worked for many years in research for the areas of surfactant therapy and application of nitric oxide, in Sweden as well as China. Neonatal special care services in China have been established only within the past decade, and his most recent research was conducted together with the Chinese Collaborative Study Group for Neonatal Respiratory Diseases to investigate the incidence, management, outcome and cost of neonatal respiratory failure treated by mechanical ventilation at NICUs in major hospitals in southeastern and midwestern China.

Dr Bo Sun explains: "This has been a systematic survey of 23 intensive care units in major cities in China, to investigate neonatal respiratory disease, and in particular respiratory failure which is most severe and commonly requires very extensive treatment. So there is a requirement for a high level of intensive care and respiratory support. From a total of 13,000 patient admissions, we got some 1700 cases of severe respiratory failure requiring a high level of intensive care support. We charted how these cases were treated, and in particular how the respiratory therapists used different modes of ventilation and outcome."

The investigation by Dr Sun and his colleagues revealed that nasal CPAP was utilized in 52% of patients receiving mechanical ventilation. He states that "In different age groups and in the very premature newborns more CPAP is being used than conventional mechanical ventilation."

In context of the major results, mortality in the group with severe respiratory failure remains very high at 35%. Dr Bo Sun explains that among those clinical results, half of the patients were withdrawn from treatment. "The major reason that they were withdrawn from treatment was economic factors. Although this data is from major cities, the population is very mobile and transient in looking for work and seasonal work and with very little opportunity for prenatal care and follow-up, and



Dr Bo Sun has conducted intensive care and ventilation research for many years, in Sweden as well as China.

frequently with delivery at home. We find that this accounts for a very severe form of RDS and infections." As head of the Laboratory for Neonatal and Pediatric Intensive Care Medicine, the institution is also in the position to influence regional clinicians and therapies. Dr Sun described the operations: "We are a special research lab, but my role in a clinical aspect is for design and research coordination. For the lung disease my major work is for research, we have a separate chief who is in charge of intensive care, whom I work together with to coordinate efforts, like this one. I have another paper published by Intensive Care Medicine describing acute respiratory distress syndrome in pediatric intensive care across China, another epidemiology study. This is how we have been working for the past ten years, as well as other things such as continuing education, workshops and some symposia we have every year, domestic and internationally, so we are progressing and influencing many regional clinicians in regard to understanding and use of lung protective therapies in pediatric and neonatal patients."

When asked about how he sees research focus in the near future, Dr Bo Sun states: "I think that the way we are organized in China, towards a

close relationship with clinical works due to economic factors, among others. We are playing a role like locomotives in research; later on we wish to help participating centers to become their own locomotives in the regional areas, to conduct their own studies. Our center plays a leading role to influence regional centers in their research efforts. However, if we compare our epidemiologic papers to Western papers, usually they are controlled studies or randomized studies. We are not at this stage yet in China. We may be there in five or ten years, but for the time being we feel working with epidemiological studies is a good progress, since our resources are limited and this is a big country. The population and clinical workload is enormous, and the resources for studies are limited, so we feel that this is a practical approach for us to investigate and implement technologies."

"Some things in China are very different yet compared to the West. The neonatal aspect of premature newborns in China is different; we have a very low premature birth-rate below gestational age of 28 weeks, a very small proportion even in the countryside data and in cities. For the general population in China, when developing the neonatal care program, we need to put the major focus and



Neonatologists Dr Rong Zhang, Dr Jin Wang, and Neonatal Intensive Care Chief Dr Chao Chen.

effort within neonatal intensive care by not judging on the size of the babies that are delivered, rather systematically focus on the patients with the birth weights of 1,000 or 1,500 grams instead of the extremely premature low birth weight infants. We must systematically study this patient group to establish where we are, before attempting major resources and efforts in the more uncommon patient group. For instance, this is a national center and ten years ago this facility was the same size as the centers in provincial cities that I travel to now. You can clearly see the trend of the development. In our own clinic the mortality rates are becoming closer to a mid-level or the Western level of mortality in terms of respiratory distress

syndrome and respiratory failure. We consider that we are catching up and will be using more advanced technology, but we must consider our general situation in a pragmatic manner to find our best solutions to reach our targets."

Developments in standards of care and training

The Neonatal Intensive Care Unit of the Shanghai Children's Hospital of Fudan University Hospital has rapidly expanded in recent years; moving to a newly constructed facility has allowed the unit to grow from a 40 bed facility for neonates to 150 neonatal patients

in a very short period of time. The NICU staff members have also expanded their horizons with an International Training Program in Neonatal-Perinatal Medicine in Shanghai in joint venture with the Canadian Neonatal Network and the Canadian Pediatric Society. The objectives of the program are to establish a national training center for neonatal medicine in Shanghai, which will train a new generation of neonatologists within the PRC, to establish national standards of care and training of neonatologists and other caregivers in neonatology in the PRC, and to provide new areas for joint collaboration in the future.

The training program has already influenced ventilation therapy within the NICU. Neonatologist Dr Jin Wang explains: "For invasive ventilation in pre-term infants, Synchronized Intermittent Mandatory Ventilation (SIMV) is most frequently used, and we used Pressure Regulated Volume Control (PRVC) plus Volume Control on some occasions as well. We use SIMV with Pressure Control. Some of the spontaneously breathing babies are given SIMV with Pressure Support. Several years ago we were just using Pressure Control and sedation, but we switched to SIMV after the training program in Canada where this mode was taught. This change occurred a few years ago."

Neonatologist Dr Wenjin Shi further described the program: In our cooperation with Canada, the training program is a two year program. In the first year the respiratory therapists and neonatologists came from Canada to our center for the initial education. From there we applied to different hospitals in Canada for a one year training program. There are different hospitals and centers in Canada, but they are all university hospitals that participate and provide the collaboration with us."

Neonatologist Dr Rong Zhang described how the area of leakage was addressed in the NICU, and the weaning process and average time to extubation for most babies: "We try to insert the endotracheal tube properly from the beginning, and we position the baby as a means to minimize leakage. We usually don't use leakage

compensation, but we need to learn more and become familiar with other methods as well. In terms of weaning, it all depends if the pressure is high. If we see that the pressure levels have become lower and if oxygenation is good, we start to wean the baby by monitoring pressure and rate. Usually the mean airway pressure is less than 18 by that time."

Surfactant therapy is used within the NICU for very distinct situations.

Neonatologist Dr Lin Yuan explains: "If there is an x-ray showing signs of neonatal respiratory distress syndrome and if the baby's oxygen requirement is more than 30 or 40% we give surfactant. We do admit many babies from other centers that have had a dose of surfactant prior to being admitted here."

NICU Chief Dr Chao Chen described his opinion of the biggest challenges in mechanical ventilation in neonates: "I

think the biggest challenge is and will continue to be infection control, and a risk of infection with invasive ventilation, the neonatal lung is so sensitive. We have 40 to 50 nurses in this NICU, with 2 attending neonatologists that are always on staff as well as 12 residents, 2 chief fellows and myself as chief physician. Infection control remains as our number one priority and concern, even with the rapid development and expansion we have experienced in recent years". ■

Biography

Bo Sun, MD, PhD received his initial medical degree in 1983 from the Faculty of Medicine and Pediatrics, Shanghai Second Medical University. His advanced graduate training during the years of 1983 – 1987 was at the Division of Pediatric Pathology, Department of Pediatrics, Children's Hospital of Shanghai Medical University. Bo Sun received research fellowships from the Swedish Heart-Lung Foundation and the Karolinska Institute during 1987-1993, where he was a visiting research fellow at the Division of Experimental Perinatal Pathology at the Institute of Pediatrics at St. Göran's Hospital in Stockholm and

the Karolinska Institute, in Professor Bengt Robertson's surfactant research program, and received a degree of Doctor of Medical Science (PhD). Later on, he developed a long term collaborative research and educational program with doctors and nursing experts in Sweden and European neonatal and pediatric intensive care communities, in promoting advanced respiratory care in newborns and infants in China.

Bo Sun is currently Head of Laboratory of Pediatric and Respiratory and Intensive Care Medicine at Children's Hospital, Fudan University, Shanghai, China. He is

also a Chair Professor in Pediatrics of the Ministry of Education and Fudan University, supported by research grants from National Natural Science Foundation, Ministry of Education and Shanghai Municipality, and with international collaboration from Sweden, Germany, Canada and the U.S. He is also active in major international neonatal and pediatric intensive care societies, and serving as international member of the journal editorial board of *Acta Paediatrica*, *Neonatology*, *Pediatric Critical Care Medicine*, *Pediatric Research* and *Early Human Development*.

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Intensive care physician Dr Ian White instructs staff nurse Tracy Wooldridge about the use of the new Heliox ventilator application.

First impressions of the use of a new Heliox ventilator solution

The clinical use of Heliox (helium-oxygen mixtures) was originally used at the turn of the century as a breathing mixture in deep sea diving to avoid decompression sickness formed by nitrogen bubbles. Use of Heliox to improve symptoms of airway obstruction was reported as early as the 1930s. The use of Heliox has been documented in clinical studies in spontaneously breathing patients and non-invasive ventilation; however it is also being used increasingly in mechanical ventilation of intubated patients.

Heliox has been used for the past four years in the 9-bed general intensive care unit of St. Peter's Hospital, Chertsey, Surrey in the United Kingdom. The ICU staff at St. Peter's has been involved in the development and implementation of bedside mixing stations for Heliox delivery with different types of ventilators. The department will soon be one of the first intensive care units in the world to work with a bedside piped gas supply of Heliox. They have also recently implemented the Heliox application on their SERVO-i ventilator fleet. Critical Care News spoke with intensive care physician Dr Ian White, about their experience with Heliox in general and early experience with the new ventilator solution.

When did you first learn about the concept of Heliox therapy, and for how long have you been utilizing the therapy?

Dr Ian White: We have been using Heliox for about 3-4 years now, starting in October 2004. We introduced it very slowly, and we were involved at an early stage building up the equipment and experience together with BOC (British Oxygen Company). The main problem of introducing any new therapy in ICU is that you've got to get people familiar with it, and that means getting people familiar with the basic concept and then, in this case, with using the equipment. Once you are familiar with Heliox, it is very straightforward to use. You set up the ventilator in the exact same way as for conventional ventilation, but the patients are ventilated with helium not nitrogen as the carrier gas. But it is not just the ventilation that is important; it is the logistics of Heliox that require detailed attention. The nurses, the physiotherapists and other paramedical staff have had to be educated and the portering teams have to take on the extra workload of moving the cylinders around. That takes time in the beginning. We have over 54 fulltime staff, and things moved slowly at first. Everyone needed the chance to get trained and educated using Heliox on patients. We were one of the first units to use Heliox on ventilated patients so there was no one to refer to for advice. It was a matter of trial and error. The exchange delivery station we are currently using is the second model BOC constructed, it's a new design slightly modified from an original version.

The first ventilator we used for Heliox had some problems. It used twice as much Heliox as it should have because it had a leak, a problem that was never resolved. The ventilator was not as good as the SERVO-i ventilator, which is much more efficient. What we were gaining by using Heliox, we were losing using that ventilator, as you could set up both ventilators exactly the same but tidal volumes would drop when changing to the first ventilator compared to the SERVO-i because that brand was not as efficient. We went on to work with another ventilator brand, which was a more efficient ventilator than the first,



Dr Ian White has been gaining experience with Heliox in different intensive care patient categories for the past four years.

and comparable to the SERVO-i but not as user friendly. Now we have the SERVO-i, and everyone knows how to use it since it is the main one we use on the unit, so instigating the use of Heliox with SERVO-i has not been a problem.

Which types of patients do you normally treat with Heliox?

Dr Ian White: The only substantial clinical evidence for the use of Heliox is with severe asthmatics, the evidence for the use of Heliox in any other patient categories is mainly anecdotal. However, the more we use Heliox with other patient categories, the more experience we gain and the more we are seeing the benefits. Basically, we use Heliox on anyone with an increased work of breathing, which includes any spontaneously breathing patient going into respiratory failure, including patients with asthma, COPD, and pneumonia. For ventilated patients we want to ventilate them such as to deliver the same tidal volumes but at much lower pressures, I believe this reduces risk of lung injury. We believe that there is growing evidence that you can reduce mortality

by reducing pressures, and we believe that Heliox is a way of achieving this.

What is the average length of treatment for patients treated with Heliox?

Dr Ian White: We admit over 480 patients per year to the ICU and of these we treat on average approximately one or two patients with Heliox per week. They can remain on Heliox from any thing from a few hours to many days depending on their response. Problems arise with two patients on Heliox therapy because the staff time required in order to transport and change the cylinders at the bedside is a considerable drain on resources. This is the limiting factor on the number of patients we can treat at any time with Heliox on our unit. We will soon have piped Heliox delivered to the bedside so this will simplify the logistics and we may be able to treat more patients on a weekly basis.

What FiO₂ settings are you normally using when running Heliox and what is your philosophy related to this and the clinical effect of Heliox?

Dr Ian White: Ideally we want at least 60% helium, which makes it amenable to treating patients with bronchospasm who don't have gas exchange problems. You can get oxygen in and out more easily with laminar flow, which is essentially the mechanism of action of Heliox. Patients can breathe much easier with less work of breathing and nebulized drugs get better deposition. In those patients who don't need much oxygen you use as much helium as is possible. For patients needing a higher percent of oxygen, it can be a problem since helium and oxygen are competing for the same space. For ventilated patients, we find we are ventilating much more efficiently, we get the same tidal volumes but at lower pressures. You see a difference in tidal volumes even by adding in an extra 5% of Heliox. You have the opportunity of titrating in the Heliox so getting more efficient ventilation without compromising your oxygenation. This is anecdotal, based on our own experience and observations, at this point.

How important is evidence-based medicine when choosing a ventilation therapy, in your opinion?

Dr Ian White: It is very, very important, and unfortunately for this reason a lot of physicians aren't using Heliox, since the evidence base behind it is not significant enough yet. But the problem with this is that there will not be any evidence for anything if one is not willing to try something new. Someone must have a vision and once basic experience is in place and seems to support the vision, you formalize by means of studies and then offer a new therapy to the public domain. If your studies are significant, they will support the new therapy. The documentation behind Heliox use is increasing steadily, there is quite a lot that has been published recently but more Level 1 evidence is needed.

Are you planning to do research on Heliox therapy, and if so, please describe in general what you are interested in investigating?

Dr Ian White: We are planning to do research and we are ready to go; we have protocols in place, approval from the ethics committee and consent forms finalized. We are ready to start recruiting patients, but we are waiting for the piped facility to be finalized, so as to afford better blinding of the study. It is difficult to blind a study while using the cylinders at bedside. In terms of what we want to investigate, we will base it on a review by Hager et al in AJRCCM from 2005, an analysis of controlled trials that studied ventilation at low tidal volumes compared to high tidal volumes. From the analysis of these studies the investigators found that the mortality was only significantly higher in the high tidal volume group if the patients were ventilated at higher mean plateau pressures.

This is the fundamental reason for using Heliox in ventilated patients, in our opinion. If you can reduce the mean plateau pressures by using Heliox, according to this analysis that has already demonstrated a reduction in mortality, the outcome is much better. My research will be for a four-hour period. We will take patients within the first 48

hours of intensive care, stabilize them generally depending on their condition, and then randomize them to receive Heliox or Nitrox mixtures, and look at the change in plateau pressures over that four hour period. The nice thing with Heliox is once you get nitrogen washout, which takes 3-4 minutes in a closed circuit, you will see if Heliox has an effect or not almost immediately, it is a mechanical thing in the short term. I genuinely believe that we will see a difference within four hours. We have had enough experience at this point to be optimistic to be able to demonstrate a reduction in pressures. We will be looking at patients with $\text{PaO}_2/\text{FiO}_2$ ratios of less than 35, but we believe that Heliox should be used much earlier to reduce the potential of damage. The Hager et al study shows us that mortality is much better if you keep plateau pressures lower, and Heliox is a way of doing that. You convert from turbulent to laminar flow hence reduce driving pressure and peak pressures. It is common sense and basic physics; by reducing pressures earlier you protect the lungs earlier, thus avoid getting stiff lungs and low compliance.



The Heliox Changeover Station has been developed by Ece Medical and BOC Medical with a selector switch for cylinders and pressure indicator as well as gas outlet. The ICU at St Peter's Hospital will soon have Heliox piped supply directly to 5 patient bed-sides.

You mentioned some of the challenges of administrating and handling logistics with Heliox gas supply into the ICU. What will the opportunities be of piped delivery of Heliox to bedside?

Dr Ian White: We are in the process of finalizing our system and piped Heliox will be happening imminently. We will have a total of 5 beds where Heliox will be piped in at the bedside. We are the first ICU in Great Britain to have these pipes installed, and one of the few in Europe and worldwide for that matter.

You have recently started using the Heliox application on the SERVO-i ventilator. How many patient treatment experiences have you had so far and what are your initial impressions of running Heliox with the SERVO-i ventilator?

Dr Ian White: The systems became available in this past month, so our intensive care staff has just started using it. We have treated about 4-5 patients so far with the SERVO-i Heliox application. It seems to be working very well. We use the SERVO-i

as our standard ventilator anyway, so I think it will give us more opportunities to use Heliox as time goes by.

Since we are doing recruitment with the Open Lung Tool on SERVO-i, this will also give us opportunities to do lung recruitment using Heliox. I have modified the recommended recruitment protocol slightly; I do an inspiratory hold at the end of the cycle, which does not increase pressures, but gives the pressures time to spread diffusely. I think we can recruit the lungs better with Heliox; it gives us a new dimension, not only pressures, flow and time, but also density thus lowering the driving force.

How easy or difficult was it to implement the new SERVO-i Heliox technology among your staff members?

Dr Ian White: It has been very easy, absolutely, the staff are all familiar with Heliox therapy, and we have all been working so long with the SERVO-i ventilator that they are all comfortable with it. With new staff members, you have to be overly cautious in terms of explaining about the significance of changing the amount of oxygen and how that can affect the amount of Heliox and tidal volumes. But that is mainly for new staff members. The rest of our people here are now very experienced.

What is your experience of delivering Heliox with non-invasive ventilation therapy?

Dr Ian White: We have delivered a lot

of Heliox to spontaneously breathing patients both via a face mask and using NIV. We want to avoid putting patients on ventilators as much as possible; mechanical ventilation poses the risk of lung damage through ventilator induced lung injury, ventilator associated pneumonias to name just a couple of problems. With Heliox you can buy the patient time, they have reduced work of breathing hence reduced oxygen demands, thus giving the patient time to heal. In spontaneously breathing patients you often see an immediate improvement. Pre-clinical studies and a few individual patient studies have indicated that if you ventilate patients with Heliox, you may reduce the amount of inflammatory changes. So Heliox not only has mechanical lung protective effects, it may have anti-inflammatory effects as well. We don't know enough about this emerging data yet, but it is very exciting.

You mentioned your experience of Heliox therapy while nebulizing. Do you perceive better distribution or more optimal drug use?

Dr Ian White: There is laminar flow in the lower airways anyway, but it is the matter of getting the nebulized drug through the upper airways that may be a challenge. The harder the patient is working, the more turbulent the flow there is in the upper airways. If you can convert turbulent flow here to laminar flow and lower the patients' work of breathing, there is better delivery and deposition of bronchodilatory drugs to the lower airway and we are using Heliox to achieve this. ■

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Biography

Dr Ian White received his initial medical training at Kings College Medical School in London from 1985-1991, and qualified as MB BS in June 1991, and Fellow of the Royal College of Anaesthesia in 1998, and CCST in 2002. His previous appointments include Senior House Officer, Accident and Emergency at Wexham Park Hospital, Slough,

Senior House Officer Anaesthetics at St. Peters Hospital in Chertsey, as well as Queens Medical Center City Hospital in Nottingham. Dr White served as Registrar in Anaesthetics at Royal Marsden Hospital in London in 1996, and Registrar in Anaesthetics at Ealing Hospital in London from 1996-1997. He was Special Registrar at the Imperial College School of Medicine

at Hammersmith Hospital in London from 1997-1998, and Lecturer in Anaesthesia and Intensive Care at the Imperial College London and Chelsea & Westminster Hospital from 1998-2003. Dr Ian White is currently Consultant Anaesthetist/Intensivist at St Peter's Hospital in Chertsey, Surrey in the United Kingdom, a position he has held since 2003.



Per-Arne Lönnqvist, MD, PhD works as a pediatric anesthesiologist at Astrid Lindgren Children's Hospital in Sweden.

The need for high ventilatory performance in anesthesia — perspectives from two clinicians in anesthesiology

Critical Care News has been lending its voice to intensive care doctors around the world in their efforts to publicize the many different research papers that bring to light the need for high ventilation performance in the ICU. Much progress has been made in this field over the last years, and the applications are many. In this respect, we wanted to raise the question of the same need in the field of anesthesia. That is why we met with two highly specialized clinicians and wanted to hear what they had to say about this.

The University Hospital or CHU of Montpellier, France, is a multi-disciplinary hospital with focus on education and extensive scientific research. Astrid Lindgren's Children Hospital in Stockholm belongs to the internationally renowned Karolinska University Hospital.

Professor Capdevila has done extensive research in ventilatory mechanics and optimization of ventilation in anesthesia.

What, according to you, is high ventilation performance in anesthesia, and what are its specificities?

Professor Capdevila: That is, that respiratory management in anesthesia is making its baby steps, much in the same way as it was in intensive care, some 20 years ago. The two worlds are very different. In which way are they different? In intensive care, patients are in need of ventilatory assistance because of acute respiratory insufficiency, no matter what the cause. The world of anesthesia stands apart; why? Not only the ventilatory care of the patient is in focus, but also and foremost, the peri-operative care. Most of our patients, thankfully, have no major complications, and for these the main concern is to put them to sleep and to wake them up. However, some run greater risks and for these, the anesthesiologist has to take into consideration ventilatory, hemodynamic, neurological and renal aspects of care.

For many years, progress has been made in the field of monitoring hemodynamics and hypnotics, to the detriment of ventilation advances. What interested us was to have an SpO_2 , EtCO_2 and maximal pressure. The second aspect, is the possibility of caring for a variety of patients, the one with ARDS, chronic bronchopathy, thoracic traumas, the one with severe asthma or sepsis; recent developments in the performance of anesthesia ventilators allow us today to give almost the same level of care as one gives with ICU ventilators in terms of pneumatic possibilities, with good trigger sensitivity, rapidly increasing pressure when in pressure modes. Today, anesthesia machines have pretty well all incorporated these features. This allows us to go much further in adequate care of these patients. In the past, these patients all had aggravated respiratory conditions upon leaving the operating room, with increased ARDS, an increase in pulmonary edema, diminished ventilation/perfusion ratio, etc. We have optimized this aspect of care today thanks to the advances made.



Xavier Capdevila, MD, PhD works at the University Hospital of Montpellier in France.

A recent survey tells about 95% of patients receiving anesthesia as being lung healthy individuals. Are you met with any challenges today in terms of ventilatory performance in anesthesia?

Professor Capdevila: Yes, there has been this recent survey done by the INSERM (French National Institute for Health and Medical Research) in France, relating that approx 95 % of the patients are healthy in their lungs. However, an ASA-2 patient could present a severe asthma, at a young age, and thereby be a concern for the anesthesiologist. In the same way, an ASA-1 patient who undergoes spinal surgery, or who lies prone for several hours, which also poses problems due to positioning and this can affect ventilation needs peri-operatively. The ventilator must then deliver the same tidal volume which one has preset, with the possibility to correct the internal compliance of the machine. There are augmentations in PEEP, variations in the delivery of fresh gases, variations in resistance which make that there are many ventilatory changes in anesthesia; in the span of 45 minutes, one can have six different ventilatory conditions. What are the important elements in an anesthesia ventilator?

They are, dependability in the precision of volume delivery with a given pressure, adaptability with respect to patient specifics. An 84 year old COPD patient is not the same as an 8-month old infant, or a healthy 25 year old woman. Adaptability to varying surgical postures which can alter respiratory mechanics in the patient.

This brings us to ask the question concerning the needs and existing features of the modern anesthesia system versus the needs of ventilatory performance? What are the obstacles in increasing this performance?

Professor Capdevila: One very important aspect is simplicity. The anesthesiologist has several things to do at the same time. The anesthesiologist needs to look at the ventilation mode, fluids to be given, anesthetic and neurological parameters, and all this in concordance with the surgical constraints, and patient positions at a given point in time. The settings must be simple to make on the Interface, no sub.menus, or sub/sub-menus! They shall not be done in this case! But there is also an aspect relating to the modern-day anesthesiologist's competence level and knowledge of ventilation.

They have extensive theoretical knowledge, however, most anesthesiologists are light-years away from using special ventilatory modes, studies have shown this. Only 20% of patients have a PEEP level set, even though it has been proven that not setting a PEEP level leads to atelectasis already during the induction phase! Setting a PEEP level in the morbidly obese patient according to the size and weight is adopted knowledge that is in use; however, an active level of PEEP, that is to say 5 to 9 cmH₂O, is still only given in 7% of patients, thus exposing them to atelectasis and complicating their post-operative condition and rehabilitation. There is really a cleavage between the possibilities offered by anesthesia units today and the application thereof by clinicians. Of 3000 patients, only 25 are put on Pressure Support mode. Why? Because many anesthesiologists still think that Pressure Support is only a weaning mode used primarily in the ICU. It is nevertheless used widely with laryngeal masks; we know this to be good practice. We also know that many small elderly ladies are under ventilated, whereas the morbidly obese patient is often over ventilated. The settings are not made correctly, due to a lack of knowledge in the field of ventilatory mechanics, dynamics and control. One ends up with "trivial" settings, or inadequate default settings.

Maquet has conducted a survey about anesthesia segments. They divided up the anesthetic acts into Routine, Complex and Complex Advanced. What are your thoughts about this?

Professor Capdevila: I think one should not address the anesthetic act as being routine, complex or complex advanced, but rather the peri-operative care which includes the anesthetic care as being so. There is no small anesthesia, we have already spoken of how a seemingly straightforward act can be complicated by a sudden ventilatory occurrence (asthma, laryngeal spasm or other). But this is a common question which we get from the Ministry of Health in France; we at the SFAR (Société Française d'Anesthésie et Réanimation) explain to them that every act can become complicated and can turn to being problematic very fast!

What would you like to see as a development in anesthesia systems to meet your ventilatory needs?

Professor Capdevila: An anesthesia ventilator must be able to deliver precise volumes with certain given pressures, anesthetic gases, whatever the patient's condition and surgical considerations. This is starting to become rapidly known as "normal ventilatory performance" in all existing units, from the small infant to the 250 kg patient. There are those exceptional cases – we have 3 cases a year – of the pre-term baby who has immature lungs, where we must bring in an ICU ventilator into the OR. But we manage most cases today. However, in the near future I would like to see target controlled ventilation with concentration objectives on all machines. Another development would be automatic FRC calculations which would give us a visual status of the patient's lungs, with its compliance issues with respect to rising resistance values. It would allow adequate ventilation in the morbidly obese, the COPD patient, infants, etc. That should be the future of high performance ventilation in anesthesia.

Do you believe that high ventilation performance in anesthesia is important in your area of speciality?

Professor Lönnqvist: Yes, I do believe that ventilation performance in anesthesia today must pretty well match the quality of ventilation in intensive care. The patients I have are children where we do at times, use a very specific mode of ventilation, called High Frequency Oscillation; this is exceptional and I don't think that it would be necessary for anesthesia ventilators to offer this mode. However, Pressure Support is a must. But there is more than ventilatory modes to speak of. My speciality includes the very smallest pre-term babies, weighing between 500gr-1000gr. Some of these babies are born with a defect which comprises a hole between the pulmonary artery and the aorta due to incomplete closure during foetal life; they have to undergo a procedure called "closing of the ductus" if they are to survive. One must be able to ventilate these small babies who have tidal volumes between 5 and 10 ml.

It is important to have access to a system capable of delivering such small volumes, while supplying with precision, inhalation gases. This combination can be a problem. We also have to provide anesthesia to patients coming from the ICU and who necessitate the same adequate ventilation during anesthesia as they receive in the ICU. This is a central question.

Are the current anesthesia systems you have adequate in supplying this level of ventilatory performance?

Professor Lönnqvist: Modern anesthesia ventilators offer good solutions for bigger patients all the way down to the full-term infant. The problems we encounter are when the babies are under 1500-2000gr; there exists today, no good alternative which can deliver good, precise ventilation with safety to this patient category. The SERVO 900-C has been used, even though it does not offer the more "modern" ventilation modes, because one can connect a separate fresh gas flow on the low-pressure inlet (usually, the high-pressure inlet is used), having the "overflow" of gases go out through the evacuation outlet. This has been a good solution, but there is the question of spare parts, which will be available for another 1 or 2 years, not more. The question of quality ventilation has to do with modes and precision of volume and pressure delivery. In pediatric anesthesia, Jackson-Reeves and other non-rebreathing systems work well. However, most anesthesia systems today are based on circle systems with re-breathing; most have solutions via outlets where one can connect Baines or Jackson-Rees. But this doesn't solve anything! Why? It is only a solution during induction of anesthesia with inhalation gases. It offers no solutions under the maintenance phase, where it happens that we are forced to hand-ventilate our patient. One uses completely other pressures in hand ventilation than with an anesthesia ventilator; however, should you measure this pressure with a manometer, one would nevertheless be well above values one would be willing to condone if it were being delivered by the ventilator! Hand ventilation is used during the aforementioned ductus repairs, and

there is no way one can get an objective reading of pressures in this case.

What problems are you confronted with on a daily basis?

Professor Lönnqvist: Our daily concerns in pediatric anesthesia often have to do with dead space volumes, due to bacterial filters, humidifiers and other additions, as well as with how to compensate compressible volumes in the machine. This latter problem can be solved by measuring the inspiratory and expiratory O_2 and CO_2 , as well as working with pressure-volume loops. The limitation of working with these loops is, however, that one measures pressures inside the breathing circuit and not inside the patient. One can look at the difference between these pressures by inserting a catheter into the trachea, this has been done, and one would see how enormous these differences are! In bigger patients, these differences are much smaller.

What problems can you be confronted with during certain special surgical procedures?

Professor Lönnqvist: One-lung ventilation can be a probing challenge in the small pre-term baby population. Double-lumen tubes are usually used

in older children and adults for this procedure, however, this solution does not exist for tiny babies. Catheters with a balloon to be blown up in the non-ventilated lung are used in this case, but these can move, allowing unwanted air into that lung, or even obstructing the airways entirely. Proper ventilation during endoscopic surgery of esophageal atresia is also very challenging.

Maquet has conducted a survey about anesthesia segments. They divided up the anesthetic acts into Routine, Complex and Complex Advanced. What are your thoughts about this?

Professor Lönnqvist: If you have a tiny patient and a complex procedure, this will entail anesthetic care which becomes complex advanced, for sure. If one has a very ill patient to treat, it is clear that even a so-called "routine" procedure will become extremely complex. The other aspect has to do with the development of older and older patients who are sicker than before, with less possibilities in their organ systems. This means that the "Complex" group will increase and even "overflow" into the "Complex Advanced" group. These are reasonable concepts. I guess we refer to general anesthesia; regional anesthesia patients belong to an entirely different group.

What functionalities would you like to see on anesthesia systems in the future?

Professor Lönnqvist: As I mentioned previously, it would be ideal if systems in general could address the tiny pre-term 500 gr baby. Otherwise, other gases such as helium and why not, xenon, could possibly have interesting applications. Even carbon monoxide in low doses, it is thought, could be of interest. Some studies have been done on small animals with a gas called " H_2S " (hydrogen sulphide) that have shown some very interesting results; how does it work? It blocks the mitochondria in the cell and causes it to diminish oxygen consumption, CO_2 production, as well as body temperature, making them go into hibernation, or "suspended animation". But in earlier phases of studies where nitric oxide blockers were administered to sepsis patients, one saw beneficial effects on low blood pressure by raising it, while causing interference with the immune response. Many of these patients died. This is an example to illustrate how important it is to have high respect for the different phases of research before administering medication or therapies to humans. Potency goes hand in hand with potent side-effects. Toxicity results in animals must be conclusive before one can conduct trials in humans. But these are, perhaps, "Star Trek" considerations. ■

Biography

Xavier Capdevila, MD, PhD

Anesthesiologist and Intensivist, as well as University Professor, Dr Capdevila has been working at the University Hospital of Montpellier in France (CHU) where he has been Head of the Department of Anesthesia and Intensive Care since 2001. On an institutional level, he is President of the Anesthetic Pole of the CHU, as well as President of the Scientific Committee of the SFAR (Societe Francaise d'Anesthesie et de Reanimation/French Association of Anesthesia and Intensive Care).

Dr Capdevila published a Science thesis in the Physiology of Respiration

"Implications of Prolonged mechanical ventilation on respiratory muscles impairment and patient's weaning from ventilator" and has worked both in the fields of intensive care and anesthesia, but became very interested in anesthesia about ten years ago. He began first by himself, then in collaboration with his colleague, Samir Jaber, MD, PhD, to look into the care of the patient in anesthesia from the points of view of the mechanics of respiration, ventilatory control and the optimization of ventilatory possibilities provided by these patients.

Xavier Capdevila has conducted and published extensive scientific research in the field of ventilatory

mechanics in anesthesia.

Per-Arne Lönnqvist, MD, PhD

Anesthesiologist and Intensivist since 1987, as well as Sweden's only Professor in Pediatric Anesthesiology (since September 2007), Dr Lönnqvist works as a pediatric anesthesiologist at Astrid Lindgren Children's Hospital.

Dr Lönnqvist has also spent a year at Portland's University Hospital, in Portland, Oregon, where he worked with both pediatric and adult anesthesia. He has been very active in scientific research in ventilation mechanics, as well as the use of nitric oxide, among other aspects.

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The screenshot shows the 'Critical Care News' website. At the top, the 'Critical Care News' logo is on the left, and the 'MAQUET' logo is on the right. The main content area features a large article titled 'Clinical application of NAVA - the ICU team perspective' with a photo of a doctor. To the left of this article is a sidebar with links like 'ARTICLES IN LATEST ISSUE', 'SEARCH TOPICS', and 'ABOUT CRITICAL CARE NEWS'. To the right is another sidebar with 'Latest News: New NAVA review articles in Spanish and German' and 'Case of the Month: New! NAVA in A 59 YEAR OLD WOMAN WITH SEVERE HEMOPTYSIS'. At the bottom of the main article, there's a section titled 'NAVA - translating research into clinical practice'.

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