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The Prince of Wales Hospital, Hong Kong



Intensive care physician participants from over 4 countries at the Lung Protective Symposium and Workshop in Hong Kong

Lung protective ventilation opportunities in critical care patients

For the past 19 years, Critical Care News has always maintained a focus on lung recruitment and lung protective ventilation strategies. There have been many developments since the landmark ARDS study by M Amato et al in NEJM 1998. In this issue, Dr Fernando Suarez Sipmann provides an excellent overview and observations of developments in lung recruitment during the past decade, which was presented at an intensive care symposium in Hong Kong.

Critical Care News has also been continually reporting about Neurally Adjusted Ventilatory Assist - NAVA, since 2006. Many of the physicians using NAVA that have been featured in earlier issues of the magazine have recently published scientific studies on NAVA. These include Dr Karl Erik Edberg and colleagues in CCN issue 13, September 2006 from Gothenburg, Sweden who have now published an observational study of NAVA in 21 children (*Pediatr Crit Care Med* 2009; Jul 9) and Drs Brendan O'Hare, Maureen Healy and colleagues in CCN issue 15, September 2007 from Dublin, Ireland, that have published a prospective crossover comparison of NAVA and Pressure Support in 16 pediatric and neonatal patients (*Pediatr Crit Care Med* 2009; Jul 9). The use of NAVA in congenital heart diseased infants as shared by Dr Limin Zhu and colleagues at Shanghai Children's Hospital was featured last summer in CCN issue 17, and they have recently published their experiences with NAVA in these infants undergoing cardiac surgery.

The list of scientific publications on NAVA and Edi monitoring continues to grow, as the methodology is now being applied by critical care clinicians in over 30 countries worldwide. The latest updated reference list of NAVA scientific publications may always be found at www.criticalcarenews.com.

Lung Protection by means of lung recruitment and NAVA – Hong Kong Symposium and Workshop

The third Lung Protection Symposium and Workshop at the Prince of Wales Hospital in Hong Kong was an educational opportunity for over 100 attending clinicians from Hong Kong, Macao, Taiwan and the People's Republic of China. The lecture faculty included internationally known physician and researcher Dr Fernando Suarez Sipmann from Madrid, who presented two different current views on protective ventilation – one of “permissive atelectasis” and the “Open Lung approach.” Dr Charles Gomersall, another internationally known speaker and researcher, lectured on Neurally Adjusted Ventilatory Assist. He highlighted the clinical application of NAVA, and the lung protective potential of patient-ventilator synchrony. He also presented a number of NAVA patient cases from his own experience, including intermittent dyspnea and Cheyne-Stokes.

The first annual NAVA Nordic Summit Meeting

Twenty-six intensive care clinicians from three countries gathered in Stockholm for the first annual NAVA Nordic Summit Meeting. The purpose of the meeting was to provide a forum to share NAVA clinical experiences and cases, and to build a foundation for sharing ideas and cooperation with NAVA in the future.

Intensivist Dr Lisa Seest Nielsen from Kölding, Denmark, shared experience of NAVA in adult patients. The regional Ryhov hospital of Jönköping, Sweden, started using NAVA in September 2008, and Dr Armela Khorassani shared cases and experience and data collected over 9 months, with over 22 NAVA patients ranging from 10 to 89 years of age. She described some of the benefits with NAVA experience to date to include avoidance of tracheotomy in 5 patients and probably shorter hospitalization in 7 of the 22 patients. Dr Ninna Gullberg of the PICU of Astrid Lindgren Children's Hospital in Stockholm shared her experiences of NAVA in many patient treatments, and presented a special case report of NAVA in a critically ill 6 week old infant.



Dr Jim Ruddy, Monklands Hospital, Scotland

Implementing NAVA and Edi monitoring as lung protective elements in a regional hospital ICU

The 6 bed ICU of Monklands Hospital near Glasgow, Scotland, treats a wide variety of almost 400 medical and surgical ICU patients each year. These challenges have been met by a staff of five intensive care consultants that have been implementing lung protective strategies on a routine basis. They implemented NAVA and Edi monitoring at the beginning of this year.

Their very first patient experience with NAVA was a worst-case scenario – a patient that had been on mechanical ventilation for 62 days. (See this NAVA patient case report at www.criticalcarenews.com) Intensive care physician Dr Jim Ruddy shares his observations and experiences of both NAVA and Edi monitoring, which are being utilized on a regular basis.



William Twaddle, RRT and Jagadeeshan Sunderram, MD in the Robert Wood Johnson MICU

Interdisciplinary implementation of NAVA at Robert Wood Johnson University Hospital

The award-winning Robert Wood Johnson University Hospital and

its associated Bristol-Myers-Squibb Children's Hospital have been at the forefront in implementing new innovations in patient care. The institution was among the very first in the United States to introduce NAVA to the Medical ICU, Surgical ICU, Cardiac ICU as well as the Pediatric and Neonatal ICUs. Members of interdisciplinary teams share their experiences, and some ideas and plans for the future.



Transporting patient from MR to PICU at Dartmouth-Hitchcock Medical Center

Implementation of a seamless solution for bedside quality ventilation therapy in critical care patient transports and MR

The internationally renowned and state-of-the-art Dartmouth-Hitchcock Medical Center in New Hampshire in the United States faces the challenges of caring for 85 critical care patients on a daily basis. The Respiratory Care department sought and found solutions to provide uninterrupted ventilation and continuity of care to all of these critical care patients, in all areas of the medical center, including the sickest and most fragile patients in the hospital.

Peri-operative ventilation - what criteria are important for the widest range of patients and why?

The final feature of this issue highlights the ideas and reflections of Dr Javier Garcia Fernandez of the La Paz University Hospital in Madrid. He discusses the importance of certain technical possibilities in anesthesia machines, enabling safe ventilation of a wide range of patients in the operating room. ■



Participants registering for the three day Lung Protection Symposium and Workshop

Lung Protection Symposium and Workshop Summary with focus on – Lung Recruitment and Neurally Adjusted Ventilatory Assist - NAVA

Over 100 participating physicians from Hong Kong, Macao, Taiwan, and the People's Republic of China attended a three day Lung Protection Symposium and Workshop at the Prince of Wales Hospital in Hong Kong in February, for an educational opportunity to learn about lung recruitment and NAVA.

The activity, which was the third Lung Protection Symposium hosted by the Prince of Wales Hospital in recent years, featured a faculty of globally renowned guest speakers including Dr Fernando Suarez Sipmann of the Fundación Jiménez Díaz Hospital in Madrid, and Dr Charles Gomersall of the Prince of Wales Hospital in Hong Kong.

The participants were welcomed officially by CM Leung, CEO of Maquet Hong Kong, who co-hosted the activity together with the Prince of Wales Hospital. The three day program featured lectures by the guest speaking faculty, followed by two days of hands-on workshop in the physiology laboratory.

Lung recruitment – the concepts, the practical approach, and ideas about how to improve the strategy at bedside

Fernando Suarez Sipmann of Hospital Fundación Jiménez Díaz in Madrid, has a primary interest in research in mechanical ventilation and respiratory physiology, and has been working in the areas of research and treatment of patients with lung recruitment since 1996. He introduced his presentations as lectures on lung protective ventilation, especially lung recruitment and PEEP as closely linked elements of a lung protective strategy. Dr Suarez Sipmann highlighted the classic pressure-volume curve in relation to ventilator induced lung injury as a frame about how application of mechanical ventilation has an impact on patient outcome. Theoretically, the PV curve shows all of the possibilities to ventilate a specific lung mechanically. Given the different combinations, exceedingly high volume or pressure in the right upper area of the curve, subjects the tissue to mechanical stress, with risk of rupture of alveolar walls. Ventilating at those pressures over time can aggravate respiratory failure. The other extreme is the region of low volume and pressures, down left where the lung tends to collapse. Mechanical ventilation forces bring several dangers in the collapsed region, principally stress by continuously opening and closing small airways and alveoli. Dr Suarez Sipmann highlighted the concept of ventilating ideally in the safe zone, i.e. away from the area of over distention and away from the collapsed zone.

Landmark lung recruitment study

Dr Suarez Sipmann referred to the authors that first introduced the term “lung protection” in clinical practice, in the study by Amato et al in 1998 in the New England Journal of Medicine, which was a turning point in mechanical ventilation. The authors combined all those concepts that were thought at that time to have a protective effect on the lung: to reduce tidal volume and plateau pressure allowing CO_2 to rise



Dr Fernando Suarez Sipmann of Madrid lectured on lung recruitment concepts and bedside strategy

preventing the lung from overdistention and to apply higher levels of PEEP based on the lower inflection point of the PV curve to minimize collapse, and putting all of these strategies together introducing the term of lung protective ventilation strategy. A reduction in mortality of up to 30% in patients in the protective strategy, compared to a conventional group in this study taught that the way the physician turns knobs on the ventilator, without the need of expensive drugs and treatments, has in itself an impact on patient's outcomes, according to Dr Suarez Sipmann.

He stated that this landmark study was followed by a number of other clinical studies that tried to reproduce the benefits of lung protective ventilation strategies, some with positive results, some negative. The most important one was by the NIH group in the NEJM, which is also called the ARDSNet trial. After enrolling 800 patients this study could demonstrate that simply adjusting one intervention – limiting the tidal volume – had a positive impact on patient's outcome.



Fernando Suarez Sipmann of Hospital Fundación Jiménez Díaz in Madrid

Protective ventilation – two different views

Dr Suarez Sipmann illustrated an example of a patient with ARDS with a CT scan showing aeration of upper non-dependent regions combined with extensive collapse in the dorsal dependent lung regions. This is the scenario for a heterogeneous distribution of ventilation with the boundary regions of aerated and collapsed regions, submitted to a high mechanical stress. He stated that when facing such a condition there are two different views of how to best manage this patient.

One current view may be termed as “permissive atelectasis”. This view is represented by the ARDSNet approach, where the ventilation strategy is

adapted to the aerated lung which due to its reduced size has been termed the baby lung. In this approach, it is recommended to reduce tidal volume to minimize overdistention but tolerate atelectasis, in the hope that the collapsed lung will recover over time and that the mechanical stress to the aerated lung can be minimized.

The other current view of managing this condition is what Dr Suarez Sipmann calls “the Open Lung approach”, which is a ventilation strategy aimed at actively restoring and maintaining the size of the ventilated lung. This current of understanding emphasizes that atelectasis is a pathological condition of the lung, per se harmful. Their presence results in poor oxygenation and mechanics, a more heterogeneous

distribution of tidal ventilation facilitating the overdistention of the aerated regions and promoting cyclic opening and closing of the boundary regions.

Importantly, both views aim at protecting the lung sharing the idea of limiting overdistention and tidal recruitment. In the Open Lung approach according to Dr Suarez Sipmann the major difference resides in the attempt to re-expand the collapsed lung by means of a recruitment maneuver and, specifically, in the use of PEEP which in such a strategy aims at stabilizing the recruited lung at end-expiration.

According to Dr Suarez Sipmann, only tidal volume limitation might not be enough to fully protect the lung from ventilation induced lung injury. Recent



Dr Suarez Sipmann has been involved with research and clinical application of lung recruitment maneuvers for many years

studies have shown that in a certain population of ARDS patients with higher amounts of collapse, tidal volume limitation as recommended by the ARDSnet approach resulted in areas of overdistention that appeared as areas of excessive aeration in CT scans at end-inspiration. Dr Suarez Sipmann referred to the study by Terragni et al in AJRCCM 2007, which illustrated that the two main mechanisms of ventilation induced lung injury, overdistention and tidal recruitment, could be present when applying the ARDSnet strategy. Therefore, we cannot assume that just limiting tidal volume to a certain extent, is enough to protect the lung in all patients, according to Dr Suarez Sipmann.

Definition of Lung Recruitment and procedure in theory

Dr Suarez Sipmann defined lung recruitment as the “re-expansion of

previously collapsed lung units by means of a brief controlled increase in transpulmonary pressure that results in an instantaneous change of the lung’s morphological and physiological condition”. He highlighted the concepts of a controlled increase in transpulmonary pressure, so that the physician is aware and in control at each step of the recruitment process.

In terms of re-expanding the lung and keeping it open, Dr Suarez Sipmann explained that the objective in this stage of recruitment is to shift ventilation from the inflation to the deflation limb of the PV relationship, i.e. establishing tidal ventilation in the outer deflation limb, around the point of maximum curvature, away from the collapse region. To achieve this the lung must first stay a brief period on the overdistention part of the curve, which is the only way to have access to the deflation portion where we want to establish ventilation. The minimum

level of PEEP must be found that is able to maintain tidal ventilation exactly at this region where collapse is avoided, according to Dr Suarez Sipmann.

Dr Suarez Sipmann illustrated changes in lung aeration in the recruitment procedure by means of a PV curve with inspiration and expiration of a sick ARDS patient, presented as CT scans, showing that setting ventilation along the inspiratory limb of the PV curve is associated to the the presence of collapse.

Dr Suarez Sipmann stated that if the areas of the lung that are closed are recovered and stabilized, they will increase the functional lung units improving gas exchange, and lung mechanics and more importantly contributes to minimize ventilation induced lung injury.

Dr Suarez Sipmann further illustrated the differences between establishing ventilation in the inflation as compared to the deflation PV limb. In the same patient with pulmonary ARDS, stepwise increases of 2 cm H₂O of PEEP while maintaining the same tidal volume and respiratory rate provided modest changes in oxygenation and compliance. However when PEEP steps were reduced after recruitment, maintaining the same ventilatory settings, there was a marked increase in oxygenation and compliance until the critical level of PEEP, the closing pressure was reached. This means that provided the patient can be effectively kept at this level, ventilation can be maintained at lower pressures and tidal volumes over the long term, in a better physiological condition, as presented by Dr Suarez Sipmann.

Different types of lung recruitment maneuvers?

Dr Suarez Sipmann stated that life is not simple at the bedside, and recruitment is not a simple procedure. There is an ongoing debate on which is the best recruitment maneuver, and published data on patient outcome are still not available. Since the landmark study by Amato et al in NEJM 1998, a remarkably long list of clinical studies on

lung recruitment have been published. According to Dr Suarez Sipmann, lung recruitment must be aimed at recruiting as much lung as possible to efficiently establish a lung protective strategy. When only transient improvements in oxygenation or lung mechanics are sought recruitment is reduced to a matter of “lung cosmetics” not a rational ventilation strategy. In such a context its use is not justified.

The group of Amato has published an important recent study (Borges, AJRCCM 2008) where many important concepts of lung recruitment were described, and where they validated the criterion of PaO₂ for defining a fully recruited lung in 25 ARDS patients. Whenever the PaO₂ was less than 350, there was significant collapse seen on the CT scan. A sequential recruitment maneuver with different levels of pressure was applied, and in patients who were fully recruited according to PaO₂ criteria (PaO₂/FiO₂ > 300 mmHg) and CT criteria also showed an increase in static compliance of 15%.

From the many published clinical studies describing different lung recruitment maneuvers, Dr Suarez Sipmann emphasized primarily three types of recruitment maneuvers, including the most frequently described in literature; the CPAP maneuver, or the so called 40/40 maneuver. Although the CPAP maneuver is the most frequently described in the literature, in up to 40-50% of the studies, Dr Suarez Sipmann believes that this is not the best strategy and should not be used. The patient remains in apnea and maximal level of pressures are maintained for the entire period significantly increasing the hemodynamic effects.

He strongly recommends a cycling recruitment maneuver in Pressure controlled ventilation. He described two types of cycling maneuvers, one called single pulse in Pressure Control ventilation, which is recommended for patients in less severe disease, for example in postoperative patients where pressures can be increased in two or three short steps to the recruitment level, generally in the range of 45 cm H₂O. The other cycling maneuver consists in

applying several sequential incremental PEEP steps, where the maneuver can be individualized to the particular patient. From baseline, a level of PEEP is selected to be high enough to maintain the entire recruited lung stable usually in the range of 25 cm H₂O in ARDS patients, being this the level of PEEP maintained along the recruitment sequence. As shown by Borges et al, different recruitment levels can then be explored by increasing PEEP in 5 cm H₂O steps above baseline while maintaining a fixed inspiratory pressure gradient for 2 minutes and returning to baseline PEEP after each step for evaluation. If Open Lung criteria have been obtained according to oxygenation and/or lung mechanics no further levels of pressure need to be explored. If not, the next level of inspiratory recruitment pressure is explored.

Dr Suarez Sipmann described time dependency as a factor, with the need to apply a certain amount of pressure for a certain amount of time. There is a minimum threshold pressure, the critical opening pressure, that has to be overcome otherwise no significant recruitment effect, independently of the time it is applied can be expected. As the lung gets sicker, more time and higher pressure are needed according to Dr Suarez Sipmann.

Higher pressures in ARDS to optimize lung recruitment in ARDS

Dr Suarez Sipmann illustrated the complexity of the situation in regard to the heterogeneity of the ARDS lung: lungs with significant collapse show a vertical gravitational gradient of opening pressures, which means that the alveoli at the dorsal, dependent region require much higher opening pressures than those in the ventral non-dependent regions.

Dr Suarez Sipmann referred to the recruitment pressures in ARDS lungs reported by Borges et al in the AJRCCM in the distribution of opening pressures in severe ARDS patients. Although over 50% were fully recruitable with pressures of 45 cm H₂O, the most diseased lungs required up to 60 cm H₂O in some

cases. According to Dr. Suarez Sipmann this study highlighted the importance of individualizing the recruitment pressures to each particular condition looking for the minimum pressure that results in full lung recruitment.

Dr Suarez Sipmann went on to illustrate the occurrence of important uncontrolled increases in airway pressures associated with routine interventions such as bagging. He showed an example where bagging pressures were recorded with repeated pressure peaks over 50 cm H₂O –with one of the bags resulting in pressures over 80 cm H₂O. The effects of handbagging, which occurs frequently in routine clinical practice, can sometimes result in much higher pressures than those reached during controlled recruitment maneuvers.

Lung recruitment side effects

Dr Suarez Sipmann reported that in a systematic review in AJRCCM 2008 of 40 different studies with over 1200 patients, in different situations submitted to lung recruitment, the number of side effects reported are surprisingly low either before, during or after the recruitment procedure. He stated that before pressurizing the patient, a good volemic status and a stable hemodynamic condition must be confirmed. He outlined that the hemodynamic effects of lung recruitment are mainly caused by a decreased venous return, increased right ventricular afterload and compromised left ventricular filling due to ventricular interdependence. The major effects include reduced cardiac output, and reduced systolic arterial pressure. “However, when performing a recruitment maneuver in a protocolized way most of the time these side effects during recruitment maneuvers are small in magnitude, preventable and self limited”, stated Dr Suarez Sipmann. He went on to explain how hemodynamics depends on lung condition and volemia. Dr Suarez Sipmann explained: “As compliance decreases, the transmission of alveolar pressure to the pulmonary circulation also decreases so that sicker patients needing higher recruitment pressures are more protected against hemodynamic side effects.



Mr Arne Lindy of Maquet Critical Care, thanking Dr Suarez Sipmann

Dr Suarez Sipmann outlined that the type of recruitment maneuver is an important factor in influencing the hemodynamic response. This was systematically assessed in an experimental study where different lung injury models were submitted to different recruitment maneuvers by Dr Marini's group. They could show that sustained inflation (the 40/40 maneuver), caused the most important decrease in cardiac output. Best tolerated was a cycling Pressure Control maneuver, with maximum decreases of 20 - 30% in cardiac output, which recovered to normal within a few minutes after the recruitment maneuver. Dr Suarez Sipmann stated "The 40/40 is not the best approach, the pressures are not enough, patients are apneic, so the thorax is continuously pressurized, causing major hemodynamic effects." In terms of hemodynamic management in lung recruitment, Dr Suarez Sipmann recommended a protocol of baseline ventilation, and an adequately resuscitated patient with stable cardiac output and mean arterial pressure. He outlined one of his ongoing studies, looking at

the impact of right ventricular and left ventricular output during recruitment maneuvers in ARDS patients.

Rationale for using Pressure Control ventilation during recruitment

According to Dr Suarez Sipmann, the rationale for using Pressure Control during recruitment includes the following factors:

- Strict control over inspiratory pressures
- No pendelluft phenomenon: new recruited regions always receive fresh gas from the ventilator
- Cycling allows pressure relief during expiration

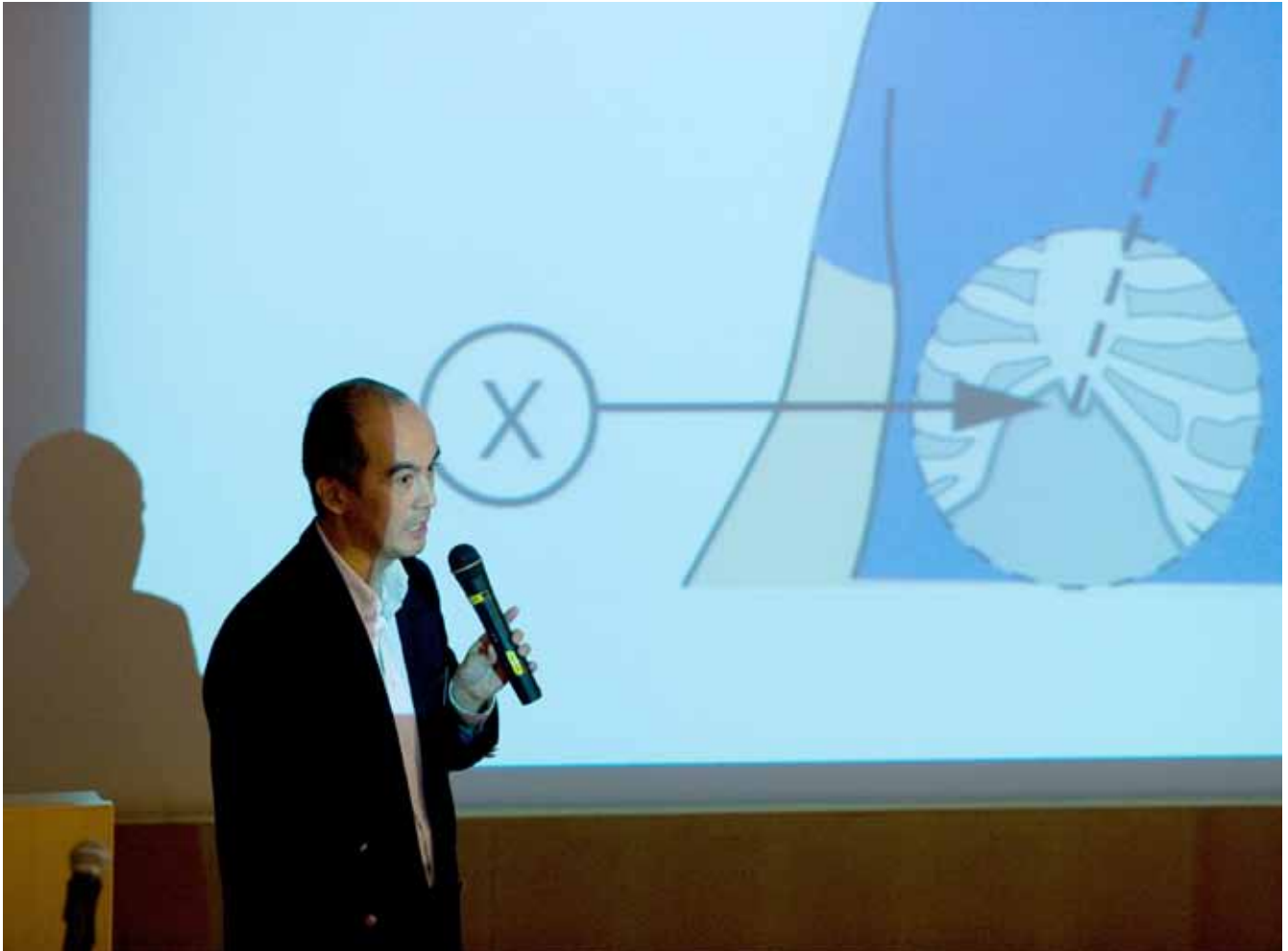
The role of PEEP

He went on to state that the NIH trial paid less attention to the importance of PEEP, which was selected as the lowest possible level for a needed FiO_2 to achieve a specific oxygenation target. He stated that this table has no physiologic rationale which is one of the major critiques to the NIH

-ARDSNet trial according to Dr Suarez.

Dr Suarez Sipmann also referred to 3 fairly recent studies focusing on high versus low PEEP; the ALVEOLI (U.S. study) reported in NEJM 2004, the LOVS study (Canada) reported in 2008, and the EXPRESS study from France, also reported in 2008 both in JAMA. He commented: "There are now three large randomized clinical trials that could not demonstrate a clear benefit of higher levels of PEEP on survival." There was however, a trend to a beneficial effect of the use of higher levels of PEEP and clear benefits on important secondary endpoints, that support the recommendation of using higher levels of PEEP. Except for the Express study, PEEP was selected according to a PEEP/ FiO_2 table, only looking at oxygenation. This resulted in a constantly higher plateau pressure in the high PEEP group as compared to the lower PEEP groups. According to Dr Suarez Sipmann the lack of control of the increase in plateau pressures may have offset the potential benefits of the use of higher PEEP in these studies.

Clinical application of Neurally Adjusted Ventilatory Assist – NAVA



Dr Charles Gomersall of the Intensive Care Department of the Prince of Wales Hospital in Hong Kong, presented the concept and clinical application of NAVA

Dr Charles Gomersall of the Intensive Care Department of the Prince of Wales Hospital in Hong Kong has been familiar with the clinical application of Neurally Adjusted Ventilatory Assist, or NAVA in his intensive care department since late 2007. He started his presentation by presenting the physiological concept of NAVA, where a patient's neural respiratory signals, or Edi – electrical activity of the diaphragm, were used to trigger the ventilator according to the patient's own requirements. Dr Gomersall outlined the differences in the concept of NAVA compared to conventional pneumatic mechanical ventilation by explaining: "Conventional ventilator technology uses a pressure drop or flow reversal to initiate

the assist delivered to the patient. With NAVA, the electrical discharge of the diaphragm is captured by an Edi catheter fitted with an electrode array. The signal is then passed to the ventilator, which executes both triggering and flow control in proportion to the received Edi signal."

Practical set up of NAVA

Dr Gomersall briefly reviewed the components needed for NAVA, consisting of ventilator, software, NAVA module, and Edi catheter with 10 electrodes. He reviewed the NEX measurement formula and procedure to estimate the insertion length of the Edi catheter needed. Dr

Gomersall went on to explain: "When the Edi catheter is in place, you see esophageal ECG – an added benefit of the Edi catheter. I am waiting for a broad complex tachycardia, so that I can say that I diagnosed a type of tachycardia from a nasogastric tube and ventilator. Verify the position of the Edi catheter by means of the ECG waveforms."

Dr Gomersall also presented information about what NAVA levels entail. He described the NAVA level as an amplification factor. In the NAVA mode the SERVO-i will amplify each Edi sample as determined by the set NAVA level, after the following formula: $P = \text{NAVA level} \times (\text{Edi signal} - \text{Edi min}) + \text{PEEP}$. The

amplification depends on the selected NAVA level and results in a smoothly rising pressure. The shape of the pressure curve mirrors the Edi signal until the Edi signal drops to 70% of peak Edi. The ventilator cycles to expiration, and the pressure will drop to the set PEEP level. Dr Gomersall explained: "Not only does NAVA give you a way of triggering the ventilator, the profile of the breath is determined by the patient's effort."

To address the question if NAVA unloads respiratory muscles, Dr Gomersall referred to the literature, where a study in healthy volunteers comparing 0 and high levels of NAVA support (Sinderby et al, *Chest* 2007; 131(13): 711-717), NAVA allows the patient to take the same tidal volume while making less effort, according to Dr Gomersall.

Dr Gomersall also showed data from a patient in his intensive care unit, where the NAVA level was 1.5 cm H₂O/ μ v, increasing the NAVA level to 3 cm H₂O/ μ v resulted in a reduction in Edi with maintained tidal volume. This indicates that the respiratory work was taken over from the patient by the ventilator.

Ventilatory dyssynchrony and its consequences

Dr Gomersall addressed the subject of ventilatory dyssynchrony and its consequences, referring to Thille et al (*Intensive Care Med* 2006; 32(10):1515-1522) where the authors studied 62 patients triggering the ventilator. They investigated the impact of dyssynchrony in assist controlled and Pressure Support ventilation. The main outcome of the study was that the length of mechanical ventilation was much extended in patients with dyssynchrony.

He summarized that from an outcome perspective, patients with an asynchrony index higher than 10% were likely to have a longer time on mechanical ventilation and a higher incidence of tracheostomy.

Does NAVA have an effect on asynchrony?

Dr Gomersall addressed this question

by presenting some of the original pre-clinical scientific studies, comparing NAVA and Pressure Support ventilation, in low, medium and high levels. He said: "It is difficult to set equivalent level of NAVA to Pressure Support, but if you used peak pressure, the waveforms are different, and pressure time curve is different in NAVA. Tidal volumes don't change much with NAVA. In terms of peak airway pressure and tidal volume there is a contrast between NAVA and Pressure Support modes," according to Dr Gomersall. "As you increase the NAVA level the peak airway pressure and the tidal volume doesn't change much. When you increase the inspiratory pressure level in Pressure Support, the peak airway pressure and tidal volumes increase markedly. Pressure time product of diaphragm or work of breathing of diaphragm, with NAVA as you increase level, the work goes down. With Pressure Support, it falls initially, but then rises."

In terms of trigger delay, with NAVA the trigger delay is not really a factor, as presented by Dr Gomersall. With Pressure Support the trigger delay increases as you increase the level of Pressure Support, reflecting hyperinflation induced trigger load. According to Dr Gomersall, the explanation is that what happens in Pressure Support is that as the pressure and therefore the tidal volume goes up there is more gas trapping, resulting in trigger delay. On one hand work of breathing decreases by increasing Pressure Support, on the other hand it is harder to trigger as Pressure Support levels are increased.

Human data

Dr Gomersall reviewed a study by Colombo et al consisting of 14 patients in Pressure Support and NAVA, with equivalent levels of Pressure Support and NAVA on maximum voluntary breaths. Edi was suppressed in Pressure Support compared to NAVA. In high levels of Pressure Support the triggering was not effective. Diaphragmatic activity in Pressure Support was found to be variable, and tidal volume to be constant in Pressure Support. In the same study NAVA provided variable

Edi and variable tidal volume, as the patient is controlling tidal volume much more effectively than in Pressure Support, according to Dr Gomersall.

He also stated that the grouped data from this study showed that neural inspiratory time does not change with level of support. "Inspiratory time increases in Pressure Support as you increase level of Pressure Support. Neural expiratory time and flow time goes up in Pressure Support. The reason for neural expiratory time increasing in increasing levels of Pressure Support, is that the inspiratory time is being artificially prolonged, the patient is unable to exhale when they desire, and expiration is delayed," as explained by Dr Gomersall.

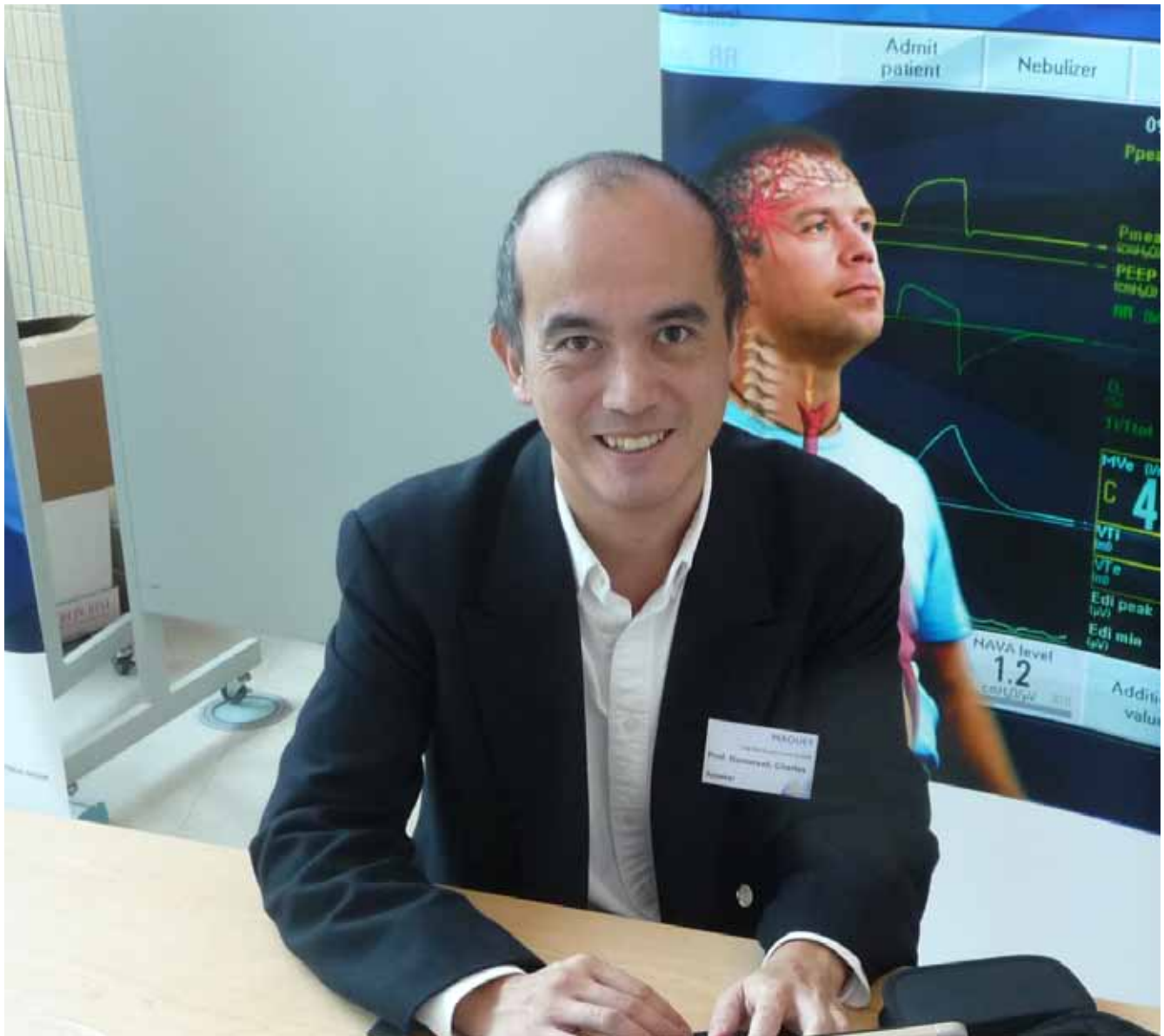
He summarized the study by stating that using a cut-off of asynchrony index greater than 10, five patients in the Pressure Support group were found to be asynchronous, but none in NAVA group.

NAVA experience in clinical practice

Dr Gomersall said that he did not yet have systematic data, and for this reason preferred to present a few patient cases from his practice.

Intermittent dyspnea

This patient case was an obese lady with neuropathia, who was difficult to wean and had intermittent dyspnea on Pressure Support ventilation. A bronchoscope was placed for observation, and in her trachea it was found to be moving inwards on inspiration. It revealed some collapse down to about one-third of its normal diameter. The patient had PEEP and Pressure Support, of which some was lost during bronchoscopy. The ICU team interpreted that there was signal trigger delay and that the ventilator did not deliver breaths as fast as the patient desired. When the patient was taken off the ventilator, no dyspnea occurred, however she was not strong enough to stay off the ventilator for a long period of time. She was started on NAVA, which obliterated trigger delays, and clinically



Dr Charles Gomersall

she was much more comfortable. The patient was now easily weaned on NAVA.

Cheyne-Stokes

Dr Gomersall and his colleagues have experienced some advantage with NAVA in the category of patients with Cheyne-Stokes respiration, with crescendo-decrescendo pattern of breathing in rate and depth, with periods of apnea. He explained: "If you ventilate these patients on Pressure Support, you get standard tidal volume for each time they trigger the ventilator. So instead of getting a crescendo and decrescendo in rate and depth, you get constant values, which

exacerbates the problem of apnea, so that the ventilator, even if set at max apnea time, goes into back-up ventilation, therefore it is difficult in getting the patient to breathe more. If you take these patients off the ventilator, the issue of apnea becomes less of a problem, but these patients are not able to tolerate spontaneous breathing for long periods of time. In this group, when we put in the Edi catheter and switch to NAVA, it is much easier to wean these patients, since they have control; the tidal volume is dependent on their respiratory effort."

Dr Gomersall also illustrated experience with examples of ventilation in PRVC,

with significant dyssynchrony between PRVC breaths and Edi and no correlation between PRVC breaths and attempts to breathe. He added "NAVA gets perfect synchrony in these patients. In a recent patient with a flow pattern that was odd, she was attempting to breathe between breaths with failure to trigger; perfect synchrony was obtained in switching to NAVA. Dr Gomersall concluded his presentation by summarizing that NAVA is a promising new mode of ventilation, simple to use, and will effectively off-load respiratory muscles. He stated that NAVA reduces dyssynchrony.

Hands-on physiology workshop and participant feedback



Some of the many workshop participants

The purpose of the workshop was to give the participants the opportunities to perform recruitment maneuvers while individualizing treatment to the specific lung, with extensive monitoring of the respiratory as well as the hemodynamic side. On the respiratory screen, the Open Lung tool, trends on time scale on pressures, inspiratory and expiratory tidal volumes, and the inspiratory dynamic compliance and tidal CO₂ elimination were utilized for lung protective recruitment maneuvers.

The workshop also gave the opportunity to observe electrical activity of the diaphragm by means of Edi signals and to monitor patient-ventilator synchrony by means of NAVA.

Critical Care News spoke with some of the participants of the lung protective symposium and workshop, to hear their feedback after the sessions.

Dr Dennis Kin Long Wong, Macao Government Conde de São Januário Hospital

I am an ICU physician and medical officer treating adult patients in a government hospital in Macau. I had read to prepare before coming here to join the two day lung protective course. We can have a real chance to practice here to consolidate our clinical knowledge, which is a nice opportunity for us.

When returning home after the workshop, will you be trying to do recruitment maneuvers?

Yes, I will definitely try, on ARDS patients and maybe ALI patients and some severe pneumonia patients to start out with. I will start with a few patients first, we have 10 beds in our ICU which is a general medical/surgical/neurological ICU. The symposium and workshop have been very good, I learned a lot. I would like to join similar courses in the future.



Dr Wong is Medical Officer at the Macao Government Hospital ICU



Dr Hsinkuo Kao and Mrs Shiu Hui Qua, from Taiwan

Intensivist Dr Hsinkuo Kao, and Mrs Shiu Hui Qua, Respiratory Therapist, Taiwan

Dr Kao: We work at the UGH hospital in Taipei, where we currently have a 30 bed ICU, which is on the way to increasing to 36 beds. It is a medical ICU; most patients belong to the medical care program.

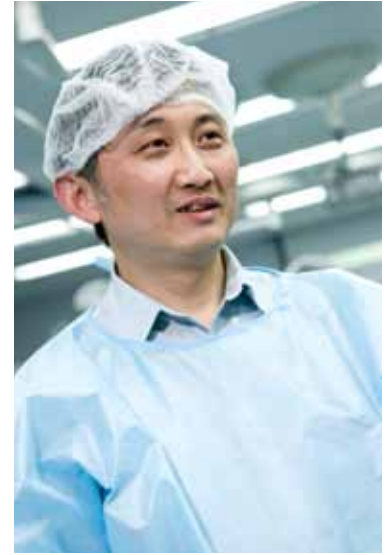
Are you familiar with lung recruitment procedures?

Dr Kao: Yes – we have had meetings about lung recruitment, and we perform these maneuvers in our patients, we select patients with ARDS and we look at hemodynamics as a major individual factor in performing the maneuvers. We know the patients conditions and the situation to stabilize, we perform the lung recruitment maneuvers and we check by chest x-ray. In our department, ARDS is often complicated by pneumonia, so that in these patients with pneumonia related ARDS we perform these maneuvers.

How will you teach your fellow respiratory therapists about lung recruitment?

Mrs. Qua: As Director of Respiratory Therapy, I have 40 RT therapists that report to me. We have education by coworkers but are more interested in this technique, and we need doctor approval to teach the technique, in order to support it and apply it. Education is the first step and we have other physicians that perform various types of recruitment maneuvers in our hospital, but we know we can monitor useful parameters with the Open Lung tool and dynamic compliance as a new element in our treatment practice. In the past we have perhaps performed lung recruitment by more traditional methods, but it was not apparent exactly what was happening to our patients, and there is more data today to support different methods than in the past.

Dr Kao: By using the Open Lung tool, I can see parameters that might help me to diagnose and understand the



Dr Zhou Suming of The People's Hospital of Jiangsu Province, PRC

results at bedside. This has been a very valuable workshop for us. We see the lung recruitment effects in ARDS patients today, but I think we are finding the value of recruitment maneuvers in other types of patients as well.

Zhou Suming, Director of ICU, The People's Hospital of Jiangsu Province, People's Republic of China

It was the first time I have seen lung recruitment maneuvers. We have SERVO-i in our ICU and sometimes we see ARDS patients, so that is the basis of my interest in attending this workshop. My intensive care unit is 10 beds, and it is a geriatric ICU, we see a lot of COPD, and sometimes we see surgical patients as well.

Are you interested in NAVA?

I think that has been the most interesting aspect of the workshop for me, it is very hard for us sometimes to wait for the ventilation to gather information; NAVA might give us information at bedside. With geriatric patients and issues in regard to sleep quality at night, NAVA might be an interesting opportunity for us in future. This information, as well as the lectures and questions and workshops have been very useful. ■

Biographies

Fernando Suarez Sipmann

conducted his initial Study of Medicine at the University of Navarra, Pamplona, Spain and earned his degree there in 1990. During the years of 1991 and 1996, he specialized in Intensive Care Medicine at the Fundación Jiménez Díaz University Hospital of the Universidad Autónoma in Madrid. Since then he has been working as a consultant in Intensive Care Medicine at the same institution.

He earned his PhD degree at the Department of Clinical Physiology of the University of Uppsala, Sweden in 2008. He is internationally known for his research in intensive care, is well-known within the lecture circuit, and has been a frequently invited speaker, main lecturer or chairman in international congresses, symposia and other venues during the past ten years.

Dr Charles Gomersall is Associate Professor of the Department of Anaesthesia and Intensive Care at the Chinese University of Hong Kong. He received his undergraduate training at the Westminster Medical School, University of London. His postgraduate training has taken place in internal medicine at St. George's Hospital, London, in anesthesia at St. Mary's Hospital in London, and in intensive care at the Prince of Wales Hospital in Hong Kong.

Charles Gomersall has conducted scientific research in special interest areas, which currently include triage, antibiotic pharmacokinetics and probiotics. He is currently Editor of ICU Web. This website for ICU healthcare professionals receives approximately 65000 visits per month. Charles Gomersall has also been initiator, editor and major author of BASIC (Basic Assessment and Support in Intensive Care), and the Very BASIC and Not So BASIC courses. He is also heavily involved in the CoBaTRICE project.

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Some of the many NAVA Nordic Summit meeting participants

Neurally Adjusted Ventilatory Assist: The first annual NAVA Nordic Summit Meeting

Twenty-six intensive care clinicians from over eight hospitals in three countries participated in the first NAVA Nordic Summit meeting in Solna, Sweden, in April. The purpose of the meeting was to provide an opportunity to share NAVA clinical experiences and cases, and to build bridges for ideas for future cooperation with NAVA, as presented by Claes Goderlöv of Maquet Nordic.

There was a range of experience with NAVA, from ICU departments that are just starting out, and units that have been using and gaining experience with NAVA as treatment methodology since the product became available in November, 2007. Experience in patient categories ranged from neonates to elderly patients. Participants were also updated about ongoing NAVA clinical studies and future developments. The one day summit meeting is intended to be held for NAVA users on an annual basis.

The twenty-six participants were welcomed by Thomas Lindström, MD of Maquet Nordic, who gave a brief presentation about the history of the SERVO ventilator, from the early 1970's to recent developments, such as the MR and NAVA applications in the SERVO-i ventilator.

The agenda for the meeting consisted of presentation of NAVA patient case experience from various Scandinavian hospitals. Dr Ninna Gullberg of the Astrid Lindgren Children's Hospital in Stockholm presented, from her unit with experience of 20 patients. Dr Amela Khorassani of Ryhov Hospital in Jönköping, Sweden presented the experience of NAVA in her adult patient ICU from an 8 month perspective, and Dr Lisa Seest Nielsen of Kölding Hospital, Denmark, where NAVA has been recently implemented, shared a few cases from their 10 patient collective experiences.

The meeting was moderated by Sylvia Göthberg, MD, PhD, pediatric intensive care physician from Queen Sylvia Hospital in Gothenburg, Sweden, and Arne Lindy of Maquet Critical Care.

Recent NAVA experience from Denmark in adult patients

Intensive care physician Lisa Seest Nielsen from Kölding in Denmark, described her ICU as an 8-10 bed medical unit for adult



Moderators Sylvia Göthberg, MD, PhD and Arne Lindy



ICU physician Dr Lisa Seest Nielsen from Kölding, Denmark

patients, who are often lightly sedated. NAVA had been implemented in the ICU a few months prior to the meeting, and she described two patient cases of interest that they have observed.

Case 1

The first patient was a 78 year old woman, admitted for pneumococcal-based pneumonia. The patient had been in hospital for over 2.5 months, and NAVA was utilized to wean this patient. Since the patient was ventilated conventionally for 2.5 months, there was a condition of hyperventilation and diaphragmatic atrophy. Initial settings included a NAVA level of 1.4 cm H₂O/ μ v, with tidal volumes of 750-800 ml. The Edi peak value was about 20 μ v. The NAVA level was adjusted down to 0.4 cm H₂O/ μ v to obtain tidal volumes of 350-400 ml, and an Edi peak of 75-80 μ v.

The patient was also being treated with hemodialysis as a complicated case with acidosis. The NAVA level was increased to 1.5 cm H₂O/ μ v with Edi max of 20-25 μ v and tidal volumes of 350-400 μ v. Dr Nielsen said that the strategy was to

decrease the NAVA level in increments of 0.2 cm H₂O/ μ v, as the diaphragmatic muscle regained strength. The strategy also succeeded by maintaining a very low PEEP of about 4, in order to titrate in relation to the acidosis.

Case 2

The second patient case reported by Dr Nielsen was a 55 year old woman with difficult respiratory patterns, who had been ventilated for a period of time with Pressure Control and Pressure Support ventilation, with significant hyperventilation. The Edi catheter was placed, and the Edi signals and irregular respiratory pattern were observed in switching from controlled ventilation to Pressure Support. NAVA was implemented, and as the sedation levels started to decrease, NAVA worked very well and the patient was able to be extubated without any difficulties at all. Dr Nielsen commented: "The patient weaned herself with no difficulties on NAVA, it was us physicians at bedside that disturbed the order of the process by switching between controlled and supportive modes, prior to NAVA."

Experience of NAVA at Ryhov Hospital, Jönköping, Sweden in 22 patients

The Ryhov Hospital of Jönköping is a regional hospital with 7 intensive care beds. Dr Armela Khorassani has been working with NAVA since it was implemented in September 2008. Together with Chief ICU Physician Peter Nordlund, she has collected data from 22 NAVA patients, between the ages of 10 and 89 years. These patients have had diagnoses such as pneumonia, pulmonary fibrosis, sepsis, peritonitis, diabetes, COPD and muscle hypotrophy. She presented the preliminary results of the data collection so far:

Total days in NAVA:	1-10
Average days in NAVA:	4-7
Total days of MV:	2-23
Average days of MV:	< 10 days

Benefits with NAVA:

- Tracheotomy was avoided in 5 patients.
- Probable shorter hospitalization in 7 patients.
- Edi led to diagnosis in 1 patient.

Difficulties with NAVA:

- Asynchrony alarms in 6 patients due to earlier software versions, but also deep sedation and high PEEP.
- No or little Edi signals in 3 patients, who had sedation difficulties due to cramping and anxiety, and required higher levels of sedation.
- NAVA did not work in 2 patients, Dr Khorassani observed that in patients with large hiatus hernia it is difficult to place the Edi catheter and get signals.

Complications due to NAVA:

- No complications have been observed to date.

Dr Khorassani went on to describe two NAVA patient cases, one of the early experiences and a more recent patient case that had been treated.

Case 1

The first NAVA case was an 80 year old woman, with respiratory difficulties, an ex-smoker who had fatigue and difficulty



Dr Armela Khorassani, of Ryhov Hospital in Jönköping, Sweden

to breathe in the past 6 months. In the two weeks prior to emergency admittance, she had increasing symptoms of an upper airway infection. When admitted she had saturation of 85%, respiratory rate of 33, pulse of 110 with sounds of secretions when auscultated. She was given oxygen by mask and antibiotics. However, she rapidly became worse, with an atypical pneumonia. A CT scan of her thorax showed findings of tree-in-bud which were interpreted as an airway infection and bronchiolitis. The lung x-ray showed different areas of infection.

As she had more difficulty to breathe, she was intubated, and the staff believed she would be difficult to ventilate, with a long period of mechanical ventilation. Her antibiotics were changed and increased. NAVA was implemented directly. Initially the patient was difficult to ventilate, followed by steady improvement. Dr Khorassani

presented the following results:

- NAVA for total of 7 days, of total of 8 days of MV
- Initial Edi 11 μv , end Edi 24 μv .
- Initial PEEP 16, end PEEP 4.
- Initial PIP 30, end PIP 11. Initial NAVA level 1.5 cm $\text{H}_2\text{O}/\mu\text{v}$, end NAVA level 0.2 cm $\text{H}_2\text{O}/\mu\text{v}$
- FiO_2 initially 45%, end FiO_2 30%.
- Initial PaO_2 14, end PaO_2 9.96.
- Initial $\text{PaO}_2/\text{FiO}_2$ ratio was 32, end $\text{PaO}_2/\text{FiO}_2$ ratio was 33.

There were some difficulties with asynchrony alarms, with very high Edi values on two occasions, bronchoscopy indicated stagnating secretion in the tube, which was switched to a larger tube.

The final result was summarized by Dr Khorassani as a diffuse pneumonia and pulmonary hypertension. The patient could be extubated without need for tracheotomy. The Edi was monitored after extubation, and the patient needed intermittent NIV for 2 days.

Case 2

The second NAVA patient case presented by Dr Khorassani was a 89 year old man, diabetic, with a recent history of orthopedic surgery in the hip and pelvis after an accidental fall. He was admitted into the emergency room with a rapid onset of loss of strength and motor function in his entire body, and a limited consciousness. He could not neurologically lift his legs. Upon CT examination of the brain there was no finding, however an X-ray of the neck revealed a fracture through the C7 area.

The patient was moved to the orthopedic clinic. An MR showed a degenerative tumor behind C1-C2 level which compromised bone marrow and caused edema in the area. This was judged to be the cause of the

recent rapid onset of degradation.

The patient was then transferred to the neurosurgical unit for cervical surgery with fixation from C6-Th1. Post-operatively, the patient had worsened neurologically with a complete tetraplegia. The patient was tracheotomized, after unsuccessful attempts to extubate, no respiratory drive and complete dependency upon mechanical ventilation.

The patient was moved to the ICU for continued mechanical ventilation and to observe for signs of neurological restitution. He was awake and communicating with miming and blinking upon admittance to the ICU. Initial ventilator settings were Pressure Control, PEEP 10, PIP 29, RR 15, with no sedation. NAVA was attempted in

this patient as a means to determine if the diaphragm was functioning. NAVA was only used for 2 days, since, due to a weak diaphragmatic signal and function, the ventilator switched back to back-up modes.

Dr Khorassani presented the final result as meddular damage with no phrenic activity, and little accessory muscle activity, the diagnosis was provided by NAVA and the Edi signal. The patient became vasoplegic and died. Utilizing NAVA and Edi in this case probably meant that this patient had a shorter period of hospitalization and suffering, according to Dr Khorassani, since receiving the diagnosis by another means, for example MR of the neck may have required more time on the unit.



Dr Armela Khorassani and colleagues



Dr Ninna Gullberg, of the PICU of Astrid Lindgren Children's Hospital, Stockholm, Sweden

Experience of NAVA at Astrid Lindgren Children's Hospital, Stockholm, Sweden

Dr Ninna Gullberg began her presentation by summarizing the experience with NAVA within her unit. NAVA was implemented in the autumn of 2008, and has since been used in 15 to 20 patient treatments. The case she presented was one of the first infants to be treated with NAVA during the autumn of 2008.

Infant NAVA case

A six week old infant was transferred to the ICU, ventilated and sedated, and treated with Sildenafil, Bosentan and Iloprost inhalations. The baby was treated with Pressure Control ventilation with settings PIP 25, PEEP 7, RR 50-60 and FiO_2 0.35-1.0. The baby was triggering but needed intermittent heavy sedation as the child did not tolerate to be awake. Since the child did not seem to be

tolerating the ventilator, he was switched to NAVA and immediately seemed much more settled. For this particular infant, Dr Gullberg stated that NAVA offered the possibility to be awake and more stable, with less problems of "near death episodes"; but with higher pressures, high tidal volume and high Edi signals.

The initial settings with NAVA were the same volumes installed with Edi signals, a NAVA level of $0.8 \text{ cm H}_2\text{O}/\mu\text{v}$, while the child was still under sedation. As the child awoke, pressure was limited and with a low respiratory rate, the NAVA level was adjusted to $1.4 \text{ cm H}_2\text{O}/\mu\text{v}$ and the Edi signal decreased but the alarm limits were a limitation, due to an older version of NAVA software. Despite the alarms, the child was awake, seemed to be improved and the blood gases looked good.

As the child was improving it was decided to make an extubation trial, which resulted in immediate failure.

There was high airway obstruction, and a tracheotomy was made, and CPR given in connection with bronchoscopy. Postoperatively the child was returned to Pressure Control ventilation, although with frequent recurring "episodes". After switching back to NAVA, the child seemed more stable again. Cause and effect were discussed, a general worsening situation perhaps due to sepsis, according to Dr Gullberg, with a vicious cycle of Pressure Control and episodes. The child seemed to do much better when switched to NAVA, however with the older software version alarms it became a bit of a department joke; "The baby had a hard time to live without NAVA, but the staff had a hard time to live with it!" said Dr Gullberg.

The staff determined that more investigation was needed to determine the cause of the high pressures, the high Edi signals, if this was due to the long period of ventilatory treatment or diaphragmatic function.



Screen values of infant treated with NAVA at Astrid Lindgren Children's Hospital

Upon a new failure to wean, an MRI angio was made and found no perfusion of the right lung. Thereafter, bronchoscopy indicated intermittent obstruction of the main lung bronchus which was compressed by the right atrium. A V/Q scint confirmed that the right lung was better ventilated while the left lung was being perfused but intermittently not ventilated.

After these investigations, there were extensive national and international discussions regarding possible treatment for this severe situation. Thorax surgeons from the University Hospital of Lund, and specialists from Stockholm and Great Ormond Street Hospital in London were consulted. It was determined that there would be no chance to win any significant time by any means, and that no treatment was available for this case. Palliative care was initiated until the infant passed away.

Dr Gullberg summarized the experience of NAVA in this patient situation:

- NAVA provided time to explore options
- NAVA provided comfort and:
 - A relationship between the infant and the parents
 - Some joy in a short life; between crises, NAVA allowed the infant to be awake and to laugh and smile when trying mango puree for the first time.
 - Knowledge for the future

Dr Gullberg ended her presentation by saying that this patient had been on NAVA for an extended period of time with no symptom of thoracic involvement, and the limitation of NAVA was not the NAVA level but the alarm settings in the older software versions.

A final presentation was made showing milestones in development since the NAVA application for invasive use was released for sale in November 2007. A number of clinical studies were summarized that are currently ongoing with NAVA:

- Patient-ventilator synchrony
- Comparing NAVA and Pressure Support
- Sleep studies
- Sedation studies
- Studies of NAVA and hemodynamics
- Local and regional NAVA studies that are currently generating scientific abstracts.

Educational resources currently available for NAVA were reviewed, consisting of an e-learning package, a study guide, tutorials, a pocket guide, and NAVA interviews, lectures and patient case reports located in www.criticalcarenews.com.



Dr Rory Mackenzie, Clinical Director and Consultant Anaesthetist; Dr Sanjeev Chohan, Consultant Anaesthetist; Dr David Clough, Consultant Anaesthetist, and Dr Jim Ruddy, Consultant Anaesthetist/Intensivist have all been gaining experience with NAVA

Implementing NAVA and Edi monitoring as lung protective elements in a regional hospital ICU

Monklands Hospital on the outskirts of Glasgow in Lanarkshire, Scotland is a district general hospital with 521 inpatient beds. Monklands Hospital provides the Lanarkshire district patients with renal care, an emergency department as well as inpatient services for ENT, dermatology and communicable disease.

This means that the six bed intensive care department of Monklands Hospital treats a wide variety of between 360 and 380 medical and surgical ICU patients a year. These ICU patient challenges are met by five intensive care consultants and 26 critical care nurses, who are implementing lung protective ventilatory strategies on a routine basis. The ICU staff members of Monklands Hospital recently implemented Neurally Adjusted Ventilatory Assist – NAVA as well as Edi monitoring in their unit. They became positive to this new methodology after experiencing it in a worst-case scenario, with a patient that had been on mechanical ventilation for 62 days. Critical Care News spoke with Dr Jim Ruddy to hear of their experiences and observations.



Dr Jim Ruddy at patient bedside

Can you describe the primary factors and process leading to the decision to investigate and implement NAVA in this ICU?

Dr Jim Ruddy: It was the fact that we were changing our ventilator fleet, but also the fact that many of us were curious about NAVA, and are wondering where its niche is going to be. Quite a few of us here have an interest in lung recruitment maneuvers and ventilator strategies, it seemed that this package of the ventilator with options for lung recruitment and NAVA gave us the opportunity to combine recruitment with weaning opportunities as a lung protective package.

When did you have your first patient experience with NAVA?

Our first case was the patient case that we had in the beginning of the year, about 5 months ago, which turned out to be a worst case scenario for a 25 year old patient with severe pneumonia, who developed polyneuropathy, sepsis, ARDS, renal failure and so many complications that we were constantly afraid of losing her. She was in the ICU for 100 days, and it was one of those cases where everything went from bad to worse. We were able to wean her off over a month of HFO with the help of NAVA. It worked an absolute treat, and made believers of us all here. Since then we

have treated about 10 patients with NAVA. *(Editor Note: this NAVA patient case report will be published and located on www.criticalcarenews.com).*

How routinely is NAVA used in the ICU?

We have NAVA at every bedside but we only have 2 Edi modules, which is enough at a unit of this size of 6 ICU beds. That is enough for the potential use of NAVA on a weekly basis, with the capability available for all ventilators. At the current time, we have experienced an average of 1 or 2 patients a month on NAVA.

Are there specific staff members using NAVA, or has all the general ICU staff received training?

Training is an ongoing process, and we conducted initial training for key users, and we have been educating the rest of the staff in succession ever since. The trainees that are interested in intensive care are quite keen on learning NAVA; they see it as a useful knowledge base to mention when they go on to train at other intensive care units and hospitals. That is spreading the news in a good way as well, since the trainees are seeing what could be useful in monitoring Edi; is it high or low, or affected by sedation, and in conventional modes as well as NAVA. It is quite nice that the interest from the trainees can flow from the bottom up when they go to other institutions. We conducted a study day as well, where we offered NAVA training sessions to staff in all the intensive care units in Lanarkshire. All of the critical care nurses got insight into NAVA and why we are using it here.

Who within the ICU is responsible for insertion of the Edi catheter and who is responsible for placement verification and use of the Edi catheter?

We consultants change the Edi catheter, place and verify it, unless there is a trainee on the unit that would like to learn. This is about the easiest part of the procedure, to place the Edi catheter and verify placement by means of the esophageal ECG signals.



Dr Jim Ruddy

Is monitoring of the Edi signal used in conventional ventilatory modes or in stand-by?

In terms of monitoring Edi in stand-by on patients that have been weaned but not yet extubated, we have not tried this yet, but it may well be if the work of breathing correlates with the Edi peak, we can conclude that the patient is getting tired and may need to go back on the ventilator.

With regard to monitoring of Edi signal in conventional modes, in the patient presented in our case report, this girl had a severe critical polyneuropathy, probably the worse I have seen, she couldn't lift her hands up. Even on the HFO, she would make respiratory motions but she was so weak she would not interfere with the oscillation. In weaning her, we thought that since she was making these

movements or attempts that it might be helpful to measure her Edi, which would give us a chance to gauge her level of support so much more closely than any other conventional means of monitoring. While she was on the oscillator, we noted that she was making attempts to breathe, and her Edi was in the 70-75-78 μV range. She clearly wanted to breathe, but did not have the diaphragmatic muscle power to do that. From this first patient, it has been actually quite useful to think of Edi monitoring in this perspective, of diaphragmatic monitoring, even in conventional modes. We also had a patient who we suspected might have a primary neurological insult, such as a brain stem injury, and we placed an Edi catheter to see if she actually had any activity from her phrenic nerve, or was making respiratory effort. Interestingly, her activity was minimal; her Edi

Ppeak was only about 2 μV which again caused us to believe that her breathing center was impaired. We have also had the usual type of patients where we wanted to see if NAVA could improve their ventilator dyssynchrony and Edi monitoring gives us the possibility to see the diaphragm activity and synchrony in conventional modes and in NAVA.

What is the average time on NAVA?

From our experience in hard to wean patients so far, it is difficult to say. I would say that we will trial it in the category of difficult to wean patients in 2 or 3 days to see if it will make a difference. If it is making a difference, we will carry on until we must change the Edi catheter. We then switch them briefly back to the equivalent Pressure Support mode, to see how their NAVA values are corresponding with that.

Does the team do a follow-up or review of the progress of each NAVA patient case?

Certainly, we are fortunate to have a tight knit consultant group. We discuss the individual management of all patients here on a regular basis. On top of this we consult each other in regard to NAVA. If there are consultants with less NAVA experience, but they see a patient that they think might benefit, they usually discuss together with other colleagues that have more experience, prior to placing the Edi catheter. There is a lot of positive feedback in general on the unit. We are quite unified in all things we do, which is great for a new therapy, it means that the enthusiasm is there all the time, we are quite lucky that way.

What in your opinion are the specific elements or factors needed in order to implement NAVA on a routine basis? What is most important to think about when implementing NAVA?

You've got to be enthusiastic about it. I think it is helpful to be someone who is interested in the concept, and what it may potentially provide, not necessarily what it is giving at the present. I think

people still are not clear on that, in our department we are really interested to see how NAVA will help us in the area of sedation and sedation-related issues. We think that in giving sedation breaks and spontaneous breathing trials, that maybe the Edi will help us to gauge the depth of sedation used in the unit. And Edi monitoring is fairly non-invasive; a nasogastric tube usually goes down anyway, so we believe that the additional information provided by Edi will hopefully decrease ventilator time, decrease length of stay, and decrease costs, which can only be a good thing. We do not know yet how NAVA or Edi monitoring will deliver on these variables, but I think one must have the enthusiasm to realize this is a new novel way of getting to the heart of what is controlling the respiratory cycle. I think, to improve patient synchrony and perhaps avoid sedation or deep sedation to do that, can only be positive. If you believe in the concept, then that is all you have to do, and be keen to learn about it and teach others as you go.

We have a busy unit, with a lot of ventilated cases, and we have probably the worst deprivation in Europe in this region, our co-morbidities are enormous; alcohol consumption, smoking, drug use, unemployment, poor housing, and poor diet. In the east end of Glasgow and Larnarkshire, we do have a population with a high rate of ischemic heart disease; male life expectancy is less than other regions in Europe. If NAVA and Edi monitoring can help us to improve these patient outcomes in any way in intensive care, it is good.

Do you think that this ICU will be expanding the use of NAVA in future?

Right now, we see the opportunity for NAVA in the hard to wean patient category. For complex cases, these are the NAVA candidates we see: long stayers, difficulty in weaning, medical patients with a number of different co-morbidities, which is where we find benefit at present. NAVA provides us with the next step for the patient to get them off the conventional ventilator. In terms of the oscillated patient, we think that NAVA was elementary to get her off the HFO and into weaning.

Which types of patient categories are you most interested in gaining more NAVA experience with, and why?

Acute brain injury, prolonged weaning, we used it in a high spinal cord injury, but that was at C5 and it gave a good signal without problems. I don't think we are thinking about new patient categories for NAVA, rather expanding the use to look at things like sedation levels. We are keen to use Edi monitoring to see what happens in patients that may have suffered brain stem infarct or edema. We did have one case of a patient where I wanted to know what the respiratory center was doing. Edi monitoring was

valuable to help us determine that this case was brain stem dead. We have used NAVA in the hard to wean patient category, however Edi monitoring provides opportunities in many different areas. The other monitoring opportunities we are interested in are depth of sedation, and sedation scoring. Titrating sedation by protocol with help of Edi monitoring and NAVA can have long term benefits, and avoiding delirium in patients can have long term benefits. Maybe the Edi might reflect another way of assisting the patient level of sedation, or avoiding diaphragm disuse atrophy, which may be related to sedation levels.



Dr Sanjeev Chohan, Consultant Anaesthetist, and Unit Sister Isabel Paterson

Biographies

Dr James Patrick Ruddy attended university at Edinburgh Medical School from 1986-1991, with distinctions in Obstetrics and Gynaecology and obtained the degree of M.B.Ch.B in 1991. His post-graduate degrees include FRCA in 2001, ALS, ATLS, and PALS: Provider in 2005. Dr Ruddy was awarded the Scottish Intensive Caer Society/West of Scotland Intensive Care Society Travelling Fellowship in 2005. He obtained dual C.C.T. in Intensive Care Medicine/Anaesthetics in 2006.

Dr Jim Ruddy is currently Secretary of the West of Scotland Intensive

Care Society and Lead Audit Consultant for Intensive Care Medicine Monklands Hospital together with the lead for Research. He is also Clinical Lead for Organ Transplantation in Lanarkshire. Dr Ruddy is also principle investigator for the "TRAPPHIC" study (Prophylactic Aciclovir in ICU) and has also recently been appointed Senior Clinical Lecturer in Intensive Care Medicine and Anaesthesia from the University of Glasgow.

Dr Ruddy is currently employed as Consultant in Intensive Care Medicine and Anaesthesia at Monklands Hospital, Airdrie, Scotland.



William Twaddle, RRT and Jagadeeshan Sunderram, MD at bedside with MICU patient

Interdisciplinary implementation of Neurally Adjusted Ventilatory Assist – Robert Wood Johnson University Hospital

The award-winning Robert Wood Johnson University Hospital and its associated Bristol-Myers Squibb Children's Hospital have been at the forefront in implementing new innovations in patient care. They have been ranked among the top 50 in Cardiac and Respiratory Services in the US by US News and World Report for the past two years.

The institution was among the very first in the United States to introduce Neurally Adjusted Ventilatory Assist, or NAVA to the Medical ICU, Surgical ICU, Cardiac ICU as well as the Pediatric ICU and Neonatal ICU. Critical Care News spoke with members of the interdisciplinary teams to hear about their experiences with NAVA, and plans for the future.

Gaining experience with NAVA in the neuro and cardiac units of the surgical ICU

Kumar DeZoysa, who is surgical clinical care coordinator, has been working within Robert Wood Johnson University Hospital for over 20 years, and has seen implementation of a number of ventilatory modes during that time span. He describes his experiences and impressions: "When NAVA became available to the US, we were one of 4 centers to begin to implement it. I am very excited about NAVA because I think it is the future within respiratory care."

"Our first case was a cardiac surgery patient, and we learned a lot from him. The patient was paralyzed and sedated, and it was tumultuous, a CABG surgery. We did not get good Edi signals to start out with, but it was a learning experience."

"Each NAVA patient was a memorable experience, but probably the most memorable experience was a patient who presented with chest pain in the emergency room. He was transferred to the floor, and the patient coded while being transferred. They intubated him and brought him down and for the next two weeks he was considered a failure to wean patient. We had two major disciplines involved in the case, pulmonary and cardiology services. Each conflicted in the diagnosis. Pulmonary insisted that it was cardiac etiology that kept the patient from being weaned; cardiology insisted it was a pulmonary issue. The attending intensivist who was a pulmonologist requested that an Edi catheter be placed so we could monitor the Edi during the weaning process. The patient did not demonstrate any increasing Edi, which the physician implied was correlated to no increase of work of breathing, so cardiac insistence that this failure to wean was due to pulmonary etiology was ruled out. The Edi provided information that we would not have otherwise."

Kumar DeZoysa sees a role for NAVA as well as Edi monitoring in NAVA and in conventional ventilation modes in future: "I think there are a few things that will be developing in the future:



Kumar DeZoysa, RRT, is Surgical Clinical Care Coordinator at Robert Wood Johnson

amounts of tidal volume and rates as prescribed by the Edi signals will become more acceptable, as well as the amount of PEEP that will be prescribed by the patient Edi signals. Once that is established, the future is set. Hospitals generally use inadequate PEEP, and once we start using optimal PEEP, patients will recover faster, we will see patients leaving the unit and the hospital faster, all of those things will fall into place. Right now, everyone prescribes a standard PEEP level, which may not be right for every patient. In general, we are not giving the PEEP required, so patients struggle with a lot of tension

on the backbone and a lot of work of breathing, with difficulties to wean."

Kumar DeZoysa regards every patient admitted to the ICU as a potential candidate for Edi monitoring and NAVA. He also regards NAVA as a generational shift in ventilation therapy: "The analogy we draw is the Swan-Ganz catheter to the heart is what the Edi catheter is to the lung. What did we have to monitor the lung prior to this? We only had x-rays, blood gases, and respiratory rates. I do encourage anyone in respiratory care to learn about NAVA and use it when possible."



Medical Director Jagadeeshan Sunderram, MD, shared his experiences with NAVA in MICU and CCU patients

NAVA in the MICU and the CCU at Robert Wood Johnson University Hospital

Dr Jagadeeshan Sunderram is Medical Director and head of the Medical Intensive Care Unit with 16 beds and overflow Critical Care Unit with 15 beds since 2002. He has also been a member of the faculty of the Robert Wood Johnson Medical School since 1999. When he first heard about the possibility to implement NAVA within the unit, it was not a totally foreign concept to him. "My research actually was implanting diaphragmatic EMG electrodes and measuring neural output directly in animal models, so obviously that piqued my interest in NAVA."

"We saw our first NAVA patient about a year ago, which was a patient overflow from the MICU to CCU, a case of failure to wean. The question was if there was a cardiac element to his failure to wean, or was it a problem with strength? I thought he would be a good candidate for NAVA, which would assist us to differentiate the two. That was our first start."

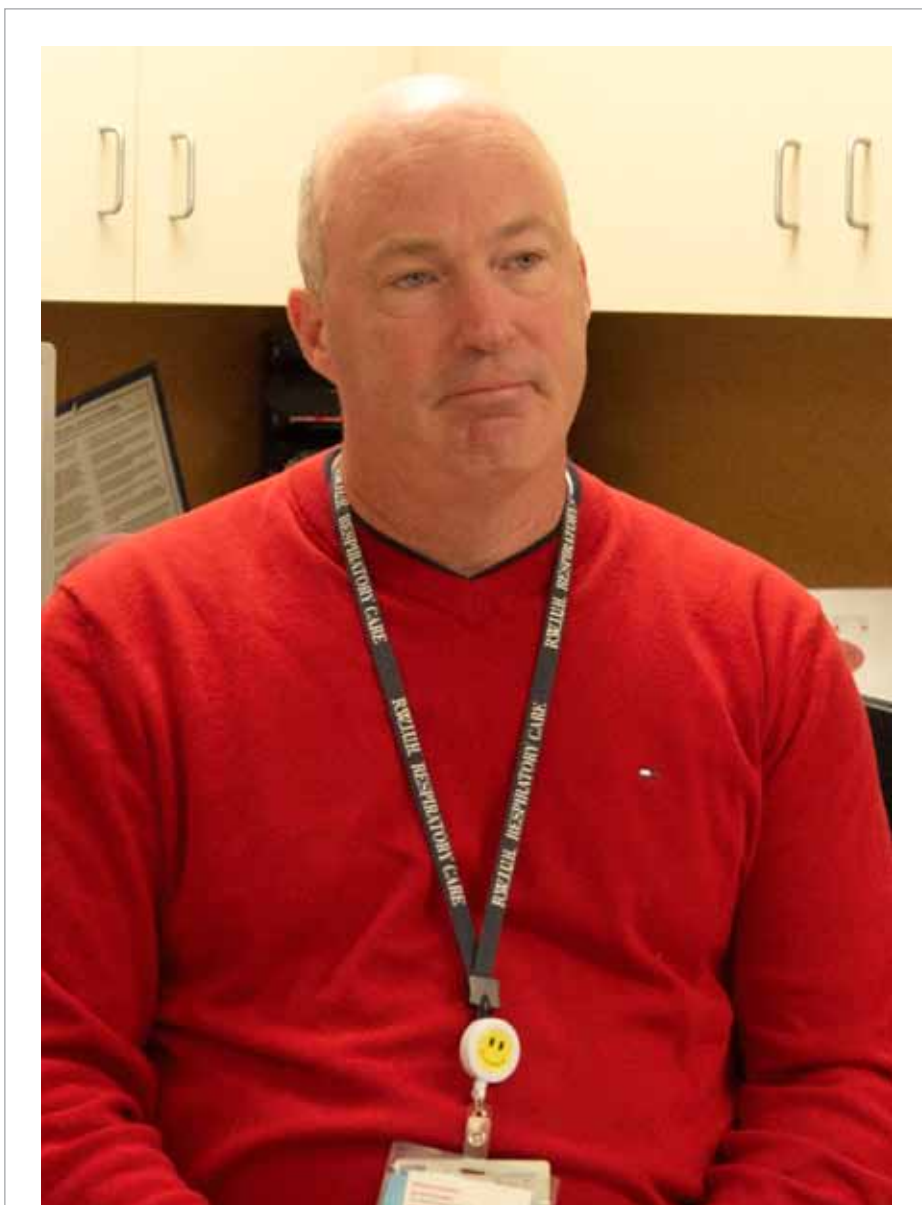
"It was interesting with the Edi catheter detecting the diaphragmatic effort, and as we monitored the Edi we were able to see a cardiac issue that led to his inability to get off the ventilator, and once that was fixed, he was weaned. NAVA helped us to distinguish if it was an issue of heart failure or strength."

Dr Sunderram sees a role for NAVA particularly in the failure to wean category, which he estimates to be about 10% of patients with persistent respiratory failure. "The other 90 percent of our patients are extubated within 2 days of their intubation, on average. It is the ones that do not wean successfully that we suspect may have an issue of ventilator dyssynchrony, impaired drive or strength, or a cardiac versus lung related issue, where NAVA is able to help us and we use NAVA in these situations," explains Dr Sunderram. He describes another NAVA patient case: "We have had a situation in another patient where he was transferred from another hospital due to failure to wean, with repeated episodes of hypercapnia and respiratory

failure and we did not know the cause of that. We decided to place an Edi catheter so we could better understand what was going on and we could see what was happening with his diaphragmatic status and ventilator synchrony. He had multiple infiltrates, and heart issues, among other complications. When we placed the Edi catheter we could see that he was in total synchrony with the ventilator, his diaphragm was working fine, and within a couple of days we were able to extubate him without a problem. NAVA really gave us an insight into his problem, and his hypercapnic respiratory failure turned out to be more of an issue of cardiac loading that needed fixing.”

Dr Sunderram states that the educational effort for NAVA and Edi monitoring is an ongoing process of experience by doing. “Every patient on NAVA gives us a learning opportunity, and we work together and review Edi monitoring during rounds.” He also states that in the difficult to wean category of patients, such as COPD, patients with neuromuscular weakness, patients with issues of drive or stroke and/or cardiac problems are particularly interesting in regard to NAVA: “Those are the patients that if they stay on the ventilator for a longer period of time, we start to have a difficult time discerning the physiology behind their failure to get off the ventilator. The more ventilator support ICU patients are given, the greater potential for diaphragmatic muscle atrophy. I think NAVA is a very valuable tool for us to understand their diaphragmatic effort, issues of drive and strength versus load, and to separate them and to treat them accordingly. I see a clear benefit for NAVA in this group of patients.”

William Twaddle, who is clinical coordinator for the MICU, and CCU at Robert Wood Johnson University Hospital has been working in this capacity for the past few years, and has been working at the hospital for more than 20 years as a respiratory care staff member. He is very excited about NAVA, and clearly recalls his first NAVA experiences in the MICU: “Our first patient was a tough patient. We wanted to use it on a COPD patient to start out with, and we had a physician who said to try it on a bad asthmatic.



William Twaddle, RRT, is MICU and CCU Clinical Coordinator at Robert Wood Johnson

Our experience with that was actually very good, since we saw all kinds of different and new things. We saw by the Edi signal that the patient was still in status asthmaticus, and was not ready for weaning. The Edi catheter was in for a while and we monitored and saw when the patient was ready to wean. It was a very valuable learning experience for us. That maybe should have been our fifth patient, but was our first which was good since it was more challenging and we learned so much in the process.”

William Twaddle says that Edi monitoring is also valuable in conventional ventilation modes: “If we can get them to NAVA, we want to try, since we want them

to be spontaneously breathing. If I have to work with them, depending on the patient response, we look at the Edi signal to take workload off, to put workload on, we look at Edi to see if they are tolerating and when they are failing.”

He describes the Edi catheter insertion and placement procedure: “When it comes to Edi catheter insertion, it is a nursing process here, per hospital policy. The nurses verify placement as a nasogastric tube, and we verify placement as an Edi catheter with the preview screen and the ECG readings, and we do tend to reposition slightly if needed for the Edi signals.”



Dana Saporito, RRT is Clinical Coordinator of the NICU at Bristol-Myers Squibb Children's Hospital of Robert Wood Johnson University Hospital

Experience transitioning from jet ventilation to NAVA in the NICU

Neonatal Intensive Care Unit Clinical Coordinator **Dana Saporito** has seen NAVA in two infants with bronchopulmonary dysplasia patients, which were patients of attending neonatal physician Dr Mehta. She describes these cases: "Both of the patients were difficult to wean, but one was more difficult than the other to wean from the jet ventilator. One baby who we thought would be a candidate was born on December 24, and he had a week of conventional ventilation, after two weeks we tried to wean him but at every weaning attempt we saw his CO₂ rise into the 70s and 80s. Dr Mehta had read about NAVA and wanted to try it. After we started NAVA in this baby, the very first blood gas we got back was phenomenal. The improvement was pretty instantaneous. The baby

was on NAVA for five days and he was doing wonderfully. We were planning to extubate him but he had a seizure."

"Because of what we saw in this patient, we decided to try NAVA on another difficult to wean patient that was on conventional ventilation on a baby ventilator by another manufacturer. We inserted and placed the Edi catheter and monitored the baby on the baby ventilator by another manufacturer, but he seemed very out of synch. We monitored the asynchrony by means of Edi signal for 24 hours and switched him over to the SERVO ventilator and NAVA after that. He was on NAVA on the SERVO ventilator for 24 hours and we extubated him with no difficulties. He had failed two prior extubations on the baby ventilator."

Dana Saporito sees a continued role for NAVA and Edi monitoring of both NAVA and conventional modes in the NICU:

"I definitely think that we will see the continued use of NAVA as well as Edi monitoring of NAVA and conventional modes. Dr Mehta is interested in utilizing NAVA in looking at apnea of prematurity, where he sees a potential value."

Increasing future use of NAVA and Edi monitoring in the PICU

The first patient experience with NAVA in the PICU of the Bristol-Myers Squibb Children's Hospital of Robert Wood Johnson University Hospital was a 4 month old infant, where NAVA ventilation and Edi monitoring were utilized on the child for one week. **Jacqueline Williams-Phillips, MD**, Director of Pediatric Critical Care Medicine describes the case: "This child presented with respiratory failure a number of times of unclear etiology. We were unsure if it was a muscular-skeletal problem or a neurological problem. Genetic issues could come into play. We thought we would try NAVA to see how his brain stem and diaphragm relationship was working, before more invasive measures such as muscle biopsies or diaphragmatic biopsies."

"He continued on NAVA for some time, and Edi monitoring gave us a lot of valuable information in terms of neural input to his respiratory function, and we could avoid painful muscular biopsies and nerve conduction velocities and took that diagnostic arm out of the process. He did go on for further tests at another institution after he left us."

Dr Williams-Phillips is excited about some opportunities she sees with NAVA and Edi monitoring in future. "I am very excited about a couple of ideas I have. Within the evolution of pediatric critical care, we have all experienced a cohort of patients who develop chronic respiratory failure. There is a time frame in these patients when tracheostomy is needed, but we cannot predict reliably when that will occur. It may be due to genetic disorders, neuromuscular disorders, and there will be a time when we must inform the parents that their baby or child is ready for tracheostomy. We do not have objective data about when that time is. What we do now is evaluate after the first respiratory failure event, and see how frequently it may



Jacqueline Williams-Phillips, MD, Director of Pediatric Critical Care Medicine, is excited about many potential opportunities with NAVA



Gerald Schlette, Director of Respiratory and Pulmonary Services, sees the capabilities of utilizing Edi monitoring, in NAVA and conventional modes

recur, every month or a few times a year. Sometimes these patients do better with tracheostomy later on with better quality of life. Many patients have parents that then tell us, "We wish this would have been done earlier" but we do not have any data to help us know when the optimal time for tracheostomy is. We know that once we do tracheostomy that it decreases hospitalization in this patient category. My thought is when these children come in with respiratory failure, NAVA and the Edi catheter can provide us with information about the status of the diaphragm in relation to the respiratory failure, and other information. NAVA would be a useful tool to predict if tracheostomy should be initiated in patients with chronic respiratory failure due to neuromuscular diseases and other diseases. It would also be useful to look at the condition of the diaphragm post tracheostomy, if nighttime ventilation is needed in some circumstances."

"The second idea I have is that we have the largest pediatric rehabilitation hospital in the country right next to us, and we often send children from our PICU to them for rehabilitation for better outcomes in neurological recovery after brain injury. I think that NAVA and Edi can provide valuable information in these patients to help determine when to wean them and bring them to the next level, as a means of transitioning the patient off the vent, to improve the rehabilitation potential, and bring them home more quickly."

Summarizing experiences with NAVA and Edi monitoring to date at Robert Wood Johnson University Hospital

The Respiratory Care Department at Robert Wood Johnson University Hospital has grown in recent years, from 45 to a total of 56 registered respiratory

therapists on staff, according to **Gerald Schlette, Director of Respiratory and Pulmonary Services**. He states: "Pretty much all respiratory therapy staff members working in ICUs have been trained in the use of NAVA at this point and I feel that support from the physicians has been strong." "The capabilities of utilizing the Edi monitoring gave us much more than we expected, the diaphragmatic condition is revealed to us. This was an eye-opener for us, although we had expected this was to be the case, this is the first time we had our own evidence. Seeing is believing."

As Robert Wood Johnson is one of the first university hospitals in the US to start to use NAVA, as a teaching institution, there is motivation to include training and education about NAVA for future clinicians. Gerald Schlette explains: "Training physicians is an ongoing

process, and every July 1st we have an onslaught of new physicians. We have a course we teach for residents in surgical and medical. We will be including NAVA in these courses, so after a four year period everybody will have had an in-service and there will be a continuum from now on.”

Derikito Servillano is Critical Care Coordinator within Respiratory Care at Robert Wood Johnson. He has been working for 14 years in respiratory therapy and is responsible for coordinating all other coordinators in MICU, SICU, PICU, and NICU as well as the educational staff members. In this capacity, Derikito Servillano has had an opportunity to observe almost every patient that has been treated with NAVA at the institution. He recalls his first NAVA patient experience: “The first patient I remember very well, my first impression was letting go – it is very important to let go but difficult to transition from absolute control to no control. It was an asthmatic patient, that was difficult but we took the opportunity since the physician requested for NAVA to be used. We learned many things from that patient. I remember revisiting my physiology book to relearn how the diaphragmatic and respiratory muscles work. That first patient gave us a huge educational advantage of what the Edi signal really measures, and the learning curve was so high that I vividly remember it.”

“After seeing it for the first time, it was really a validation that what they were saying about NAVA was true. One thing that helped us was the monitoring capability of the Edi signal. It is easier to convince the physicians that it is a good tool as it shows better synchrony than any other means we currently have available.” In his role as Critical Care Coordinator, Derikito Servillano also had to coordinate the educational effort to prepare for implementation of NAVA and Edi monitoring. He describes this process: “We had a core group of people trying to learn as quickly as we could before starting. When we had one patient we could coordinate all of the staff and nurses to observe and understand the application, so that they would have a buy in to what we were doing. The CICU



Derikito Servillano is Critical Care Coordinator for Respiratory Care, and has observed almost every patient treated with NAVA at Robert Wood Johnson

in the open recovery area started out with the Edi signals as a monitoring tool.”

From there we went on to implement NAVA as a mode of ventilation and Edi monitoring in the MICU, CCU and in the NICU and PICU. I recall a particularly amazing experience in the NICU with NAVA in two patients. This experience showed me that these kids can be off sedation and they respond right away.” “In the adult arena, we continue to collect experience with NAVA and Edi monitoring in the hard or difficult to wean patients. We try NAVA and build confidence that the patient is strong enough, and so far we have not seen any reintubation or reinstatement of mechanical

ventilation with any of our NAVA patients yet. In this respect, we need more time with NAVA. I think maybe we need to go to NAVA earlier in the process of hard to wean patients, and evaluate from there.”

Derikito Servillano says that the physicians have been accepting of NAVA as a mode of ventilation, and Edi monitoring as a new vital sign in the ICU: “Yes, actually they are the driving force. I would say about 50% of our patients so far have been physician driven, and the rest have been on our recommendation. To me, the monitoring tool is a future value for us, especially as an educational institution it is important to identify and tell where dyssynchrony is on any mode.”

Doug Campbell, Assistant Vice President of Operations at Robert Wood Johnson leaves a final summary of the implementation of NAVA at Robert Wood Johnson University Hospital: "The introduction of NAVA has been in a structured manner, through means of input and feedback from key staff members, which provides a solid base for the next level of experience. It is important that there is a forum for communication between user groups from different hospitals using NAVA to sharing the experiences as everyone goes forward with quantum leaps in technology. NAVA is cutting edge and we want to make sure that we are on the forefront of that process, in order to be competitive." ■



Derikito Servillano, with Doug Campbell, Assistant Vice President of Operations at Robert Wood Johnson, has been supportive of the implementation of NAVA at Robert Wood Johnson University Hospital

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Return transfer of a 12 year old patient from the MRI to the PICU at Dartmouth-Hitchcock

Implementation of a seamless solution for bedside quality ventilation therapy in critical care patient transports and MR

The internationally renowned Dartmouth-Hitchcock Medical Center in New Hampshire in the United States is an academic medical center that has venerable roots stemming from Dartmouth Medical School, which was the fourth medical school founded in the United States in 1797.

The current state-of-the-art medical center facility was opened in 1991 as a 429 bed regional referral and teaching facility, including a trauma center and pediatric hospital. With 85 critical care patients throughout the facility, the Respiratory Care department faced challenges for in-hospital patient transports, including the MR environment – how to provide a solution for critical care patient transports without compromising ventilation therapy?

Critical Care News spoke with Scott Slogic, RRT, RCP, Director of Life Support, and Clinical Educator Matthew McNally, RRT to hear of the solutions to these challenges.

The fifty registered respiratory care therapists on staff at the Dartmouth-Hitchcock Medical center face daily challenges in caring for critical care patients in the adult medical CCU, surgical and trauma units, as well as a pediatric intensive care unit and a 30 bed level III intensive care nursery. The facility also offers a coronary referral center and CICU where patients arrive from over 28 hospitals within the region. With an average of 82 critical care patients from all categories – infant, pediatric and adult, the Respiratory Care Department were looking for an opportunity to standardize in 2002, without compromising quality in ventilation for their critical care patients.

A concept for standardizing ventilation therapy

Director of Life Support, Scott Slogic, RRT, RCP has been head of the Respiratory Care Department at Dartmouth Hitchcock for over twelve years. He describes the resources and activities within the Respiratory Care Department: “We have about 50 registered therapists, and we run typically 8-9 staff members per 12 hour shift. We have a clinical educator and an equipment manager, and transport therapists also, that are flight qualified that go on specific types of transports. We have two helicopters, and two ambulances, we do about 400 external transports per year. The majority of these are intra-hospital and planned transports, rather than trauma and emergency, although that may occur periodically. More frequently it is a matter of a hospital contacting us with a sick child that is referred over to our institution.”

“I have been working in this capacity in Respiratory Care for 12 years. Life Safety is a new concept, that of a virtual department that functions to improve patient safety throughout the organization. We have a Life-Safety Nursing Consult service, and these RNs are also part of the Rapid Response Team, termed HERT (Hitchcock Early Response Team). The nurses are part of the Life Safety Department, which is part of Respiratory Care. We have had great success at improving patient safety on non-critical care floors,



Scott Slogic, RRT, RCP is Director of Life Support at Dartmouth-Hitchcock for the past twelve years

reducing the number of intubations and codes on the floors with this Life Safety program, so we are thrilled with it. We started it three years ago.”

Scott Slogic and his co-workers identified a concept for standardizing from another industry that was applicable within his own department: “I believe in the Southwest Airlines model, with one standard aircraft, the Boeing 737. This means that every pilot, maintenance engineer, every crew member knows how to work on that plane. When there is an equipment change, they can substitute another and it is seamless. It is an engineering concept that many places have bought into. For use, we bought into the standardization of SERVO-i ventilator in 2002. It took a couple of years to phase in but we now have 50 SERVO-i ventilators. Everybody knows the ventilator and is familiar with it, physicians and nurses as well as the RT staff members.”

The educational effort

The standardized ventilator solution required an educational effort for respiratory therapy staff members to learn the new platform. Scott Slogic explains: “Education was seamless, we do a lot of ongoing education

with the SERVO –I. Every quarter we have educational series specifically about unique aspects of the ventilator: internal functioning, application of modes, but we continuously educate the staff on the ventilator. It is a fairly straightforward platform to use, with a few idiosyncrasies, such as inspiratory cycle off when to use it and how to tell if it is being used correctly. In future with NAVA, it probably won't be necessary. It was seamless for us. The universal application means we do everything between 500 gram babies and 300 pound adults. Because of its flexibility, the SERVO ventilator can be used for all patients.”

Patient transport challenges in the past

According to Clinical Educator Matt McNally, RRT, the technology limitations of solutions in the past would impact on patient care, requiring interruption of the circuit or the ventilation strategy. “We do upwards of 8 in-house transports per day, not including the times we transfer patients from the operating room to the ICU. In the past we would have used either an antiquated ventilator which required us to alter ventilator settings or oversedate the patient to help



Scott Slogic with some of his staff members

them tolerate the ventilator, or manual ventilation with a resuscitation bag.” Scott Slogic concurs: “We would use an old model of transport ventilator, which provided basic ventilation, but we obviously could not ventilate the more complex patients well with this device. We eventually modified a SERVO 300 ventilator by putting batteries underneath it and adding tanks, but that was a big platform and very unwieldy. For MRI, many may remember that there was an article published in *Respiratory Care* about how to modify the SERVO 900C for use in MRI in order to do MRI ventilation. We did that and it worked out pretty well, but the problem is that it is a 30 year old platform that my staff had to convert the patient to in the MRI and many of the younger staff members were not familiar with it. To be honest, we had two of them that got too close, even if they were modified. Before that, we were using basic pneumatic ventilator, but it was very clear that there were patients that needed MRI that we simply could not accommodate properly. The settings would not be appropriate; we needed to ventilate them in the MRI environment just like we

ventilated them in the critical care unit.”

The new solution – continuity of care in ventilation, even to the MRI

One of the advantages of standardizing to the SERVO-i ventilator was the ability to transport patients within the facility. The ability to provide uninterrupted ventilation to all patients is paramount, and continuity of care is the key objective according to Scott Slogic and Matt McNally, who explains: “This feature has enabled us to provide uninterrupted ventilation to some of the sickest and most fragile patients in the hospital. We use the SERVO-i to transport patients to and from diagnostic studies and interventions including CAT scan, MRI, X-ray, angiography and the cardiac catheterization lab.”

The new solution also provides some clinical advantages in patient transports, according to Matt McNally: “We are often requested by anesthesia providers in the operating room to assist with patients who are difficult to ventilate. In this case, we are able to bring the SERVO-i,

stabilize the patient, and then transfer to the ICU without interrupting the circuit or ventilation strategy. The trauma room is another place where we employ these ventilators. When a trauma is admitted, they are placed on the SERVO-i and ventilation is not interrupted from the initial application in the trauma bay, to the CAT scanner, then on to the ICU. Finally, one of our most crucial applications is in the neonatal resuscitation room. Recent literature supports the use of a resuscitation system with the ability to closely monitor and titrate ventilator settings which may result in better outcomes regarding broncho-pulmonary dysplasia and chronic lung disease. By using the SERVO-i, we feel that we can deliver consistent care from the delivery room to the NICU without interruption.”

The new solution was also made to be compatible for the 5 MRI suites at Dartmouth-Hitchcock Medical Center. Scott Slogic describes the implementation: “When we found out that an MR-compatible SERVO-i was available, it just made sense to us since there would be no interruption in ventilation, other than to transition them over to the MRI ventilator, and even then we learned. In the beginning, we thought that the SERVO MR compatible ventilators should be kept in the MRI department, and that we would transition the patient down there. That procedure actually changed very quickly after only a month or two. Now, we transition the patient right in the critical care unit to the MRI compatible ventilator, which makes for a seamless transport down to the MRI department. The MR compatible SERVO unit is used several times each day, and is used on all sizes of patients, from infant and pediatrics to adults, and some larger adult patients. We do have MRI capabilities for larger patients. For a typical MR transport procedure there is one respiratory therapist, one critical care nurse and two orderlies that accompany the patient.”

Scott Slogic also explained some of the clinical advantages that the new solution provides in MR transport situations: “With our particular procedure with the SERVO-i, we transition the patient at the bedside in the critical care unit to the exact same settings on the MR



The MR compatible SERVO-i ventilator is used in up to 8 transports a day at Dartmouth-Hitchcock Medical Center

compatible vent and monitor them for a while to make sure that they are stable. Even if they are transferred to the same settings there is the possibility of in some cases with larger settings to lose some lung volume very briefly, which should be recruited back up again. The transition down to the MRI unit is seamless after that. As we disconnect and reconnect, we might do a breath-hold and pinch the endotracheal tube in a breath-hold maneuver and reconnect so they don't lose lung volume. We don't know if that has an outcome effect, but it is a brief moment in time. We do know from lung modeling that a breath or two off of significant amounts of PEEP can mean lost amounts of lung volume. In a really sick patient it does not take long to lose volumes, which is why we transition them at bedside in the critical care unit, and monitor them before we go down to the MRI suite."

Future innovations in the Dartmouth-Hitchcock Respiratory Care Department

In terms of ventilatory strategies at the present time, ARDSnet guidelines are used for patients who qualify for ARDS, according to Scott Slogic. "For non-ARDS patients we ventilate usually in Pressure Support, and some level of PEEP that is appropriate for their FiO_2 requirements,

somewhere between 5 and 10 cm H_2O of PEEP. We analyze graphics to determine if they need reduced inspiratory times, or have air trapping. The vast majority of our adult patients are in Pressure Support, for our infant patients we use SIMV with Pressure Control for the most part, pediatrics are a mix of Pressure Control and Volume Control, depending on their condition."

"In future, we are pretty excited about starting up Neurally Adjusted Ventilatory Assist, or NAVA. We have only used Edi monitoring on one patient so far, but we are going through the process of the educational model with the physicians, step by step. We used it on an infant that was asynchronous, to see if the asynchrony was real or not, and it was. It was more a matter of using the Edi signals diagnostically rather than running the NAVA ventilation mode, but we are really excited about it. Dr Christer Sinderby was here last year and spoke about NAVA, when we heard about this concept, which is truly new in mechanical ventilation for us. Mechanical ventilation has been kind of the same for the last decades, with maybe some variations on the theme from a pneumatic perspective. In terms of mechanical ventilation, neural ventilation is truly unique. We don't know if it will change outcomes, but we believe it has the potential to do so." ■

Biographies

Scott Slogic, RRT, received his certification in Cardiopulmonary Science at Parkland College, followed by his Bachelor of Science degrees in Respiratory Therapy and Business Administration at St Petersburg College in Florida.

Scott Slogic has worked within Respiratory therapy at St Josephs Medical Center in Bloomington, Illinois and at the Bayfront Medical & Trauma Center in St Petersburg, Florida. He joined the Dartmouth-Hitchcock Medical Center in New Hampshire as Staff RCP in 1990, and was named Director of Respiratory Care in 1996 as well as Director of Life Safety in 2006. Scott Slogic has published a number of scientific studies in peer-reviewed critical care publications.

Matt McNally, RRT received his Bachelor of Science degree in Respiratory Care from Quinnipiac University in Hamden Connecticut, and worked as Staff Respiratory Therapist at Connecticut Children's Medical Center from 1998-199, and was employed as Respiratory Therapist Traveler with Cross Country TravCorps from 1999-2001.

Matthew McNally was employed by Dartmouth-Hitchcock Medical Center in Lebanon, New Hampshire as Transport Respiratory Therapist in 2002 and worked in that capacity until 2008, when he received his current position as Clinical Educator, Respiratory Care.



The Dartmouth-Hitchcock Medical Center in New Hampshire, US



Javier Garcia Fernandez, MD, PhD, works as a pediatric anesthesiologist at La Paz University Hospital in Madrid, Spain

Peri-operative ventilation – What criteria are important for the widest range of patients?

Following the spring issue in which two European anesthesiologists were interviewed, Critical Care News was interested in meeting yet another clinician, this time in Spain, to hear what he had to say about the most important considerations in peri-operative ventilation mechanics for a wide range of patients.

The University Hospital of La Paz is situated in the Fuencarral-El Pardo district of Madrid and is a multi-disciplinary public teaching hospital with focus on maternal and infant health care. La Paz is a reference hospital for all of Spain, as well as a reference burn center for pediatrics.

Dr Javier Garcia Fernandez has done extensive research in ventilation mechanics and has developed an anesthesia simulator, making it thus easier to explain the principles of a circle system, as well as the importance of certain principles that can have clinical implications.



Dr Garcia is Head of the Pediatric Surgical Intensive Care Unit

Can you tell us about your professional background?

My residency was done at the La Paz hospital in Madrid, after which I worked for a year with adults in a general hospital. After that year, I returned to La Paz hospital and have been working with children; I have also earned an MBA in Sanitary Business Administration. I have been running the surgical Intensive Care Unit in pediatrics for the past 2 years. I am working both in the ICU and the department of anesthesia, and have been focusing on mechanical ventilation for the past 8 years.

Can you tell us about your research and publications in the field of mechanical ventilation?

My first research in anesthesia and mechanical ventilation, was about the use of Pressure Support inside the operating

room. I wanted to try and transpose the knowledge from the critical care unit into the world of the operating room, looking at the differences between the used ventilatory modes, the clinical approach in using these modes, how one does the machine settings, and so on. The first point was how to convince the rest of my colleagues on the use of the different ventilation modes which were of benefit to our patients and to simplify these techniques for the use in the operating theatre. After that I published two more articles on how to set and use Pressure Support in the OR for children, as well as the differences in PEEP settings between adults and children in the OR. Most clinicians don't want to use PEEP in the OR with children, because they are afraid of the pressures they may be using, even though they regularly apply them in the ICU. I realized that focusing on transferring this knowledge from the ICU to the OR would make its use easier.

How would you define high ventilatory performance in anesthesia and what criteria would you base it on?

In order to give an appropriate definition, I would refer to the use of all the available ventilatory therapeutics which are available in the ICU. Machines in the ICU have improved notably in the last ten years, but the advancement on anesthesia machines has not followed the same pace: here, there are limitations. However, we have today high risk patients entering the operating theatre, adults as well as children, elderly and the very young, with high morbidity and critical situations, such as critically ill patients, the morbidly obese, to name a few; among these are critical care patients necessitating surgery, whose status is thought to be improved by surgery. One special case is also very small children, who used to die several years ago but who, thanks to medical and technical advancement, are now



La Paz University Hospital, Madrid, Spain

saved and given a chance to live through surgical procedures. These children undergo, at times, several procedures, and their prognosis remains critical. If one does not have access to the same possibilities of ventilatory modes and techniques, and if moreover, one does not know how to use them in the operating room, then the outcome can really be compromised.

What are the most commonly performed surgical procedures on neonates?

Most often we see congenital pathologies, such as esophageal atresia, or diaphragmatic hernia. But prematures also undergo surgical procedures for necrotising enterocolitis and intestinal ischemia, who in the past would die, and who today survive thanks to advances such as intestinal transplants, thus allowing them to go forward in their

development. The number and success of these transplants is increasing, however, many of these children remain in a critical state, as they often have multiple pathologies, renal, hepatic, intestinal.

When speaking about neonatal surgery, do you define these cases as full term neonatal or pre-term?

This question seems to me very important. From the point of view of mechanical ventilation, there are anesthesia machines which are not capable of delivering the technology needed, based on the two fundamental conditions: the weight of the patient and the condition of the lungs. If the baby weighs less than 3 kilos, then it is often difficult to ventilate, even in the healthy lung. It can present altered lungs, pulmonary distress or hyaline membrane syndrome, something which worsens the condition. The main problem with

this group of patients is that it is difficult to ventilate them. If one does not have the same ventilatory performance in the operating room as in the ICU, then ventilating becomes very difficult.

What percent of the cases represent pre-term neonates?

Nowadays, I must say 60%. The great majority of neonatal pathology has to do with premature babies. With each technological advance in neonatal care, one was able to advance, or decrease the survival weight with an extra 500-600 grams. Today, very tiny babies are operated on more often than healthy neonates, with conditions such as pylorus defect or myelo-meningocele. These procedures can be done without complication on full-term babies, but on the very tiny prematures who have multi-pathologies, intestinal, renal, respiratory and hepatic it is a challenge.

They are often in much more critical condition than the healthy neonate.

These children often end up in neonatal ICU post operatively. How important, according to you, is the continuity of high ventilation performance with respect to their outcome?

This is absolutely crucial. It can mean the difference between survival and death. Whatever ventilatory changes occur, or disconnection, not being able to maintain a stable PEEP over time, can have the result of damaging their fragile lungs; if these patients do not die peri-operatively, they may well do so post-operatively if there is no continuity.

You have extensive experience in pediatric anesthesia. In which way do you think pediatric anesthesia practices can pave the way for optimal adult anesthetic practice? Can pediatric anesthesia provide guidance to the industry for developing machines able to handle the coming challenges in adult anesthesia?

I believe this question is of the utmost importance. The pulmonary physiology of neonates gives us many answers. In the last 4-5 years, there have been questions concerning which tidal volume should one use in adults with distressed lungs? The recommended VT is the same for these patients as for neonates, that is to say 6 ml/Kg. The other aspect is the use of PEEP. The best way of avoiding atelectasis is the use of PEEP. You need to have a good understanding of neonatal pulmonary physiology to prevent atelectasis which occurs in all neonates; this knowledge can lead to knowledge on how to respond optimally in adults. Neonatal lungs are the perfect model for respiratory distress in adults. The dynamic compliance of the lungs of a neonate (3 ml/cm H₂O) is 6 times less than in a highly distressed adult patient (20 ml/cm H₂O). If an anesthesia machine can provide good ventilatory performance for a neonate, then it will be able to adapt perfectly to the adult patient needs, even in the case of the highest pulmonary distress. Pressure



Dr Garcia has developed an anesthesia simulator which helps in understanding ventilation mechanics in a circle system

delivery in the case of bronchospasms can also be applied to both categories. One can also take the example of the obstetric patient whose lungs tend to easily collapse, much as the neonate who always suffers from atelectasis. Good recruitment possibilities in neonates ensure the same for adults.

It is astonishing to me that more anesthesiologists do not wonder about the "potency" or power of the anesthesia ventilator. They often speak about the color of the windows on the interface, the size of the buttons, the alarms, how big or small, how easy it is to move the machine... But the power of the ventilator... Why is that of importance? Much in the same way as in automobiles, acceleration can mean the difference between life and death in certain critical situations, such as bronchospasm, asthma, respiratory distress. The answer to these is the access to a full range of

settings, like in the ICU. This will ensure proper ventilation for "this" patient. For "this" patient, in this critical situation, this aspect of high performance in ventilation will be the most important consideration. Most patients have enough with a PEEP setting less than 20 cm H₂O. But in certain cases, going above 25 cm H₂O will be a life-saving strategy, especially during a pulmonary recruit manoeuvre. These aspects have to do with patient safety. Maybe not many will need it, but for the one who will need it, it will be crucial! It represents a guarantee for the majority of the patients. It is also a question of confidence for the anaesthesiologist, trusting this particular machine. With a traditional circuit system, one often goes over to manual/spontaneous ventilation in pediatrics, at the end of a procedure, because one feels to have more control. This has also disadvantages. Mechanical ventilation is security for all ranges of patients.



The pediatric post-interventional care unit at La Paz Hospital

With respect to acquired knowledge in the field of anesthesia, what aspects would you consider as important to transmit?

Inevitably, patient safety is the top question. One must know the basics of mechanical ventilation. But that is not enough. One must also understand the differences between the circular circuit versus the open circuit. Lack of this knowledge entails many extra problems for the patient and the clinician. In the future, companies will “automatically” solve these questions for the practitioner, even if one doesn’t master these aspects, one will be able to use the machine. However, it is necessary to have a minimal knowledge of advances in mechanical ventilation and physiological application.

Could you please describe the settings you would use in a 3 Kg healthy neonate?

Induction would generate respiratory arrest and after intubation, one has a situation of full lung atelectasis. In order to counter this problem, one has to increase PEEP, after reaching hemodynamic stability, 5 by 5 cm H₂O, all the while maintaining a driving pressure of no more than 15 cm H₂O, until a maximum peak pressure of 35 cm H₂O is reached, then with a PEEP of 20. Some neonates with severe distressed lungs often need a maximum peak pressure of 45 cm H₂O to open their lungs. By wanting to limit the driving pressure to 15 cm H₂O, you must then increase the PEEP to 30 cm H₂O. After which, you start reducing the pressure and set the

proper PEEP, adapted to the patient. One needs to have a wide range of PEEP levels and maximum pressures.

Could you please tell us about what you think are the needed ventilation modes?

I have a very personal point of view regarding this matter. About 5 years ago, very many ventilation modes appeared. It is crazy. When you think about it, Volume Control is the most commonly used. But Volume Control is not enough; Pressure Control and Volume Control are mandatory today. Pressure Support is also beneficial for the patient not needing muscle relaxation. It is better for the patient, the anesthesiologist and is easy to use.



One of the care units in pediatrics

What are your thoughts about trigger sensitivity?

This is a critical question for pediatrics. Adults are used to thoracic pressure trigger. Neonates or pre-terms need flow trigger, which allows perfect synchronisation in time with the respiratory drive. Many machines today have a higher sensitivity giving information much faster for a better adjustment.

Advantages/disadvantages of existing breathing systems in anesthesia?

Companies have been more focused on the flows, low-flow anesthesia than on the ventilator itself, and I think this is completely crazy. What are you using the machine for? It is to ventilate your patient safely. The power of insufflation is the focal point, then you can add

other things like the rate of the fresh gas flow used, how to save money with low-flow anesthesia...but the priority is how well you are ventilating, and how safely. At this point, not many companies have thought about that: the anesthesia machines existing today, compared to critical care ventilators have power of insufflation representing half of that of ICU ventilators. We must focus on that, not losing this power of insufflation, and not interrupting ventilation, for the sake of patient safety. Recruitment is very important and the machines must be able to perform this.

What are your thoughts about low-flow anesthesia? What are the limits?

Low flow anesthesia is mandatory; but the limit is the safety of the patient. But there are no savings between 0,5 and 0,3

liters of fresh gas flow, as one spends much more absorbent. The final reduction is much more expensive. And today, there are the risks of hypoxic mixtures. Some clinicians are however passionate about low-flow, but cost savings should be calculated. As a conclusion I would like to say that it is important for clinicians to have knowledge about mechanical ventilation, as it lies at the centre of patient safety. It is a powerful tool for avoiding negative iatrogenic effects on patients; one must have knowledge about the "open lung"; as well as all protective strategies in ventilation during anesthesia. The application of this knowledge has been shown to reduce mortality by 10-12%. These strategies should be applied to daily care. ■

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Biographies

Javier Garcia Fernandez, MD, PhD

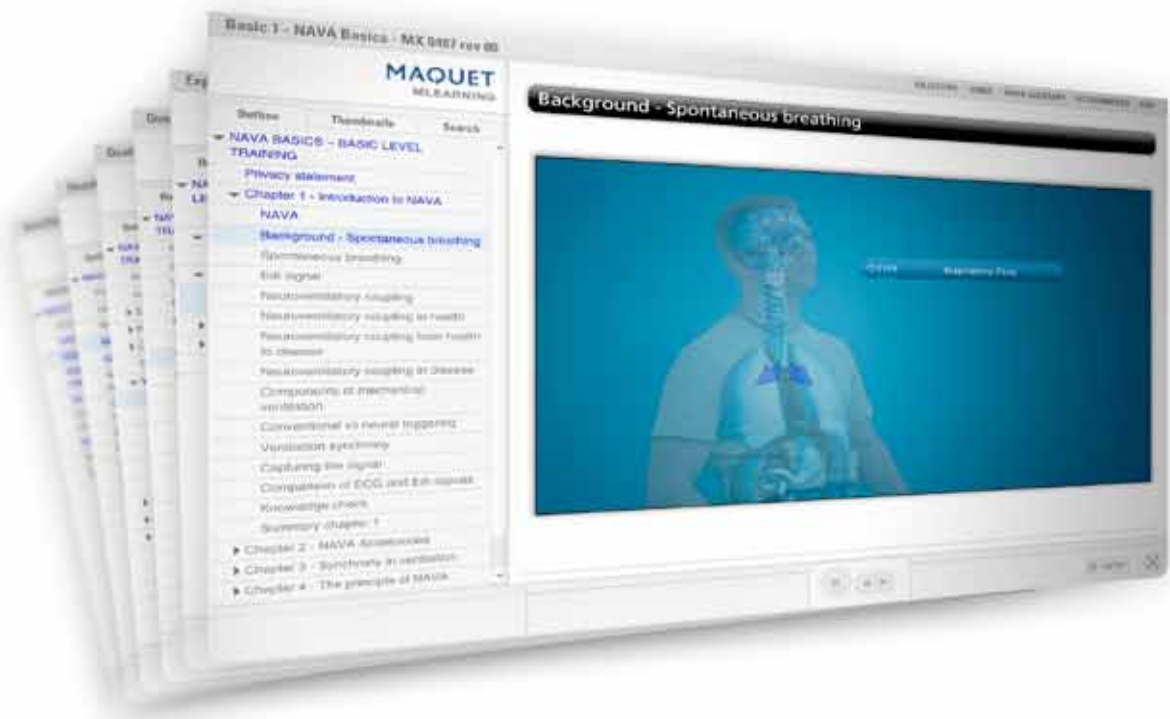
Anesthesiologist and Intensivist at the University Hospital of La Paz in Madrid, Spain, where he has been Head of the Department of Pediatric Surgical Intensive Care for the past two years. Dr Garcia is also the creator of an anesthesia simulator called "Javierito," which helps colleagues in understanding the implication of peri-operative ventilation mechanics in patient care. He has been doing research in ventilation mechanics for the past 8 years. Moreover, he has published articles in this domain.

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CRITICAL CARE NEWS is published by MAQUET Critical Care.
Maquet Critical Care AB
171 54 Solna, Sweden
Phone: +46 (0)8 730 73 00
www.maquet.com
©Maquet Critical Care 2009. All rights reserved.
Publisher: Fredrik Wetterhall
Editor-in-chief: Kris Rydholm Överby
Contributing editor: Judith Marichalar-Sundholm
Order No. MX-0554
Printed in Sweden
www.criticalcarenews.com
info@criticalcarenews.com

This document is intended to provide information to an international audience outside of the US.

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