

Critical Care News

Theme:

Defining and implementing
new strategies in ventilation
therapy and respiratory care

PAGE 2

Challenges and opportunities
in respiratory therapy for
neonatal intensive care patients

Kim Watkins, RRT-NPS, Clinical
Coordinator of Respiratory Therapy,
and Dr Terrence J Sweeney, MD,
Director of the Division of Neonatology
at Swedish Medical Center, Seattle

PAGE 12

NAVA: technology
evolving from bench
to bedside

Dr Lukas Brander, Department of
Intensive Care Medicine, University
Hospital - Inselspital, Bern, Switzerland

PAGE 22

Challenges and developments
in lung protective ventilation
for neonatal and pediatric
patients in Mumbai

Neonatologist and Pediatric Intensivist
Dr Hiren N Doshi, Program Director,
and Dr Suresh Birajdar, Balabhai
Nanavati Hospital, Mumbai, India

PAGE 30

Standardizing ventilation
technology up to the MRI
suite, in an expanding
hospital environment

Joe Dwan, RRT, Director of Respira-
tory Care, Kaiser Foundation Hospital,
Kaiser Sunnyside Medical Center,
Portland, Oregon

PAGE 38



PAGE 4

Neurally Adjusted Ventilatory Assist – NAVA: a continuing focus on physiology

Dr Paloma Gonzalez Arenas and Dr Fernando Suarez Sipmann
University Hospital Fundación Jiménez Díaz in Madrid



Dr Paloma Gonzalez Arenas and Dr Fernando Suarez Sipmann share their experiences with NAVA in adult patients.

Defining and implementing new strategies in ventilation therapy and respiratory care

One of the continuing challenges that every ICU department faces is to cope with an ever-expanding number of patients in increasingly complex clinical situations. Mechanical ventilation therapy in this challenging situation should ideally be the means of safely sustaining life during recovery from a surgical or disease process, providing the caregiver the opportunity to mainly focus on the underlying clinical process and recovery in each individual patient.

This issue of Critical Care News features articles and interviews from various clinicians around the world who are meeting these challenges by defining and implementing new strategies in ventilation therapy and respiratory care. Some of our contributors are defining, evaluating and implementing completely new methods of ventilation therapy, and others are refining existing applications according to new strategies.

Focusing on physiology with Neurally Adjusted Ventilatory Assist – NAVA, at one of the ICU “cradles” of Open Lung methodology in Madrid

The ICU of the Fundación Jiménez Díaz in Madrid, Spain was one of the first centers in the world to establish clinical adaptation of lung recruitment by means

of the Open Lung Concept over a decade ago, when Dr Fernando Suarez Sipmann returned to Madrid after studying the concept in Berlin.

Dr Sipmann has continued to research within the area of lung recruitment, and he and his colleague Dr Paloma Gonzalez have been actively involved in the clinical

evaluation in Spain of NAVA – Neurally Adjusted Ventilatory Assist in their ICU. They share their experiences and impressions of NAVA in adult patients, and Dr Sipmann shares his opinion about the parallels between the physiologically based concepts of Open Lung and NAVA.



Kim Watkins, RRT and Dr Terrence J Sweeney, Seattle

New ventilatory strategy for premature infant patients in a NICU department in Seattle

Over 700 neonatal patients were admitted to the Neonatal Intensive Care Unit at Swedish Medical Center in Seattle, Washington during the year 2006, where well-established perinatal and neonatal departments have been expanding for the past few decades. In recent years, the NICU transitioned from a conventional ventilation approach in their premature infant patients to adopt and successfully implement a new low volume ventilatory strategy. Kim Watkins, RRT-NPS, the Clinical Coordinator of Respiratory Therapy, and Dr Terrence J Sweeney, MD, Director of the Division of Neonatology at Swedish Medical Center contribute with their experiences in regard to the new strategy.

The evolution of NAVA as a technology from bench to bedside

The Bern University Hospital – Inselspital is internationally known as a center for education and research, and Dr Lukas Brander of the Department of Intensive Care Medicine has been currently involved in the clinical evaluation of Neurally Adjusted Ventilatory Assist – NAVA in a series of adult patients.

While attending a research fellowship in Toronto in 2004, Dr Brander was involved in experimental studies with



Dr Lukas Brander has unique experience of the development process of Neurally Adjusted Ventilatory Assist - NAVA

NAVA as a new technology. He shares his unique experience with NAVA as a new generation in ventilation therapy, from the early research and development phase to translation into industrial production for bedside clinical application.

Adapting and implementing ventilation strategies for neonatal and pediatric patients in Mumbai

In 1962, Mother Teresa brought her first child to Balabhai Nanavati Hospital in Mumbai for treatment. The state-of-the-art Blessed Teresa Advanced Paediatric Center was opened at Nanavati Hospital three years ago, where over 5,000 children have been treated and a survival rate of 92% has been attained in the NICU/PICU, for children requiring mechanical ventilation.



PICU patient and family members at Nanavati Medical Center, Mumbai

Program Director Dr Hiren N Doshi and his associate Dr Suresh Birajdar share their experiences with lung protective strategies in a rapidly expanding and challenging environment.

Standardizing ventilation technology, up to the MRI suite

At the award-winning Kaiser Foundation Hospital – Kaiser Sunnyside Medical Center in Portland, Oregon, the objective of the Respiratory Care Department is to improve patient safety and provide more focus on patient bedside care. Director of Respiratory Care, Joe Dwan is one of the driving forces behind standardization of ventilator technology to achieve this objective.

Joe Dwan outlines his experiences and perspectives in regard to the solution of standardizing ventilatory technology throughout the hospital, and as the first hospital in the United States to implement this solution in the MR environment. ■



Joe Dwan, RRT with respiratory therapy colleagues at Kaiser Sunnyside.



Dr Paloma Gonzalez Arenas and Dr Fernando Suarez Sipmann in the ICU at the University Hospital Fundación Jiménez Díaz in Madrid.

Neurally Adjusted Ventilatory Assist – NAVA: a continuing focus on physiology

The University Hospital Fundación Jiménez Díaz in Madrid, Spain, was established in 1955 as the first hospital in Spain to be devoted to medical care, teaching and research. The institution also opened the very first Intensive Care Unit in Spain.

The Fundación Jiménez Díaz ICU was also a pioneer in the research and early clinical adaptation in the area of lung recruitment and the Open Lung Concept over a decade ago, and continues to expand their physiological experience in clinical evaluation and adaptation of NAVA - Neurally Adjusted Ventilatory Assist.

Critical Care News spoke with Fernando Suarez Sipmann, MD, internationally known researcher and lecturer on Open Lung methodologies, and Paloma Gonzalez Arenas, MD, about their experiences with NAVA.

Could you start with a general description of the ICU department, average number and mix of patients and staff?

Dr Gonzalez Arenas: We have a balanced proportion of medical and surgical patients. I would say that currently 55% are medical patients, and 45% surgical patients. In the past we had a higher proportion (about 65%) of surgical patients. The ICU has 15 beds of a total of about 500 beds in the hospital. We have 7 intensive care specialists on staff and 4 residents per year, with an additional number of rotating residents from other speciality areas.

What are your respective positions within the department?

Dr Suarez Sipmann: We are both on staff as intensive care consultants. I am currently combining my clinical activity with an increasing research activity, a nice balance between my two passions. It is important to always stay close to the patient's bedside as this is where you keep track of the relevant clinical problems that you need to address in research. Dr Gonzalez is working primarily as a clinician, with some research collaboration with me.

Which types of patient situations are most frequently encountered in your ICU?

Dr Suarez Sipmann: We have a mix of medical and surgical patients, a true polyvalent ICU. In Spain, we have a unique situation in which Intensive Care is an independent specialty – and we are trained to take care of the entire spectrum of critically ill patients. This is important, since critically ill patients share many patho-physiologic features that need to be taken into consideration and evaluated under the same scope and perspective.

Which types of modes or methods of mechanical ventilation have been generally used in the majority of ICU patients?

Dr Gonzalez Arenas: In our ICU, with respect to the research Dr Suarez Sipmann has conducted, we believe



Dr Suarez Sipmann is an internationally known researcher and lecturer.

it is important to take a physiological approach, and we are mainly utilizing pressure controlled and pressure supported ventilation modes. This is perhaps in contrast to other ICUs in Spain; where volume controlled ventilation is very often the only mode used for controlled mechanical ventilation. Our fellow staff members have adopted the use of pressure generated modes as they consider them a more physiological means for ventilating patients. Even in situations where a strict control over the minute ventilation delivered to the patient is required, such as in neurocritical patients, the use of pressure regulated volume controlled ventilation is of preference over pure volume controlled ventilation modes.

Dr Suarez Sipmann: To change attitudes and long standing clinical routines is always a long process. During my

specialty training, I had the chance to learn from important groups of active researchers in the field of lung physiology and mechanical ventilation. When I started as a consultant I slowly introduced the principles I had learned into new approaches to mechanical ventilation in our unit based on the use of pressure controlled ventilation and later, on lung recruitment and PEEP titration. This slowly set the basis for the current approach to lung protective ventilation that we have adopted in our unit. The result is that we have created a clinical culture of lung protection in which there is a strong awareness of the potential complications related to mechanical ventilation right from the first moment of its implementation. We have had new staff members joining us in recent years, and they come with their own preconceptions on mechanical ventilation. There is usually always the

same process, in the beginning we have fruitful discussions confronting concepts and ideas and in the end they begin to understand the advantages of a more physiologically based approach after seeing the responses of patients and the potential of reducing the complications related to mechanical ventilation.

Can you tell us more about the historical background to the early adaptation of the Open Lung concept and lung recruitment methodology at this institution?

Dr Suarez Sipmann: As I said, it has been a long process but we have been able to change strongly rooted routines and slowly introduce an open lung ventilation concept. This process, like any new conceptual approach, takes time, just like NAVA will. To my satisfaction today, most of the staff members here strongly believe that this is a better way of treating patients. We are not using any specific written protocols, we leave room for flexibility, trying to apply the physiological principles on which this ventilation concept is based as our guideline and adapt it to the individual patient situations. In addition, the clinical research projects in which we have been involved have grown in number and have provided us with valuable information as to the practical and systematic implementation of this strategy.

You have recently started working with NAVA. How many and which types of patients have been treated with NAVA so far?

Dr Suarez Sipmann: We have started to use NAVA a few months ago but still have a limited experience. As a new technology we are implementing it on a stepwise basis. We have used it in different types of patients mainly medical but also in complicated surgical patients submitted to prolonged mechanical ventilation during the weaning phase.

What are your first impressions of NAVA?

Dr Gonzalez Arenas: It offers an entirely



Dr Gonzalez Arenas has been involved in the first series of adult patients to treated with NAVA in Spain.

new way of ventilating patients. Our first impressions have been quite positive, we have noticed that patients' synchrony with the ventilator is improved, in many occasions and we are learning how to adjust the NAVA level in different situations. In general patients seem to be quite comfortable while on NAVA.

Dr Suarez Sipmann: I would say that the best way of describing it is that NAVA has met our expectations so far and that in general the experience of the group has been positive. This in itself is a big and important step with any new technology. There were aspects of the theoretical principles of NAVA that we were very interested in evaluating during its practical application at the bedside. When you introduce a new ventilation mode based also on new technological aspects, the initial focus is on its performance which is always put in relation to the known conventional modes. How patients respond, based on its principles, trying to understand from patients' responses, why some respond in a positive and others in a less positive way. This has been occupying much of our time during this first evaluation period. We have also been cautious to introduce

NAVA in a stepwise fashion. We have started its use in those situations where we knew from the available scientific literature and from the experiences of other groups that it was easy to implement with an expected benefit for the patients. This has enhanced the initial acceptance and has improved the learning process of the team. With NAVA we are facing a new way of looking at things, and it is important to have first positive experiences, and learn its practical aspects from easier situations. Taking these precautions and introducing it in a stepwise fashion has helped the entire team to become comfortable with this new method and technology.

What is your perception of patient-ventilator synchrony in regard to NAVA?

Dr Suarez Sipmann: I would say positive, we have treated some COPD patients that were in asynchrony with the ventilator in which we had difficulties in finding a good pattern of assistance while on Pressure Support. When switched to NAVA synchrony clearly improved and patients were more comfortable with the proportional assistance that they



Dr Fernando Suarez Sipmann has been conducting research in lung recruitment for many years.

received which facilitated the weaning process. In those cases we could see the gain of using this new way of triggering and assistance. However, still more experience is needed to learn to improve the adjustments of the trigger threshold and the level of assistance in different clinical situations to fully exploit the potential of NAVA. For other more conventional patients that were already comfortable on Pressure Support during the weaning phase, the improvement with NAVA was not so obvious. In general, in terms of patient comfort and breathing pattern NAVA seems to be very promising. It is important to say that it is absolutely essential to have a good and reliable Edi signal to implement NAVA and this has not always been the case.

Are there some specific patient experiences that are of special interest? For example, did you find anything that you were not expecting to see, or vice versa?

Dr Suarez Sipmann: We realised that the Edi signal is very sensitive to sedation, much more than we were expecting. Coming into that discussion, sedation is in itself a complex issue.

Oversedation is not an uncommon problem in the ICU interfering with the transition from a fully controlled to an assisted mechanical ventilation, especially on those patients that have been some time on the ventilator. During this transition period it is often difficult to find an appropriate pattern of ventilatory assistance as dyssynchrony is a frequent problem. One of the great potentials of NAVA is to become a means of introducing assisted spontaneous ventilation earlier and in a more efficient way in these patients. We have also been exploring this possibility. To our surprise in most occasions we did not obtain a good Edi signal as sedation, especially during this washout period, was still interfering much more than expected. After having the Edi catheter in place for several days the signal became stronger and at the end we were able to start using NAVA once the patient was fully awake. This apparent limitation of the early use of NAVA can even turn into an advantage as the quality of the Edi signal can be a way of evaluating the level of sedation and the readiness to start assisted-spontaneous modes of ventilation and the weaning process during this critical phase of mechanical

ventilation. I think that this can lead to a positive development in the future, since anything that helps the physicians to reduce the amount of sedation and to fine-tune its administration in an objective way, and Edi may provide objective additional information, will be of benefit for the patient.

On the other hand unless much care is taken with the administration of sedation the early use of NAVA will be limited during this phase.

So this is one of the observations we experienced, we also had other unexpected situations when patients were fully awake, triggering the ventilator in Pressure Support in synchrony without apparent difficulties but showing a very low Edi signal. We tried to modify the NAVA level and the trigger threshold in an attempt to improve the signal but could not obtain a good enough Edi to start NAVA. We started to ask why, could it be a problem with the catheter positioning, or with the signal itself? To answer these questions is still difficult at this stage since you have no reference to compare with and still little information is available. All you have is a patient that is triggering spontaneously that for some reason is not showing enough diaphragmatic activity. There are reports on patients that are not using the diaphragm as their main inspiratory muscle at these stages and this might be an explanation for these observations. This is something that we have not been able to detect and monitor in patients in the past; in other words we might be able now to take a closer look on the diaphragmatic and respiratory muscles' function and improve our understanding of the complex problem of patient ventilator interaction.

Dr Gonzalez Arenas: This experience gave us the idea to take a closer look at sedation and muscle relaxants protocols; another area that now with the additional information from the Edi, we realize we need to reassess.

Dr Suarez Sipmann: With practice you learn how to stimulate the patient to use the diaphragm more efficiently by modifying the trigger threshold and the level of assistance in order to obtain a better Edi signal. We had one very

interesting patient where we could not apply NAVA because of a very erratic and low Edi activity. We noticed that he had a non-physiologic respiratory rate that did not correspond to the patient situation. The Edi was quite low, and not followed by a pressure/flow response from the ventilator. After some checking we realized that it was the implantable defibrillator pacemaker the patient had, that was stimulating the diaphragm. It could be clearly seen on the positioning screen of the ventilator that the Edi was consistent with the ECG signal and each cardiac cycle stimulated the diaphragm. So in fact the ventilator screen was displaying the heart rate instead of the respiratory rate and the Edi was inefficient to trigger the ventilator. Interestingly this pacemaker derived stimulation was not constant as it was related to the patient's position and probably the fact that the patient had a large heart lying on the diaphragm was a major contributing factor.

We could not have a steady use of NAVA in this case, but we learned from this patient since we started to look more at the effects of modifying the trigger threshold in a situation with such interferences. As soon as we got the patient to use his diaphragm more actively and efficiently, the true Edi would sometimes dominate over the pacemaker derived stimulation and the patient could

trigger the ventilator. The fact that this was an otherwise stable patient in the weaning phase allowed us to detect this problem. In a more complex situation this information would have been more difficult to obtain and this particular problem may have remained hidden. This is why, as I mentioned before, it is important to start the use of such a new mode in easy and controlled situations where we can learn about its functioning and potential problems. I don't know whether in general pacemakers will cause difficulties with NAVA and this will have to be investigated in more detail as it might become a limitation for its use.

What are your perceptions of esophageal ECG? Is it a complement, and if so, in which cases?

Dr Suarez Sipmann: We are not used to looking at esophageal ECG, but that doesn't mean that it is not a useful potential signal that can be of added value. I can foresee that it might become important, since the surface electrodes used for routine monitoring are very useful in tracking heart rate and some general arrhythmias but limited in their ability to give a more detailed description of the morphology of the ECG complexes and more specific types of arrhythmia. We did have one case during the initial evaluation of NAVA where we could

make the specific diagnosis of an arrhythmia, by looking at the esophageal ECG which in that particular case gave us additional relevant diagnostic information. When evaluating the case, we used it as a Q and A to our fellow staff members: we showed the surface ECG tracings from the monitor and asked them to make a diagnosis of the arrhythmia. After some guessing, we showed the solution with the esophageal ECG. Definitely any additional bedside parameter can be of value for ICU monitoring. We need to learn what additional information we can obtain from these signals and how to make the best use of it.

Have you utilized Edi monitoring in other modes of ventilation than NAVA?

Dr Gonzalez Arenas: Yes, in Pressure Support, Pressure Control and CPAP. We have been trying to introduce the catheter to follow and monitor the patient during transition period from controlled to assisted ventilation, but in this respect in many cases the signal was not that strong during other modes in probable relation to the sedation washout period.

Has it been difficult to interpret Edi signals, either in NAVA or other modes of ventilation?

Dr Suarez Sipmann: There are many things we still don't know. First what should the normal signal look like, what are the "normal" Edi values and curve shapes for a particular patient? What is the normal or the expected activity especially in patients after prolonged mechanical ventilation? For the Edi signal, there is not yet a base for a systematic reference. Each patient is its own control at this point, and we must learn from this signal and try to understand its implications in each particular patient. There is a lot of work ahead to use Edi more actively as a monitoring tool. And there are some erratic signals, that can't be judged yet due to catheter related problems, drugs used, or artefacts due to other yet unknown factors. I think that more work is needed and will be done in this particular field.



Dr Suarez Sipmann is maintaining a balance of clinical work at bedside, and research.



Dr Suarez Sipmann and Dr Gonzalez have educated their fellow ICU staff members in regard to the clinical application of NAVA.

Dr Suarez Sipmann, you are known for your research in the field of electrical impedance tomography, or EIT as a tool for bedside monitoring in the ICU. What is your opinion of Edi signals as a completely new bedside parameter for diagnosis and monitoring in mechanical ventilation?

Dr Suarez Sipmann: I am convinced that the Edi signals will be of great value as a bedside parameter. Of course, the signal you finally see on the ventilator has been processed and filtered, but still it is a very important piece of information that we never had available until now. The little we know about the diaphragmatic activity is from experimental studies that involve complex measurements, in very specific conditions, not applicable in routine clinical practice. One of the beauties with the Edi will also be that we have it with every breath, and over time we will have so much more information as a continuing measurement. This is of great potential, the continuity and the ability to obtain a breath by breath information at the bedside that we can use in clinical practice. This is an area where we have no reference; we are not used to thinking about how the diaphragm is performing in a patient, since we could never measure it in the past. There is very little knowledge

about diaphragm activity in mechanical ventilation and this is in contrast with the increasing awareness of the problem of diaphragmatic dysfunction in ventilated patients. The weaning process is very complex in some patients, and one of the factors adding complexity is the lack of monitoring. We have to be able to recognize problems early in the process, and there is no single parameter telling you if a patient will be successfully weaned or not. We need more objective information, especially to evaluate the response to the progressive steps during weaning. The importance of the transition phase from controlled to assisted and spontaneous ventilation is often underestimated. Very frequently this is a critical phase where we can even inflict damage to the lung and the diaphragm if we do not implement a careful strategy. One of the potentials of the Edi is to provide us with a parameter that gives us additional valuable information about how the patient is progressing through this critical phase.

Has it been difficult to teach other ICU staff members in regard to the concept and application of NAVA?

Dr Suarez Sipmann: We educated the entire staff, and made clinical sessions

for nurses and physicians to explain about the concept and the principles of this new mode. Regarding the nurses, one critical aspect was to emphasize the importance of the proper positioning of the catheter combining its use as a conventional nasogastric tube and as a sensor for the diaphragmatic electrical signal. I would say that in general they were quite positive about the ease of handling and positioning of the catheter. In their experience with the usual patient mobilizations, the catheter continued to provide reliable signals in most of the circumstances. We also had discussions about potential indications and advantages over the conventional modes. Aspects of the triggering, cycle on and cycle off criterions and the way NAVA provides inspiratory assistance were discussed in detail. The general attitude has been positive and the good response observed in most of the patients has created a great interest.

What advice and recommendations would you give to other ICU colleagues that are interested in using NAVA?

Dr Suarez Sipmann: As already mentioned, first you must be clear that it is a new conceptual approach, which means a new way of applying an assisted ventilation mode and to look at the patient and the ventilator signals you obtain. You have to be in an open mindset to be willing to incorporate a new mode and make the effort in understanding its principles and differences to other conventional modes. This willingness to understand and to test a new mode must be there, and the basic assumption that this has the potential to improve patient management is essential for the initial acceptance. Next, I would be very cautious with the indications at the beginning, especially for those with more limited experience with mechanical ventilation. It would be important to define its indications more precisely and let physicians increase their comfort and knowledge under these better known situations progressively. There is a risk with NAVA as a new mode with so many potentially interesting aspects, to have the temptation to test it in all possible circumstances to start out

with, but I foresee that for those who want to try every potential aspect of NAVA in the beginning especially in complex patients, it may be discouraging as there are still many aspects we need to learn from this new mode. The introduction of new approaches in clinical practice must be cautious and demands an effort to continuously learn and gradually discover its true potential clinical benefits. Again experience must be gained in a stepwise fashion. With NAVA I see a parallel to lung protective strategies and Open Lung, if you believe that it can improve patient management, then it is important to ease the path for its understanding and acceptance and make a joint effort to learn in the beginning, before increasing the complexity of its use. Use it in well defined situations, learn and compare it with what you are used to, when you feel comfortable and recognize essential aspects of its functionality, slowly move into other more complex areas of application.

Dr Suarez Sipmann, you have had many years international experience of lecturing and educating fellow intensivists about lung recruitment. Do you see any parallels in the challenges to adapt treatment culture from conventional pneumatic mechanical ventilation to include neurally driven ventilation?

Dr Suarez Sipmann: The major parallel is physiology. The Open Lung concept is based on sound physiological principles. The other aspect is the practical implementation of the physiological concept into patient management. I believe that NAVA is very much the same, if you really make the effort in understanding how it works and the physiology behind it; it is a very attractive concept. Perhaps I am biased, but I think that principles based on sound physiology related to the specific patho-physiological context should be beneficial to the patient if implemented in a rational therapeutic strategy. The difficult process is always defining how to implement it in a way that is useful and applicable in clinical practice. But the main similarities are these two: – very solid clear and attractive physiological principles, and the

difficult process in moving from theory into clinical practice.

Which other research opportunities do you see with the clinical application of NAVA in the coming years?

Dr Suarez Sipmann: Everything needs to be studied in detail, I think the potential for research is enormous, as there are so many new aspects that are important to study with NAVA. I think many of us have our particular interests in this respect; and there will be a good multiplication factor as soon as the technology is being used in more and more centers, since this will trigger research on a broader scale. I think

whatever interesting aspect of the entire NAVA concept you choose needs to be studied in more detail during its clinical application. We have not yet touched on non-invasive, there I think NAVA will truly offer important advantages and I think a lot of research needs to be done in this area as well. The unique triggering mode independent of leaks, the way the breath is supported, proportional to the electrical activation of the diaphragm which is in direct relation to the central inspiratory drive and is subjected to a central feedback control, offers very exciting options. If NAVA can provide more information on how to improve and adapt non-invasive support to the patients, it could be a breakthrough in non-invasive mechanical ventilation. ■

Biography

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 course of his studies in medical school, he also participated in hospital rotations in Internal Medicine at Ruprecht-Karls Universität, Heidelberg, Germany in 1986, and in Cardiology at the same institution in 1987, as well as Internal Medicine at the Sankt Anthonius Hospital in Cologne, Germany in 1989. During the years of 1991 and 1996, he worked at Fundación Jiménez Díaz Hospital in Madrid with primary specialization in Intensive Care Medicine and 2 year general rotations in Anaesthesia, Internal Medicine and medical-surgical specialties. He also was on rotation at the Department of Anaesthesiology and Critical Care Medicine of the University Hospital Rudolph Virchow of the Free University of Berlin, Germany in 1995.

He obtained his specialization certification in Intensive Care Medicine in 1996, and has been employed as Consultant Specialist in Intensive Care Medicine at the Fundación Jiménez Díaz tertiary care teaching University Hospital in Madrid ever since.

Fernando Suarez Sipmann is internationally known for his research in intensive care, with participation in over 18 originally published studies, over 60 published abstracts and preliminary communications as well as numerous book chapters in various medical publications. His teaching experiences have been ongoing since 1994, and include doctoral and post-graduate courses as well as various workshops. Dr Suarez Sipmann is well-known within the lecture circuit, and has been invited speaker, main lecturer or chairman in over 40 international congresses, symposia and other venues during the past ten years.

Dr Paloma Gonzalez Arenas attended Universidad Complutense de Madrid where she received her degree in medicine in 1991. She obtained her intensive care training at Fundación Jiménez Díaz from 1993 to 1997. She worked at the General Hospital of Segovia, and the Politrauma Unit in Madrid thereafter.

Dr Paloma Gonzalez Arenas returned to Fundación Jiménez Díaz in 1999 as Consultant in Intensive Care Medicine, and has recently started working at the Hospital Infanta Sofia in Madrid.

References

- 1) Suarez-Sipmann F, Bohm SH, Tusman G, Pesch T, Thamm O, Reissmann H, Reske A, Magnusson A, Hedenstierna G. Use of dynamic compliance for open lung positive end-expiratory pressure titration in an experimental study. *Crit Care Med* 2007; 35(1): 214-221.
- 2) Miranda DR, Gommers D, Papadakos PJ, Lachmann B. Mechanical ventilation affects pulmonary inflammation in cardiac surgery patients: the role of the open-lung concept. *J Cardiothoracic Vasc Anesth* 2007; 2: 279-284.
- 3) Papadakos PJ, Lachmann B. The open lung concept of mechanical ventilation: the role of recruitment and stabilization. *Crit Care Clin* 2007; 23(2): 241-250.
- 4) Tusman G, Suarez-Sipmann F, Bohm SH, Pech T, Reissmann H, Meschino G, Scandurra A, Hedenstierna G. Monitoring dead space during recruitment and PEEP titration in an experimental model. *Intensive Care Med* 2006; 32(11): 1863-1871.
- 5) Tusman G, Areta M, Clemente C, Plit R, Suarez-Sipmann F, Rodriguez-Nieto MJ, Peces-Barba G, Turchetto E, Bohm SH. Effect of pulmonary perfusion on the slopes of a single-breath test of CO₂. *J Appl Physiol* 2005; 99(2): 650-655.
- 6) Reissmann H, Bohm SH, Suarez-Sipmann F, Tusman G, Buschmann C, Maisch S, Pesch T, Thamm O, Plumers C, Schulte am Esch J, Hedenstierna G. Suctioning through a double-lumen endotracheal tube helps to prevent alveolar collapse and to preserve ventilation. *Intensive Care Med* 2005; 31(3): 431-440.
- 7) Tusman G, Bohm SH, Suarez-Sipmann F, Turchetto E. Alveolar recruitment improves ventilatory efficiency of the lungs during anesthesia. *Can J Anaesth* 2004; 51(7): 723-727.
- 8) Suarez-Sipmann F, Bohm S, Lachmann B. Clinical perspectives of "the open lung concept". *Minerva Anestesiol* 1999; 65(5): 310-312.
- 9) Amato MBP, Barbas CSV, Madeiros DM, Magaldi RB, Schettino GP, Lorenzi-Filho G, Kariralla RA, Deheinzelin D, Munoz C, Oliveira R, Takagaki TY, Carlvahllo CRR. Effect of a protective ventilation strategy on mortality in the acute respiratory distress syndrome. *N Engl J Med* 1998; 338(6): 347-354.
- 10) Amato MB, Barbas CS, Mediros DM et al. Beneficial effects of the "Open Lung Approach" with low distending pressures in acute respiratory distress syndrome. A prospective randomized study on mechanical ventilation. *Am J Respir Crit Care Med* 1995; 152: 1935-1946.
- 11) Lachmann B. Open up the lung and keep the lung open. *Intensive Care Med* 1992; 18(6): 319-321.
- 12) Sinderby C, Beck J, Spahija J, de Marchie M, Lacroix J, Navalesi P, Slutsky AS. Inspiratory muscle unloading by neurally adjusted ventilatory assist during maximal inspiratory efforts in healthy subjects. *Chest* 2007; 131(3): 711-717.
- 13) Emeriaud G, Beck J, Tucci M, Lacroix J, Sinderby C. Diaphragm electrical activity during expiration in mechanically ventilated infants. *Pediatr Res* 2006; 59(5): 705-710.
- 14) Beck J, Weinberg J, Hamnegard CH, Spahija J, Olofson J, Grimby G, Sinderby C. Diaphragmatic function in advanced Duchenne muscular dystrophy. *Neuromuscul Disord* 2006; 16 (3): 161-167.
- 15) Spahija J, Beck J, Lindstrom L, Begin P, de Marchie M, Sinderby C. Effect of increased diaphragm activation on diaphragm power spectrum center frequency. *Respir Physiol Neurobiol* 2005; 146 (1): 67-76.
- 16) Beck J, Tucci M, Emeriaud G, Lacroix J, Sinderby C. Prolonged neural expiratory time induced by mechanical ventilation in infants. *Pediatr Res* 2004; 55(5): 747-754.
- 17) Sinderby C. Ventilatory assist driven by patient demand. *Am J Respir Crit Care Med* 2003; 168(7): 729-730.
- 18) Navalesi P, Costa R. New modes of mechanical ventilation: proportional assist ventilation, neurally adjusted ventilatory assist, and fractal ventilation. *Curr Opin Crit Care* 2003; 9(1): 51-58.
- 19) Beck J, Gottfried SB, Navalesi P, Skrobik Y, Comtois N, Rossini M, Sinderby C. Electrical activation of the diaphragm during pressure support ventilation in acute respiratory failure. *Am J Respir Crit Care Med* 2001; 164(3): 419-424.
- 20) Sinderby C, Spahija J, Beck J, Kaminski D, Yan S, Comtois N, Sliwinski P. Diaphragm activation during exercise in chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2001; 163(7): 1637-1641.
- 21) Sinderby C, Spahija J, Beck J. Changes in respiratory effort sensation over time are linked to the frequency content of diaphragm electrical activity. *Am J Respir Crit Care Med*. 2001; 163 (4) 905-910.
- 22) Yan S, Sinderby C, Bielen P, Beck J, Comtois N, Sliwinski P. Expiratory muscle pressure and breathing mechanics in chronic obstructive pulmonary disease. *Eur Respir J* 2000; 16 (4), 684-690.
- 23) Sinderby C, Navalesi P, Beck J, Skrobik Y, Comtois N, Friberg S, Gottfried SB, Lindstrom L. Neural control of mechanical ventilation in respiratory failure. *Nat Med* 1999; 5(12): 1433-1436.



Kim Watkins RRT, and NICU nurse Janet Wyatt attending to a newborn premature patient.

Challenges and opportunities in respiratory therapy for neonatal intensive care patients

The neonatal intensive care unit of Swedish Hospital in Seattle is one of the largest centers of the kind in the northwestern United States, with over 700 neonatal patients admitted during 2006. They have seen major developments within perinatal and neonatal intensive care during the past decades. In recent years they have successfully implemented a new low volume ventilatory strategy for their premature infant patients.

Critical Care News discussed these developments and new strategies with Kim Watkins, RRT-NPS, Clinical Coordinator of Respiratory Therapy, the Neonatal Intensive Care Unit of Swedish Medical Center.

When treating pre-term infants with invasive ventilation modes, which modes or methods do you frequently use?

Our primary mode of ventilation is Pressure Regulated Volume Control (PRVC) and we have chosen to use a low-volume strategy. We typically target our volumes around 5 ml per kilo on each baby, so it is very individualized. We use a shorter inspiratory time of 0.3 seconds and a typical set respiratory rate of 30-40 and then we titrate their FiO_2 based on their O_2 saturations.

We started targeting volumes in 2002, so essentially we have been using this strategy for the last 5 years. Prior to that we were using some volume ventilation, but it was not specifically measuring that low volume target. It was more a question of pressure controlled ventilation, which is more traditionally used to ventilate micropreemies. Currently, we use Automode to determine extubation readiness, it is a really good indicator of how much the baby can trigger and if their own inspiratory time is enough. We have already been ventilating them on a low tidal volume, but we use Automode to be assured that they will not become apneic. Apnea is the number one failure for these babies, so that is why we use Automode. We started using Automode when it first appeared in the SERVO 300A ventilators. Prior to the development of Automode, we used PRVC, but we had to use Volume Support to determine extubation readiness which was frustrating because every time they exceeded the trigger time out limit, which was not adjustable at that time they defaulted back to PRVC, and it would alarm until the practitioner reset it. We were very excited when Automode was refined and put into the SERVO-i, but it was not perfect yet, since the trigger time out phase was still pretty short, as we just didn't find that 7 seconds was long enough to evaluate the baby. When the software was upgraded to allow a trigger time out of 15 seconds we were thrilled, as we feel this gives us a good sense if the patient will have significant apnea once extubated. With the current software in the SERVO-i, all our infants, regardless of weight, can trigger the ventilator.



Kim Watkins, RRT is currently Neonatal/Pediatric Coordinator of the Respiratory Care Department of Swedish Medical Center.

Have you had any history of using synchronized intermittent mandatory ventilation (SIMV) here?

Yes, and on occasion we will still use SIMV, as well as Pressure Control and Pressure Support ventilation, typically babies that require SIMV with PC and PS tend to be a lot sicker. We are pretty proud that we don't get a lot of chronic lung disease. Chronic lung disease still exists but not as we used to define it, meaning ventilator dependent, they are still oxygen dependent but not ventilator dependent. The infants who are managed on SIMV, PC, PS are typically septic and need a lot higher pressure support, but as soon as they start healing and improve, we try to get them back to PRVC as soon as we can. We really like to control those volumes. And as soon as they are stable on PRVC with tidal volumes approximately 4-6 ml/kg, and we establish that they are at a point where they are triggering the ventilator, and their FiO_2 is at a low enough point we assess their readiness for Automode, as part of the weaning process.

Do you utilize rise time to create laminar flow?

We set this parameter per individual patient comfort. Most of our neonatal patients do well with the same setting of 0.15 seconds. However, at times there are a few outliers who need adjustments to this setting.

What is your opinion in regard to cycle off criteria, to reduce work of breathing?

In regards to inspiratory cycle off, that is actually a more important feature that we use when they are in a supported mode of ventilation, Volume Support or Pressure Support. We usually start at a 5% inspiratory cycle off, we basically want them to get their entire tidal volume since we are in a low volume state anyway. When we see signs of asynchrony with the ventilator or if they develop an air leak, as these infants with uncuffed endotracheal tubes often do, we start fine-tuning our inspiratory cycle off, so that you don't have those long delays. For instance, the baby we were assessing for extubation readiness this morning had a 50% air leak, so I set his inspiratory cycle off at 50% and it did not compromise his ventilatory needs and he was much more in synchrony and more comfortable.



Kim Watkins, RRT and Janet Wyatt, RN, in the neonatal intensive care unit of Swedish Medical Center, Seattle.

In regard to the 24 hour trends on the ventilator, which parameters do you feel are the most valuable?

For this unit, as far as trending is concerned, we typically only utilize it when they are in Automode and when we are evaluating extubation readiness. We evaluate the respiratory rate parameter on the trending menu.

If it is a post op surgical baby, we might only look at the trend from the last hour to 2 hours, just to see if they are triggering the ventilator. For some of our micropreemies we look at monitoring for over a 24 hour period. For example, if we were thinking of putting them on Automode today, I would start looking at the trends for the next three hours, and the next morning, we might look at the window over 12 or 24 hours, to see if they are continuously triggering, or if there have been relapses to PRVC. If you

determine there are some time periods of concern when the infant relapsed to PRVC, we need to collaborate with our nursing team and evaluate the time period and if it coincided with sedation or handling. If there was nothing in particular, and a lot of periodic breathing, maybe they are not ready to be extubated.

So you are not monitoring CO₂?

We do have the capability of doing mainstream CO₂ monitoring, but we haven't found that it is the most valuable tool for what we want to do. We typically base our ventilator changes on blood gases.

How do you address the challenges of leakage?

There is potential if a patient has a

significant leak, that autocycling can occur. If we have a situation like this we may adjust our trigger flow and occasionally increase the rise time. For a patient we had this morning, we had already dropped his trigger sensitivity flow to 2, and that has stopped any autocycling from occurring. If this air leak is positional, then the practitioner needs to be cautious because any time you change your trigger flow, the patient might not trigger the ventilator in another position. The other adjustment we make is to the inspiratory cycle off during patient supported modes of ventilation and asynchrony. If an air leak is present in one of our patients, we acknowledge it; assess ventilation and/or oxygenation and readiness for extubation. If the air leak is significant and compromising our ability to ventilate or oxygenate then we may reintubate with a larger endotracheal tube. But this is very rare.

Is the Y-sensor utilized for tidal volume verification, and if so, how is it used?

Whenever we are initiating ventilation, we always use the Y-sensor. We get the baby's weight, and we establish what we want for range between 4-6 ml per kilo. We will get a blood gas and see where we are at, and how we will titrate from there. We will also do spot checks on verification of tidal volume.

How do you address trigger time-out with Automode in the NICU?

Our standard default is 15 seconds with the latest software, and that we feel is really essential to give a clear picture of where we have consistent breathers, rather than periodic breathers with long periods of apnea. Apnea is the number one reason to reintubate, so we tend to load them with caffeine, to help them keep up that breathing. Very rarely do we lower our trigger time-out to be less than that, since if they are failing to trigger at 15 seconds, they are not ready to wean, so we put them back into PRVC.

What are your policies in regard to suctioning and oxygenation?

Suctioning is used as needed, we use in-line suction catheters, and only suction to measured depths of a half centimeter beyond the tracheal tube. We tend not to pre-oxygenate. If a baby is tending to decompensate, or desaturate with suctioning we will use the suction support mode and have the preoxygenation set at 5% above baseline. We do not lavage with saline; we only use saline for oral care or to rinse out the catheter. Saline has a potential to wash any colonization that is in the endotracheal tube into the lungs, so we want to avoid that.

In regard to oxygenation, our delivered FiO_2 is determined by oximetry, we have targets and we have limits. The limits are when the oximeter is going to alarm, and the targets are ideally where we want their O_2 saturations. Our oximetry limits and targets have just been adjusted this year based on COMP-ROP. COMP-ROP stands for Comprehensive Oxygen



Kim Watkins, RRT.

Management for the Prevention of Retinopathy of Prematurity. We rarely have to do surgery on retinopathy of prematurity, but we still do get a few rare cases. Basically all of our infants who are admitted born at 34 weeks or above have limits set at 85% SpO_2 at the low end and 100% SpO_2 at the high end, with a target between 92 and 97% SpO_2 . The babies that are born under 34 weeks have a limit set at low end of 80% SpO_2 and the high end of 95% SpO_2 with a target of 85 to 92% SpO_2 . That 34th week is a cut off for which scale you are in. Since we have initiated COMP-ROP the majority of our babies

are on low oxygen concentrations. It will be interesting to see when they evaluate the data, how we made progress in retinopathy of prematurity, and what has happened with everything else, status of chronic lung disease for example. All of our blenders at the bedside are set at about 10% O_2 above what their baseline FiO_2 delivery is.

What is your procedure for internal transport for the ventilated babies?

If we have to go to surgery, MRI or CAT scan, we put them in a transport



Kim Watkins, NICU Medical Director Terrence J Sweeney MD and other NICU staff members at Swedish Hospital.

incubator and we support them using the Cross vent 2i, and have volume ventilation with a pneumotach, so we measure our volume with the same settings as the SERVO-i ventilator. All our x-rays are done by portable scans, so we are able to keep them on the SERVO-i ventilator.

Can you describe the weaning process you utilize, criteria for initiating weaning, and how you determine appropriate time for extubation?

We typically wean per blood gases, and by maintaining those low volume strategies, we look for the FiO_2 to be essentially less than 30%, our peak inspiratory pressures that are generated by our low target volume to be less than 17 cm of water pressure. We are usually pretty generous with PEEP and it is usually around 5-6 cm H_2O , which is probably another reason why we are able to keep our FiO_2 so low. We have not had any instability from using PEEP at about 6 cm H_2O . When they have reached those settings, and their ventilation status is stable, i.e. their pH status is between 7.25 and 7.35, and their CO_2 is between

50 and 60 mmHg, we consider their blood gases to be stable. We will then assess them to switch to Automode, and we will watch their trending for 2 to 12 hours, and if they are not apneic, we pull the endotracheal tube. In other cases, we observe the trend for about 24 hours to be certain before extubation. Especially in cases with very low gestational age, we want to be certain that they can maintain spontaneous breathing before we extubate. Our goal for babies less than 28 weeks is to assess within 3 days of intubation, and then our goal is to extubate them by day 7. Most of the low birth weight babies are extubated, and are maintained on nasal CPAP for a long period of time, in most cases for many weeks. For babies over 28 weeks gestational age, we have a goal to get them extubated as soon as possible. It could be a matter of getting them intubated, giving them surfactant, and getting them extubated within hours or it could be longer, depending on the reason why they were intubated in the first place. If intubation was due to Infant Respiratory Distress Syndrome (IRDS), they are probably more rapid to wean; if it was due to sepsis, abdominal defects

or for a surgical patient, more ventilation time is involved.

What is your average extubation success rate?

Our extubation success rate on babies over 30 weeks is probably in the high 90% range, in maintaining and not having to reintubate, depending on their disease process. We usually do not use nasal CPAP on these babies, if they are intubated for IRDS they typically don't need to be supported on nasal CPAP. For babies under 30 weeks, they might need short term support on nasal CPAP, for example a 28 week baby might need nasal CPAP one week post extubation. The younger gestational ages, the higher the risk of extubation failure; statistically at 1-3 days we have a 70% success rate of extubation. At the second or third day, there are many circumstances giving reason for reintubation. Overall, for 28 weeks and below, the extubation success rate is about 48 to 50%. The number one reason for intubation is apnea. Sepsis is also a factor for higher risk of reintubation. They are at risk for so

much, the younger they are. On average, 50% is our success rate for the Early Low Birth Weight Infant. If an extubation criterion is met successfully, and they can be extubated for longer than 7 days, we can typically manage them on nasal CPAP. If they do need reintubation, we go right back to the low volume strategy to keep it as protective as possible.

Is surfactant therapy used regularly in the NICU, and how?

In 2001, we took on a delivery room approach. Our protocol is we take surfactant with us for any delivery of gestation of 30 weeks or under. We estimate the weight, intubate and we administer surfactant to all infants under 28 weeks. We ventilate them with Neopuff at low pressures, 20 peak inspiratory pressure over 5 PEEP, and initiate our FiO₂ in room air, and place on an oximeter. We will only increase our FiO₂ if the saturations are below 80% and add O₂ in 5% increments to get saturation to over 80% and rising. We use the Neopuff during transport in an incubator up to the NICU, and put them on our low volume strategy. For re-dosing, a second dose surfactant can be given if their FiO₂ is greater than 30%. We re-dose every 6 hours for up to 48 hours. For the babies outside that window, from 28 to 30 weeks, if they are showing signs of respiratory distress we will intubate them and assess their need for surfactant.

Exactly how is non-invasive ventilation therapy utilized in the NICU?

In addition to nasal CPAP, we do have the SERVO-i non-invasive ventilation mode and we have used it on separate occasions, in PC mode. We use it on babies who have failed their extubation, at their second or third attempt. We don't want to reintubate them, but know they need a little stimulation, so we use it at low pressures, 14-16 cm H₂O at a PEEP of 4-6 cm H₂O, respiratory rate of 10 and 0.4 s inspiratory time. In those cases, the babies have done well, and we have used the Fischer Paykel humidifier and application device. We use nasal CPAP very diligently and have great compliance

by our staff. But non-invasive utilizes a different technique and in order to use it successfully it requires diligence, skill and regularity.

Are you using high frequency oscillation ventilation?

Yes, prior to our current protocol, our practice was to admit the babies less than 28 weeks from the delivery room to the NICU, on HFOV. But when looking back at the data, we did not find that it was any more beneficial with HFOV than a low volume strategy on the conventional ventilator. I was confident with the latest software that our volumes would be low enough for these babies, and that our alarm settings would be adequate. One of our concerns was autocycling, so we just set our upper respiratory rate alarm tightly, so with any deviation we would catch it right away.

HFOV is a great rescue ventilator, but I don't think it is necessary for all patients. It is a matter how to best manage these micro-preemies, which we have found possible with the conventional ventilator with a low volume strategy.

Do you utilize nitric oxide therapy?

We basically are very strict and only use it for persistent pulmonary hypertension, and not for any other indication. The research is not there, and we stick to what we know.

What in your opinion are the biggest challenges in regard to mechanical ventilation therapy in neonates? You have worked 22 years so you have seen a lot, are the challenges today different?

The challenges today are still focusing on the goal of extubation as soon as possible. It is certainly easier to keep the babies intubated, but it is not the best for them. That is a cultural challenge, and you have to be dedicated to wanting to get the babies extubated, and staying on your protocol. I think we have done a good job of working with our low volume strategy, and our delivery room management and our FiO₂ criteria; these all work together

to prevent ventilator induced lung injury. The challenge is staying focused on extubating these infants, and keeping them extubated. The other challenge is to have an acutely ill baby who might have a lot of complex changes, to find the correct ventilator settings for his acid base balance, without inducing injury. That is a challenge. Our goal is create no harm.

But treatment is advancing, and today we can accomplish many things that would have not been possible in the past. Right now we have a 600 gram baby who is 16 days old, who was born at 25 weeks gestation, and we only had her intubated and ventilated with SERVO-i for a day and a half before she was extubated. She has not been reintubated but has managed well on nasal CPAP since then. We also have another baby who is 24 weeks gestation, less than 500 grams, who has not been reintubated but managed on nasal CPAP since extubation.

Based on your experience from the past years and challenges, what do you perceive in the future will be fundamental in respiratory therapy in the NICU?

Definitely enhancing non-invasive products and interfaces as far as pre-mature infants are concerned, or even how the pediatric population is concerned. They must be expanded and improved. We attempt non-invasive ventilation but it has not taken hold in the NICU because we want the babies to trigger, and it is difficult in non-invasive. In this respect, we know that Neurally Adjusted Ventilatory Assist - NAVA is coming and will be definitely interesting, also in terms of the aspects of leakage that we have discussed. A lot of people don't understand that these premature babies are capable of triggering the ventilator but they certainly can. Our smallest baby we have had triggering on the SERVO-i was about 490 grams. She did well, had no troubles triggering the ventilator, and we kept the low volume strategy. She was 25 weeks gestation. She was initially extubated by day 7, but one of those micropreemies that we had to reintubate later, due to apnea. Long term nasal CPAP for up to 4 or more weeks is no problem at all, but maintaining on NIV is a challenge.



Kim Watkins and Terrence J Sweeney, MD, Medical Director of the Neonatal Intensive Care Unit, Swedish Medical Center, Seattle.

Critical Care News discussed organizational and operational issues with Kim Watkins, RRT-NPS, and Dr Terrence J Sweeney, MD, Director of the Division of Neonatology at Swedish Medical Center.

Could you tell us something about the historical background and development within the NICU operations at Swedish Hospital?

Dr Sweeney: Probably half of Seattle was born here at Swedish Hospital. It is an old hospital, and was known as Doctors Hospital quite some time ago. It was consolidated with Swedish, which was founded by a fellow named Nils Löfgren, a Swedish hospital for a

group of Swedish physicians. We had a grand opening of our NICU and labor and delivery unit a few years back, and offered the community a chance to send in pictures and stories. This resulted in an 80 year retrospective of all the people born here, and all the hospital corridors were lined with the photographs.

What development within the NICU organisation have you personally experienced?

Dr Sweeney: I started here in 1985. I was in Stanford for training prior to that, and I came here in 1985, and I have been here ever since. We started keeping ventilated patients about 3 months after I started here.

Our NICU at that time would be considered a level 2 nursery by today's standards. We kept babies on oxygen,

who needed extra monitoring and intravenous therapy, but without any ventilator support. We have such a large presence of perinatal specialists here, they needed a more robust neonatal environment, so that is why we started to become a level 3 nursery to support them, and that relationship has continued over the years since they are the primary gateway to the institutions. Most of our babies arrive here in utero to the perinatal program and are delivered here. A very small number, less than 10%, are born outside and transported here. The majority of our babies are born here because of the maternal program.

When you first started, what size were the babies at that time?

Dr Sweeney: At that time it was rather unusual to have babies do well at 25-26



Dr Terrence J Sweeney has been on staff at the Swedish Medical Center in Seattle since 1985.

weeks gestation. A few of the babies were that size even back then, but with the advent of surfactant and certain ventilation modes, we could start to expect some reasonable outcomes at 24-26 weeks, before that it was really case by case.

What is the patient capacity and patient volume of the Swedish Hospital NICU on an annual basis?

Dr Sweeney: We have 30 beds in our main NICU, and we have 31 beds in our Level 2 Infant Special Care Nursery, or 61 beds in total, with overflow capacity to some of the pediatric wards. We are at a capacity of between 40-50 beds here on a general basis, at any given time. This is the biggest center in the region, if you combine the perinatal and neonatal program here.

Could you tell us about the geographical patient uptake area for the NICU?

Dr Sweeney: Our main area is the region west of Seattle, up to the Canadian border, and to mid-state around Centralia, with quite a large population density and delivery base in this area. There are some intra-state transports here; we get some mothers down from Alaska, and some mothers from Canada, due to the shortage of beds in certain regions. Some moms come from as far away as Oregon and Montana, but this is less common since there are large perinatal programs closer to them, in Spokane, for example.

What are the most frequent clinical situations that are encountered in the NICU patients?

Dr Sweeney: I would say prematurity certainly by the numbers. The largest single group of patients we have, and the group 10-16 weeks premature are here for a long period of time. Nearly all our infants, for the larger babies, the stay is typically 1.5 to 2 weeks, depending on gestational week born. Smaller babies are considerably longer, in the range of 8-12 weeks for the micropreemies. We are the womb for them for that considerable amount of time.

Could we have a description of the NICU department staff, in number of staff members, positions and areas of responsibility?

Dr Sweeney: We have about 140 nurses for the amount of babies we have. We have around 6 neonatologists on staff, and another 6 who are on part-time



The low volume ventilation strategy has been in use for the past few years in the NICU at Swedish Medical Center in Seattle.

basis. We have a staff of 7-8 nurse practitioners who work side by side with us, who are doing procedures on babies and covering deliveries and daily care. A few other staff members include dietitians in the two nursery care settings, three social workers dedicated just to our parents and babies, staff of physical and occupational therapists who are specialised in pediatric patients and are on a weekly basis, speech therapists who help with feeding issues, pastoral support, discharge coordinators, so we are a pretty large team when we are all here in full force. We have 2 dedicated pharmacists, right on the floor here, and at least 2 NICU respiratory therapists 24 hours a day. Most of the resources are pretty close at hand.

What is your nurse to patient ratio?

Dr Sweeney: It varies, for our sickest babies it might be 1:1 or rarely 2 nurses to one baby. Typically in less severe cases, the ratio is about 3 babies per nurse. In the step down level, it might be 3-4 babies per nurse, as they are getting ready to go home.

How many respiratory therapists do you have on staff?

Kim Watkins: We have 22 RT's on staff, who are trained to our NICU. In the NICU we have 2 respiratory therapists on shift 24 hours a day. We go to all deliveries that are moderate to high risk,

and this keeps us busy since we are a big perinatal high risk center. We help with rescues in the delivery room.

How do you maintain training and continuing education for the respiratory therapist staff members?

Kim Watkins: On an annual basis we conduct a four hour skills day, for respiratory therapists, about the holistic package in neonatal and pediatrics. In addition, on a monthly basis, I produce a newsletter for my group, with at least one educational component in it. My current issue is focusing on the neonatal group, and the strategy to prevent ventilator induced lung injury. It is so

involved that I need to do it in 2 parts, I usually list frequently asked questions at the end. For any new protocols or procedures we schedule in-services for the staff. There are also lots of other educational opportunities throughout the year, regional seminars and workshops, for example.

On training to specific ventilation modes, MAQUET has been offering a lot of training. Our adult ICU respiratory therapy group is divided between 2 different types of ventilators, but they are replacing with SERVO-i, so they are being in-serviced. We recently provided three super-user classes, 4 hours in length from the NICU to the adult ICU therapist, with 10-15 attendants which was very beneficial on a peer-to-peer basis. We talked a lot about non-invasive, and ventilator graphics, fine-tuning points like inspiratory cycle off and weaning, as well as a Bi-vent lecture. We have also had a NAVA lecture for some of our physicians and staff with a positive response in the class.

Can you describe family involvement in the NICU?

Dr Sweeney: We think it is important to keep the families involved in the babies care, for the sake of the mother-father bonding, and for the baby's sake, with nutritional focus, breast milk is best, which is well known. We have a very liberal policy, parents can visit at any time of day or night and stay as long as they like. They can bring in siblings or other family members to visit the babies. As the babies get closer to going home, we have opportunities for them to stay in the hospital, with the babies, for a while before going home. This is especially helpful for multiple births, since they all usually don't go home at the same time.

Can you give us some of your experiences in regard to the development of mechanical ventilation in the NICU during your years here?

Dr Sweeney: Our unit is a long-time SERVO user. We used Bear Cubs when I first came here, a good old standard ventilator for many nurseries; we transitioned to Infant Stars for early HFO

support. As the SERVO became available, we started using those more and more as the Infant Stars phased out. We still use the Sensor Medics HFO for certain babies, but the trend in recent times is more use of SERVO in PRVC, which by far is our widest mode of ventilatory support, with Automode in weaning, as a step down from ventilation to extubation.

We have had SERVO-i here for many years, 2002 or 2003, and before that it was the SERVO Ventilator 300A. We did use the SERVO Ventilator 900C in our old unit for our chronic, larger infants.

One of the interesting side notes is that as we have changed modes of ventilation over the years, it has made the bedside ventilation adjustment and management much less complicated, which has made the physician's life a little easier. In some ways we are almost superfluous at times, which is just as it should be.

There should be fewer and fewer opportunities to do things differently and frequently, and increased opportunities to keep things per protocol and standardized. PRVC with Automode fits that really well, there is just much less to adjust in terms of pressures and rates, etc. And this is good for the babies; there are less risks of making errors. We had stepped back from using too much HFO on our smallest babies, and transitioned to volume ventilation. The big HFO seemed a little too beefy for our smallest babies, with larger risks to overshoot, and maybe not sensitive enough for the smallest babies.

Can you tell us about your patient load and category mix?

Dr Sweeney: We did 6800 deliveries last year, and are on track for 7000 this year. The NICU admitted 723 babies for 2006. We have a number of surgical cases here in addition to the preemies; we have cases of congenital obstructions, fistulas, diaphragmatic hernias and in those babies the preferred ventilation mode is the same as the preemies, PRVC. In a few cases where stiff lungs are an issue, we will use HFO, but these are exceptions. For chronic lung disease we have SIMV. In terms of surgical cases, they are probably around 10-15% of our

case load. There is a little overlap with prematurity that are surgical cases as well.

We are unique in our perinatal program, so many babies are managed optimally right from the time they get here, and are delivered here and are sent home. We have a world class ultrasound facility here, to find high risk situations and anomalies. The ability to intervene at the opportune moment is as good as it gets here. We have some advanced perinatal surgical opportunities, such as intrauterine transfusions, regional ablation for twin-twin transfusions. We are very fortunate in terms of our resources and staff competencies. ■

Biography

Terrence J Sweeney, MD, received his B.S. in Biology with a minor in Neurosciences at the Massachusetts Institute of Technology in 1975. He attended medical school at the University of Washington School of Medicine and the Bozeman WAMI in Seattle during 1976-1980. His internship/residency in Pediatrics was conducted at Stanford University Medical Center in 1983, followed by a fellowship in Neonatology at Stanford University Medical Center in 1985.

Dr Terrence J Sweeney has been on staff at the Swedish Medical Center in Seattle since 1985, and his research interest has included developing clinically practical techniques for measuring pulmonary function in premature and ill newborns. Dr Terrence J Sweeney is currently Medical Director, Neonatal Intensive Care Unit at the Swedish Medical Center.

Kim Watkins, RRT is a registered Respiratory Therapist with neonatal and pediatric certification. She has worked at the Swedish Medical Center in Seattle for 22 years, and is currently Neonatal/Pediatric Coordinator of the Respiratory Care Department of Swedish Medical Center.



Dr Lukas Brander in the Bern University Hospital ICU.

NAVA: technology evolving from bench to bedside

The Bern University Hospital - Inselspital, with origins from the late Middle Ages, is today considered one of the leading university hospitals in Switzerland. Employing over 6,000 staff members to care for over 220,000 patients annually, the University Hospital - Inselspital is also an internationally renowned centre for education and research.

Dr Lukas Brander of the Department of Intensive Care Medicine at the University Hospital - Inselspital is currently evaluating Neurally Adjusted Ventilatory Assist (NAVA), a new technology which he first experimented with during a research fellowship in Toronto in 2004–2006. Critical Care News spoke with Dr Brander regarding his experiences with NAVA, a new generation in ventilation therapy, and its progress from the early research and development phase to translation into industrial production.

Can you briefly describe the size of the Department of Intensive Care Medicine—the average number of patients and staff at your institution in Bern?

In our interdisciplinary 30-bed ICU we treat about 3300 adult, critically ill patients per year from all medical and surgical disciplines including trauma patients, but with the exception of severe burns. Roughly one third of our patients are admitted after cardiac surgery. Half of our patients are transferred to intermediate care units or to normal wards within 24 hours of admission; the other half stay for longer than 24 hours.

The ICU staff comprises 15 full-time specialists in intensive care medicine, 7 fellows in training, 8 rotating residents from partner clinics, and 164 nurses specialized in intensive care medicine. A senior ICU physician with several years of experience in intensive care medicine is on hand at the bedside 24 hours a day, 7 days a week. Professor Jukka Takala, head of the Department of Intensive Care Medicine, and Professor Stephan Jakob, head of Research, established a research program focusing on various aspects of sepsis-induced multiple organ dysfunction, with special emphasis on perfusion and metabolism within the splanchnic region, on prevention and treatment of acute lung injury, and on long-term outcome after a stay in the ICU.

From where do you receive your patients?

We get referrals from the greater Bern area, from the Cantons Valais, Fribourg, Neuchâtel, and Jura, and up to the western border of Switzerland. To the east, the next University Hospital is Zurich. A close cooperation has been established with the University Hospital of Basel.

Which types of patient situations do you most frequently encounter?

In terms of our ventilated patients, those who come from cardiac surgery and a few others are what we call “short stayers” (i.e., expected stay in the

ICU for less than 24 hours). The “long stayers” are more generally patients with sepsis, septic shock, acute lung injury, ARDS, multiple trauma including brain injuries, cerebral ischemia, or patients before and after transplantation of solid organs (including those on cardiac assist devices).

How did you come to be involved in research with Neurally Adjusted Ventilatory Assist – NAVA?

First I became involved in various projects run by the research program of our department, looking at perfusion and metabolism disturbances within the splanchnic region in a large animal model of sepsis.

Later I became interested in mechanical ventilation, since there were some indications that an injurious ventilatory strategy not only can result in ventilator-induced lung injury (VILI), but also could translate into non-pulmonary organ damage via a number of pathways. The concepts of how VILI ultimately results in dysfunction and failure of non-pulmonary organs, summarized as biotrauma, have mainly been developed and promoted by the group of Professor Arthur Slutsky at St. Michael's Hospital in Toronto, Canada. I moved to Toronto in early 2004, became involved with Dr Christer Sinderby and Dr Jennifer Beck, the inventors and originators of NAVA, and designed a project using NAVA and conventional modes of ventilation in an animal model of acute lung injury to study the effects on lung and non-pulmonary organ injury.

Later we went on with several studies looking at subject-ventilator interaction and the physiological effects of NAVA before we performed the first clinical study with NAVA in sedated, adult critically ill patients.

When I started with the group in Toronto they were using a SERVO 300 modified to deliver NAVA. Later on, the first prototypes of the SERVO-i with NAVA became available for clinical studies. For me it was a great honor and a unique experience to work with Arthur Slutsky, Christer Sinderby, Jennifer Beck, and Norman Comtois (the technician of the

group). During my fellowship in Toronto I had the opportunity to be part of the development of NAVA and to see how this technology translated from bench to the bedside. Having seen some of the hurdles during the development process and knowing that very few new technologies travel all the way from an idea to clinical application, I highly respect the achievements of the NAVA team in Toronto, especially of Christer Sinderby.

You have been conducting pre-clinical and clinical research with NAVA, most recently in patients with hypoxic respiratory failure. Are there any particular patient experiences that you can relate?

In the first clinical study, we enrolled sedated, critically ill patients with hypoxic respiratory failure stemming from a wide variety of causes. In this study there were no patients with severe ARDS, and patients with proven or suspected brain injury were excluded. The NAVA level was first titrated, and the titrated level was then implemented for a few hours. Generally speaking, already at this point in time the technology made it possible to derive information about the diaphragm electrical activity (Edi) in high quality and to use the signal to control the ventilator in patients in their normal ICU environment. We did not encounter any major problems in implementing NAVA in these patients.

Based on those experiences, and the current clinical evaluation of NAVA that you are running, what is your impression of mean or peak inspiratory pressures?

In my experience, with NAVA the patients choose lower assist levels than those clinicians would normally employ with conventional modes of ventilation.

With NAVA the patient essentially controls the ventilator, which delivers assist synchronous and proportional to his or her demand, as reflected by the Edi. Therefore, one should expect that with NAVA a number of ventilatory parameters are different from those of conventional modes of ventilation.



Lukas Brander, MD is clinical staff physician in the Department of Intensive Care Medicine, Bern, Switzerland.

By varying the Edi the patient is not only able to choose his or her individual respiratory (and hence “ventilatory”) pattern but also to control and adjust the level of assist delivered by the ventilator. We are still learning from our ongoing research, and we will have to

try to understand how such an approach impacts all aspects and parameters of mechanical ventilation.

Simply monitoring the Edi may already provide insight into patients’ breathing patterns and how the actual ventilatory

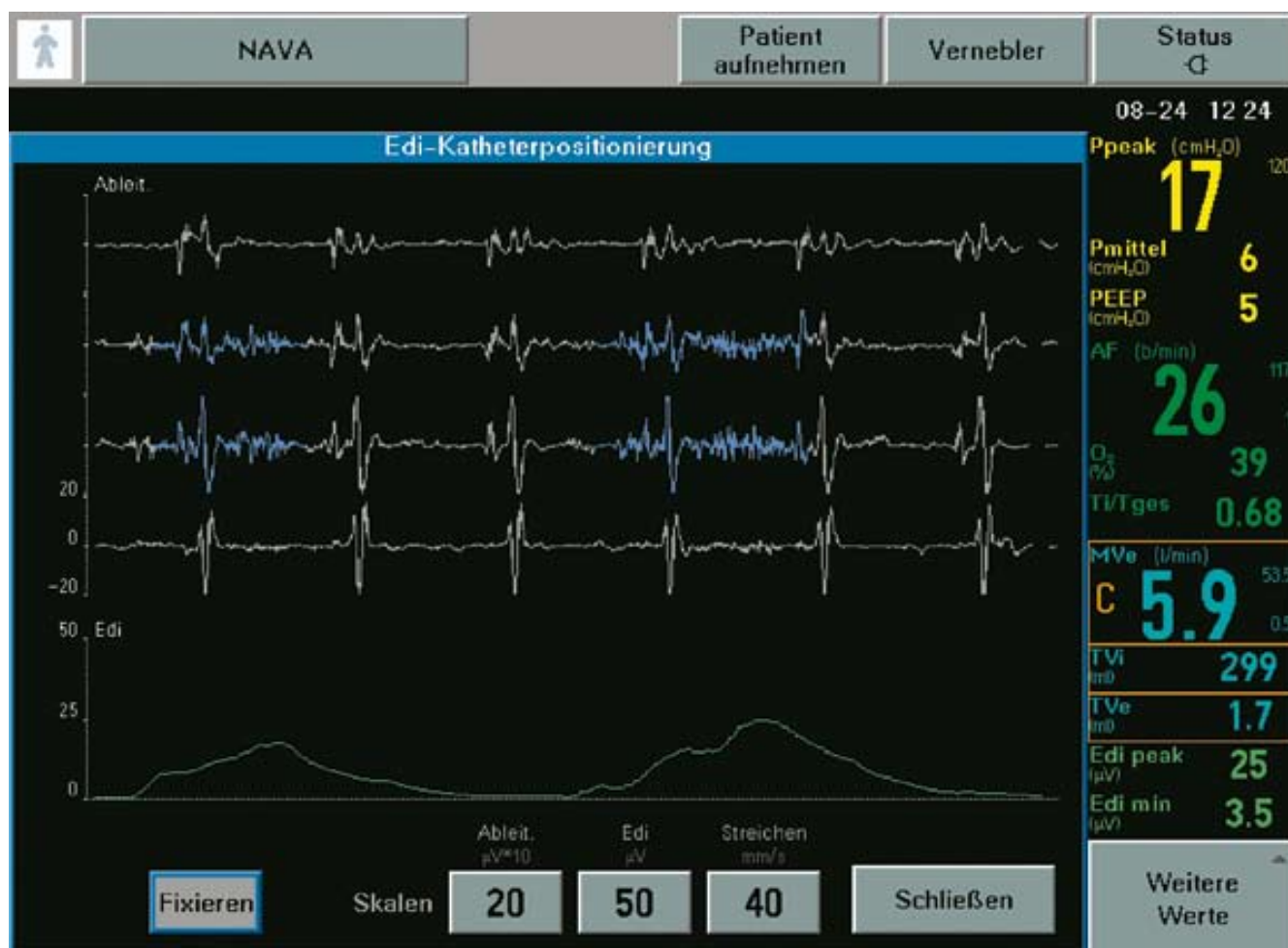
support performs in terms of synchrony and proportionality to the patient’s respiratory demand. Indeed, it is interesting to see that some patients who are ventilated with a mode that supposedly assists spontaneous breathing are actually using very little effort to trigger the ventilator (i.e., the level of assist might be too high in such patients), whereas others work much harder (i.e., the level of assist might be too low in those patients).

The Edi allows you to assess the patient’s respiratory effort on a breath-by-breath basis, to monitor changes in the respiratory pattern over time, and to detect the effects of changes in the ventilator settings on the breathing pattern. Most of this information is difficult to gain based on clinical assessment alone.

Quite a few patients whom we would consider as comfortable and being ventilated with adequate settings are not actually using their respiratory muscles. Conceptually, the respiratory muscles are designed by default to be used throughout the entire lifetime. When the respiratory muscles are not used for a prolonged period of time, disuse atrophy may develop, and resumption of the entire work of breathing during weaning and liberation from mechanical ventilation might become difficult.

Which levels of tidal volumes and respiratory rates are you observing with NAVA, compared to with other modes of mechanical ventilation?

With NAVA the ventilatory pattern is different from what you are used to see during conventional modes of ventilation. First, the variability in most parameters, such as tidal volume, respiratory rate, and inspiratory airway pressure, is higher. Often, the respiratory rate is higher, while tidal volumes and inspiratory airway pressure are lower when compared to conventional modes of assist to spontaneous breathing. Part of the lower ventilatory rate during conventional mode ventilation is explained by intrinsic reflexes in the respiratory system or by unassisted (wasted) inspiratory efforts, especially when high levels of assist are used.



Positioning of the nasogastric feeding tube (Edi catheter) that contains an array of electrodes to detect the diaphragm electrical activity (Edi) is supported by online display of the signal derived from the catheter. Progressive changes in form and amplitude of the p-wave from the most proximal to the most distal electrode and software supported detection of the Edi signal (marked in blue) help in optimizing the position of the electrode array within the esophagus.

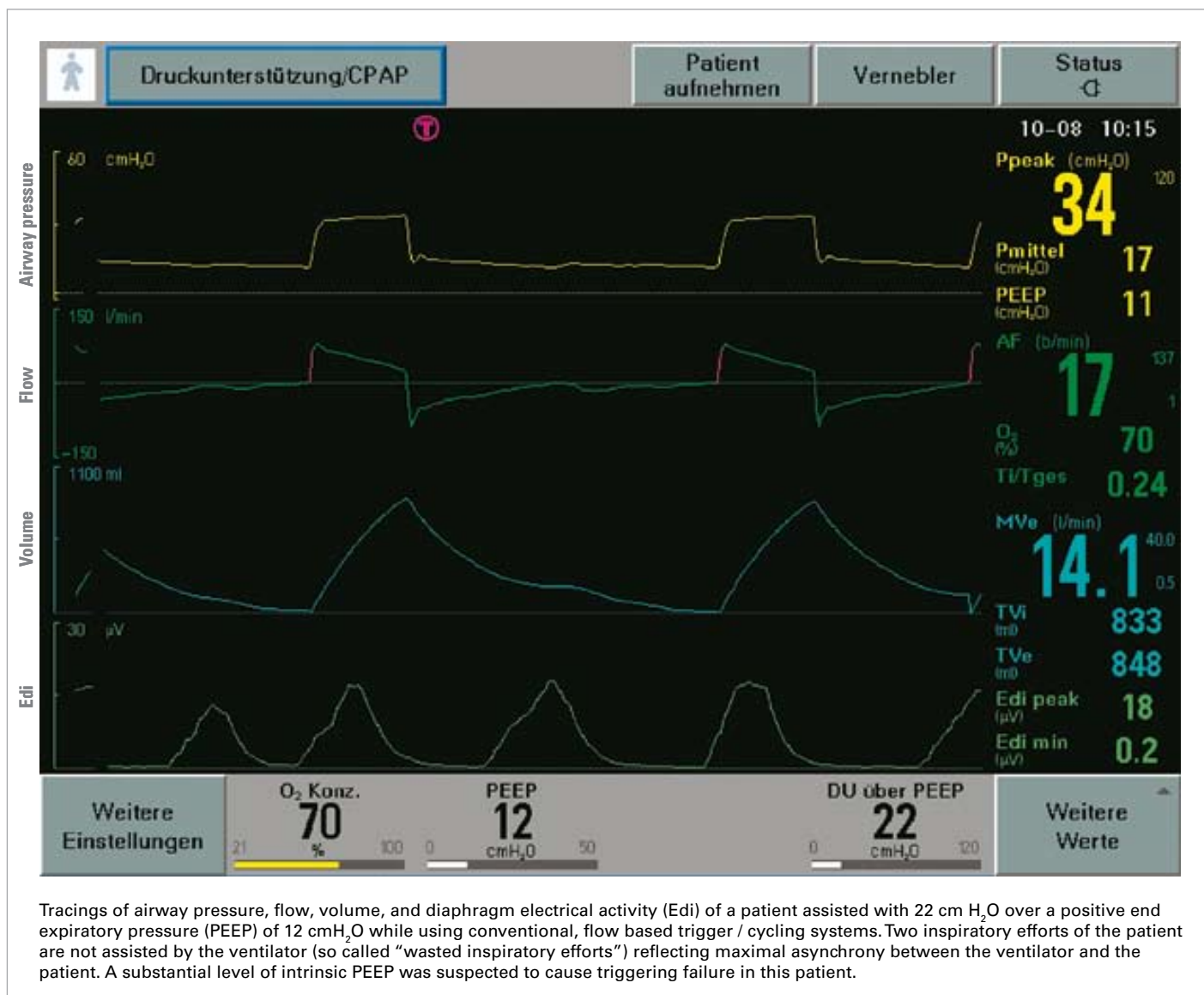
It is important to understand that the Edi is integrated in a very efficient and highly developed neural feedback system that controls breathing. Since NAVA is modulated by this feedback system, NAVA depends on the integrity of its components and on the functionality of the entire feedback system. For example, NAVA cannot be used in a patient with bilateral phrenic nerve injury or in a patient with severe damage to the respiratory centres in the brain. The functionality of the respiratory control system is also impaired in deeply sedated patients, and might be influenced by the disease process. However, in our experience, patients sedated to a comfortable level are able to sufficiently control ventilation and to limit the assist level to their individual condition. So far we have not observed

severe hypercapnia or excessive tidal volumes with NAVA. Identification of patient groups that benefit most from NAVA and those who should not be ventilated with NAVA is the focus of ongoing research.

You are currently involved in a clinical evaluation of NAVA in a series of patients. How many patients have you evaluated so far, which types of patient categories are included, and what are your impressions at this point?

At this point in time NAVA is in its infancy in terms of clinical application. In Bern we do not use NAVA in daily routine so far, but may use it in some special cases. We have enrolled roughly 30 patients in our clinical studies.

Our experience in Bern is very similar to the experience I had in Toronto with the earlier versions of the SERVO-i. We ventilated patients with a wide range of disease processes: e.g. patients with severe obstructive pulmonary disease (e.g. COPD), patients with restrictive pulmonary diseases (e.g., ARDS or severe deformation of the thorax, such as kyphoscoliosis), patients with cardiac failure and arrhythmia, and also patients without pulmonary disease. We tried to cover a range of patient conditions on purpose to learn and understand how NAVA performs under different conditions. So far we have not encountered any significant problems in positioning the Edi catheter to derive Edi and in implementing NAVA. All patients remained stable from a cardio-pulmonary perspective.



In the patients with arrhythmia, were there any difficulties in obtaining signals?

The p-wave of the ECG is used as a "lighthouse" to guide positioning of the Edi catheter to detect and derive the Edi. When there is no p-wave, as for example in patients with atrial fibrillation or atrial flutter, the positioning procedure relies mainly on the external measurement of the distance from the nose to the earlobe and then to the xyphoid. We have found that the external measurement correlates very well with the distance the catheter needs to be inserted for detection of the Edi. With the external measurements you will end up in the range of plus-minus a few centimetres of the final position. Once the Edi catheter is inserted, the positioning screen on the SERVO-i helps

to fine-tune the position of the electrode array on the Edi catheter in relation to the diaphragm.

What is your perception of patient-ventilator synchrony with regard to NAVA?

What we have so far is the data from Jennifer Beck and Christer Sinderby on synchrony with NAVA. They demonstrated in studies on animals as well as in healthy volunteers, that synchrony in terms of onset and cycling off can be improved quite substantially with NAVA when compared to pneumatically controlled modes of ventilation. The most impressive difference was found with respect to cycling off the assist. In fact, defining an adequate cycling off threshold is not always

easy based on clinical assessment of the patient alone. Also, wasted inspiratory efforts (the worst form of patient-ventilator asynchrony) are completely avoided with NAVA. Furthermore, NAVA delivers assist in proportion to the patient's respiratory demand.

Certainly, we still need to demonstrate how delivery of assist in synchrony and in proportion to the patient's demand has an impact on clinically relevant outcome parameters.

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

The Edi provides online information on



Tracings of the same patient after switching to NAVA. Each inspiratory effort of the patient is assisted in synchrony and in proportion to the electrical activity of the diaphragm (Edi). There are neither wasted inspiratory efforts nor delays in initiating (trigger-on) and terminating (cycle-off) the ventilator. Note that with NAVA, initiation and termination of the ventilator assist is entirely controlled by the Edi and is independent of the presence of intrinsic PEEP or other factors that might interfere with pneumatic control systems.

respiratory physiology that has not been available before and that is instrumental in better understanding the complex patient-ventilator interaction.

The basic principles of NAVA are very easy and intuitive. Normally, nurses, respiratory therapists and physicians get rapidly interested and involved when they understand that the patient will be able to control the ventilator and that the ventilator delivers the assist on a breath-by-breath basis in proportion to the patient's actual demand. We normally discuss the more practical issues during application of NAVA at the bedside.

First, the Edi catheter has to be positioned and kept in place. The clinical team has to learn how to identify an Edi that is of sufficient quality and quantity to run NAVA.

Similar to other signals (e.g., the arterial blood pressure), the Edi needs to be re-evaluated on a regular basis as part of the routine patient assessment.

Second, it is helpful to regard the Edi as the patient's actual respiratory demand. Once the Edi is displayed online together with "conventional" signals, such as airway pressure, air flow, and volume, it becomes easier to understand how the currently applied ventilatory settings relate to the patient's demand. We can now answer questions like: Is the assist delivered synchronous to the patient's demand? Are there wasted inspiratory efforts? Are there ventilator breaths delivered that are not triggered by the patient's inspiratory effort (i.e., false triggering)? Are we overassisting the patient?

Third, one needs to understand how the patient interacts with the ventilator when he or she is switched to NAVA.

The ventilatory pattern will be much more irregular than the uniform pressure and flow curves that we are used to seeing with conventional modes of ventilation. This will, for example, affect the way we have to set the alarm limits or how we record ventilatory parameters in our documentation systems. Then, we need to understand that the patient's respiratory drive will adjust in response to the delivered assist. For example, if the delivered assist is too low, the patient's Edi will increase in order for the patient to receive more assist during the next breath. If the delivered assist is too high, the Edi will decrease in order for the patient to receive less assist

(and hence prevent lung overdistension) during the next breath.

Is this a fundamental clinical cultural shift?

In some ways it is, in others it is not. For example, handing over the control of the ventilator to the patient is certainly fundamentally different from what we are used to doing today. It will take a while until we fully understand how such a ventilatory strategy impacts clinically relevant outcome parameters in our patients. We will have to learn which patient categories benefit most from NAVA and which patients should not be ventilated with NAVA.

On the other side, there is no need to change clinical practice. Most of my colleagues and our nurses were surprised by the stability of the Edi signal. In fact, they are normally relieved to see that the Edi signal quality is not or is only minutely affected by routine nursing activities, such as turning or washing the patient or performing physiotherapy.

Has it been difficult to teach other staff members about the concept and application of NAVA? What do you think is important to learn about capture and interpretation of Edi signals, for others who are just starting out?

It is not difficult to teach the basic principles of NAVA, but there are some adaptations in terms of the practical application. We are used to turning knobs on the ventilator to apply some airway pressure or tidal volume at some respiratory rate that we think is adequate for our patient. Today, such an approach is very fundamental to our work. With NAVA we have to learn to trust the physiology and to be confident that transferring the control of the ventilator to the patient is not only possible but also safe.

What advice would you give other ICUs that want to begin to use NAVA?

Most people working in the ICU are used



Lukas Brander, MD.

to implementing new technologies, and everybody knows their own procedure best.

For someone using NAVA for the first time, I would recommend consulting more experienced colleagues, going to seminars, using the available instructional material, or reading the published literature. One should know about the basic principles of positioning the catheter, about how to interpret the Edi, about how to choose an adequate NAVA

level, and about the modulation of NAVA by the intrinsic neural feedback system that controls breathing.

At first, I would recommend restricting the use of NAVA to more stable patients, and avoid application in the most severely ill patients in order to build confidence in the new technology. Everybody taking care of the patient must be confident with the technology, all shifts and all nurses should be able to recognize if

something goes wrong.

In summary, know the concept, start with more simple and stable cases, see that the department is educated, and gain experience.

Are there any particular patient categories which interest you in terms of gaining experience with NAVA in the future?

In general, this new strategy of mechanical ventilation provides us with the opportunity to re-investigate most

aspects of mechanical ventilation, since it is so completely different from current technology. Everything is of interest for future research. Right now we are still in the process of learning how NAVA impacts ventilatory care.

Other areas of interest for NAVA are certainly weaning from mechanical ventilation and non-invasive ventilation. Non-invasive NAVA is of particular interest, since using the Edi makes it possible to control the ventilator independent of leaks at the patient-ventilator interface, which is a relevant

problem with current technology.

At the end of the day it will be interesting to see if interesting concepts with NAVA ultimately translate into improved clinical outcomes for our patients.

Statement

The Department of Intensive Care Medicine of the Bern University Hospital – Inselspital has a research and development contract with Maquet Critical Care and was compensated for performing a user acceptance test with NAVA on the SERVO-i.

Biography

Lukas Brander, MD, graduated from the medical school of the University of Bern in 1993, and presented his MD thesis before the Faculty of Medicine at the same institution in 1997. He obtained Swiss board certification in Internal Medicine in 2001, and in Intensive Care Medicine in 2002.

Lukas Brander received Postdoctoral Research Fellowships in the Critical Care Research Program at the Bern University Hospital – Inselspital, Bern, Switzerland, under the supervision of Jukka Takala, MD, PhD, and Stephan Jakob, MD, PhD, in 2000-2004, and at the Interdepartmental Division of Critical Care, University of Toronto, Canada, under the supervision of Arthur S. Slutsky, MD, and Christer Sinderby, PhD, in 2004-2006. Lukas Brander has also received peer-reviewed research funding from several international foundations and institutions.

Lukas Brander, MD, currently holds an appointment as a clinical staff physician in the Department of Intensive Care Medicine, University Hospital – Inselspital, Bern, Switzerland. He is also team leader of the group for research in mechanical ventilation within the Research Program of the Department of Intensive Care Medicine of the University Hospital – Inselspital, Bern, Switzerland.

References

- 1) Beck J, Brander L, Slutsky AS, Reilly MC, Dunn MS, Sinderby C. Non-invasive neurally adjusted ventilatory assist in rabbits with acute lung injury. *Intensive Care Med* 2007; Oct 25: doi 10.1007/s00134-007-0882.
- 2) Sinderby C, Beck J, Spahija J, de Marchie M, Lacroix J, Navalesi P, Slutsky AS. Inspiratory muscle unloading by neurally adjusted ventilatory assist during maximal inspiratory efforts in healthy subjects. *Chest* 2007; 131(3): 711-717.
- 3) Beck J, Cammpoccia F, Allo JC, Brander L, Brunet F, Slutsky AS, Sinderby C. Improved synchrony and respiratory unloading by neurally adjusted ventilatory assist (NAVA) in lung-injured rabbits. *Pediatr Res* 2007; 61(3): 289-294.
- 4) Allo JC, Beck JC, Brander L, Brunet F, Slutsky AS, Sinderby C. Influence of neurally adjusted ventilatory assist and positive end-expiratory pressure on breathing pattern in rabbits with acute lung injury. *Crit Care Med* 2006; 34(12): 2997-3004.
- 5) Brander L, Ranieri VM, Slutsky AS. Esophageal and transpulmonary pressure help optimize mechanical ventilation in patients with acute lung injury. *Crit Care Med* 2006; 34(5): 1556-1558.
- 6) Brander L, Slutsky AS. Assisted spontaneous breathing during early acute lung injury. *Crit Care* 2006; 10(1): 102.
- 7) Emeriaud G, Beck J, Tucci M, Lacroix J, Sinderby C. Diaphragm electrical activity during expiration in mechanically ventilated infants. *Pediatr Res*. 2006 May;59(5):705-10.
- 8) Beck J, Weinberg J, Hamnegård CH, Spahija J, Olofson J, Grimby G, Sinderby C. Diaphragmatic function in advanced Duchenne muscular dystrophy. *Neuromuscul Disord*. 2006 Mar;16(3):161-7. Epub 2006 Feb 20.
- 9) Spahija J, Beck J, Lindström L, Bégin P, de Marchie M, Sinderby C. Effect of increased diaphragm activation on diaphragm power spectrum center frequency. *Respir Physiol Neurobiol*. 2005 Mar;146(1):67-76.
- 10) Spahija J, Beck J, de Marchie M, Comtois A, Sinderby C. Closed-loop control of respiratory drive using pressure-support ventilation: target drive ventilation. *Am J Respir Crit Care Med*. 2005 May 1;171(9):1009-14.
- 11) Sinderby C., P. Navalesi, J. Beck, Y. Skrobik, N. Comtois, S. Friberg, S. B. Gottfried, and L. Lindstrom. Neural control of mechanical ventilation in respiratory failure. *Nat Med* 1999;5:1433-1436.



Dr Hiren N Doshi and Dr Suresh Birajdar with a pediatric patient post weaning.

Challenges and developments in lung protective ventilation for neonatal and pediatric patients in Mumbai

Balabhai Nanavati Hospital was inaugurated in 1950 by independent India's first Prime Minister, Pandit Jawaharlal Nehru. Nanavati Hospital has grown from the original 50 bed, single building facility to the current five building complex with over 450 beds.

In 1962, Mother Teresa brought her first child to Nanavati Hospital for treatment, which marked the beginning of a longstanding relationship between her and the hospital. The state-of-the-art Blessed Teresa Advanced Paediatric Center was opened three years ago at Nanavati Hospital, and has treated over 5,000 children, with a survival rate of 94% in the PICU/NICU. They have a survival rate of 92% for children who required mechanical ventilation.

Critical Care News discussed these impressive results, and the difficulties encountered in a rapidly expanding and subtropical environment with Neonatologist and Pediatric intensivist Dr Hiren N Doshi, Program Director and his associate, Dr Suresh Birajdar.

What is the range of gestational age for the neonatal patients you treat?

Dr Hiren N Doshi: We cater to all neonates that are born at our institute, plus we get transfers from many smaller maternity homes all around the city. We have treated neonates beginning from 24 weeks of gestation. We see a large number of neonates with hypoxic-ischemic encephalopathy, along with meconium aspiration syndromes. We have a well established pediatric cardiology team and deal with many interventional and surgical cardiology patients. We also see neonates with septic shock and multi-organ failure on a regular basis. We have our share of surgical cases and genetic and metabolic disorders as in any tertiary level care NICU.

Which types of non-invasive solutions do you commonly use with neonatal patients?

Dr Suresh Birajdar: We have two dedicated locally manufactured Bubble-CPAP units, which we use in our neonates, either primarily or as a step down from mechanical ventilation. We have used nasal prongs as the most common interface in neonates. Even though we did try nasopharyngeal tubes, and masks, we were not very comfortable with them, probably because of the unavailability of proper interfaces at our center.

When treating pre-term infants with invasive ventilation modes, which modes or methods do you frequently prefer?

Dr Doshi: During the last four years I have been ventilating babies mainly on SERVO Ventilator 300, and most recently on SERVO-i. Since the shift over to the SERVO platform, we have used Pressure Regulated Volume Control - PRVC in almost all our cases. We prefer using PRVC as it has decreased the monitoring required in ventilating the baby. The ventilator adjusts itself to the changing lung compliance. This has tremendous advantages over the traditional pressure mode ventilation because the chance of accidentally causing an air leak, when



The Blessed Teresa Advanced Paediatric Center was opened at Balabhai Nanavati Hospital in 2004.

the lung compliance improves is a thing of the past. Hypoventilation in a situation of worsening lung condition does not happen. In a teaching facility like ours, where the medical and nursing staff is constantly being rotated, there is always a learning curve with a fresh inflow of personnel, PRVC mode has obvious advantages. Also with the SIMV-PRVC mode now available on the SERVO-i, even weaning babies on the same mode is possible.

When we have a shortage of ventilators in our unit, we still use the SERVO Ventilator 900 (from our adult ICU) in the

PC mode or the SIMV with PS mode. In my opinion, volume mode ventilation has a large advantage over pressure mode ventilation, and I have always been a proponent for volume modes, but I also feel that any mode of ventilation that the medical team is comfortable with, can be used to ventilate both neonates and children.

Is surfactant therapy used regularly?

Dr Doshi: We have used surfactant in around 150 neonates in the last 3 years for IRDS, in 4 cases for meconium



Program Director Dr Hiren N Doshi with neonatal patient.

aspiration syndrome, and in 3 cases for ventilator induced lung injury/ARDS. We go mainly on clinical (respiratory distress and oxygen requirement) and radiological criteria for determining need for surfactant. Once it is decided to give surfactant, we use our own protocol to give it using a special ET tube with a side channel to avoid disconnection from the ventilator while delivering it. We generally use PEEP of 8 – 12 cm H₂O in PRVC mode to keep the lung open during the time of delivery. We give the surfactant in 6 different positions, as opposed to the standard two positions. This helps in better distribution of the surfactant and at the same time avoids periods of hypoxia or increased airway pressure because of the use of smaller aliquots of the surfactant. Secondly, we repeat doses of surfactant every 6 to 12 hours if the FiO₂ requirement is above 0.3, or if the PEEP requirement is above 3 cm

H₂O. The main aim of repeated doses is to get the child off the ventilator within 24-48 hours of life. I strongly feel that exposing the premature lung to artificial ventilation beyond 48 hours negates the very purpose of surfactant therapy.

In recent times, in cases of mild RDS, we have been giving the surfactant, and then shifting immediately to bubble CPAP with nasal prongs instead of keeping the child on the ventilator. This approach works beautifully and the incidence of ventilator associated pneumonia -VAP, sepsis and bronchopulmonary dysplasia has come down significantly. Interestingly, we have seen 5 cases of “near term” above 2.5 kg babies with hyaline membrane disease in the last 2 years born of non-diabetic mothers. Even though this phenomenon is a described entity, it is supposed to be quite rare.

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

Dr Doshi: I think the biggest challenge in using ventilation therapy is to remove the fear of ventilators from the physician's mind. My endeavour is to make ventilation therapy as simple and hassle free as possible, so that all pediatricians are able to use it for the benefit of their patients and it moves out of the realm of only intensivists, neonatologists and pulmonologists. To a large extent, I think it is our community itself, which has formed this aura around ventilation therapy that causes many to remain in awe of it, and not utilize this life saving therapy to the fullest.

I feel that educating healthcare providers in the basic principles of ventilation, namely:



Dr Suresh Birajdar and colleagues.

1) gentle ventilation (preventing VILI - ventilator induced lung injury), 2) asepsis, 3) importance of chest physiotherapy, 4) accepting lower saturations and higher PCO_2 's, 5) preventing ventilator-patient asynchrony and 6) open lung ventilation concept (optimum PEEP and lower tidal volumes) is much more important than bombarding them with information and arguments on the benefit of one mode over the other and attempts to get that perfect Pressure-Volume curve on the screen. No other ventilation platform gives us as simple an interface as the SERVO-i does.

What is the range of age for the different pediatric patients treated here?

Dr Birajdar: We treat children right from the neonatal age to the age of 18 years.

We see a large variety of cases, as ours is a referral center for the entire western suburbs of Mumbai. Frequently we receive patients from outside the city and other neighboring states as well. Our center is equipped for and has the experience to treat all cardiac, neuro, and trauma cases, in addition to the usual pediatric cases. We probably see more of tropical diseases and infections as compared to centers in Europe and the West. At times we see waves of specific problems, for example dengue fever shock syndrome cases during monsoon season, bronchiolitis during winter months, etc.

Can you describe some of the challenges in mechanical ventilation of pediatric patients, in terms of anatomy and physiology?

Dr Doshi: Every case that we see is

different. The challenge is in correctly analysing the case and choosing the best mode of ventilation and initial settings for that particular child. As mentioned earlier, I am more interested in demystifying ventilation; rather than talking about complex ventilation strategies. Today, I want to use this platform to convey the message that if basic principles are followed, every healthcare provider can use ventilation therapy to the advantage of his or her patient.

For most cases with respiratory failure, (other than hyper-reactive airway disease, obstructive airway disease and in patients with raised intra-cranial pressure), our principles for ventilation are outlined in brief:

1) Gentle ventilation: Ventilation, by itself should not be an instrument for causing damage to the alveolar unit.

Practically this translates to using RSI (rapid sequence intubation) protocol while intubating, using FiO_2 of less than 0.6 as soon as possible, using higher PEEP's to prevent repeated opening and closing of alveoli, thus avoiding shear injury (open lung ventilation). Use tidal volumes of 6-7 ml / kg or less (or use the minimum possible PIP to attain the above volumes on Pressure mode ventilation)

2) Flexibility in choice of modes: Use whatever mode of ventilation your team is comfortable with, keeping in mind the above principles.

3) Higher Respiratory rates: Use higher rates to achieve an increase in minute volume, if required.

4) Never chase blood gases: Accept oxygen saturations of around 90%. Accept PCO_2 in the range of 40's and 50's initially. If the child's hemodynamics permit, and if there are no contraindications, even higher levels of PCO_2 can be accepted by further decreasing tidal volume, thus being even more lung protective. The key to this is to allow a step-wise rise in PCO_2 's every 12 hours so that the patient acclimatizes to each consequent higher level of carbon dioxide without exhibiting severe tachycardia and hypertension.

5) Lung toileting: Chest physiotherapy and proper suctioning technique of the airway every 3 to 4 hours is an important cornerstone in ventilation therapy and should never be neglected.

6) Prevention is better than cure: Preventing infections and ventilatory associated pneumonias is also a part of ventilation protocol and strict policy measures like hand washing augmented with chemical rubs and sterile gloving, care of long lines, etc should naturally be part of a PICU's culture.

Having mentioned our ventilation protocol, I would now like to share a few points that I feel strongly about. Ventilation is not a means to an end, rather it is like a transitional support until the time the basic disease process is treated or corrected. Thus, devoting more time to treat the primary disease is very important. Ventilation-patient synchrony



Family members are encouraged to visit recovering patients.

makes life much simpler for everybody. I do not deny the major theoretical advantage of conscious ventilation over using paralytics and sedatives. I admire my colleagues who have shifted to conscious ventilation, no doubt aided in a large part to the technological advances of the present generation of machines. I do not contest that physiologically they have all the points in their favor, but I personally am not comfortable with conscious ventilation in children. Also, the stress response in a consciously ventilated child increases the morbidity. I feel that air leaks are more common in the same group due to increased airway pressure when the child fights the ventilator. That look of terror on a child's face, when we ventilate without sedation, makes me very uneasy.

We still use sedation and paralysis in many cases that we ventilate, except for the two extremes of age, preterms and teens, where we are comfortable to ventilate without their use. Having said that, we also come across children who are quite comfortable being on the ventilator and with them, we are not averse to conscious ventilation.

In many children in whom we use sedation and paralysis, as a policy, we monitor Bi-spectral levels and/or continuous EEG to assess the depth of sedation and pick up seizure activity. Special care is given to chest toileting and frequent changes in positions to prevent atelectasis. We also feel that this method of ventilation has major benefits;

we have practically not seen air leaks since using this protocol. Accidental extubations, a bane of any intensive care unit, and the associated complications, are also virtually unknown in our patients. Stress related hyperglycemia and other stress related complications that have been documented by many researchers are rarely seen in our children.

We have heard that you frequently use PRVC mode in pediatric patients. What is the basis of this preference? Is it due to the delivery of preset tidal volume with the lowest possible pressure, or the opportunity of sensing small deviations in pressure? Are there other advantages of PRVC in pediatric patients that you have experienced?

Dr Doshi: Let me give you a case illustration as a practical example: I have a 2 kg preterm neonate with IRDS and have started him on VC ventilation, TV 15 ml; rr of 40, I: E of 1:2, PEEP of 8 cm H_2O and FiO_2 of 0.6. The peak pressure, measured is 30 cm H_2O . Now, we shift the baby to PRVC mode, keeping all the above settings static, and adjusting the upper pressure limit to 45 cm H_2O ; after a few breaths the baby's peak pressure stabilizes to a level of 27 cm H_2O (3 cm less than VC mode), this is the magic of the decelerative flow pattern that PRVC uses.

Now, we give the baby a dose of surfactant. After delivery, we decrease the PEEP to 6 cm H_2O and the attending nurse is trained to titrate FiO_2 downwards



Program Director Dr Hiren N Doshi is Neonatologist and Pediatric Intensivist and Dr Suresh Biradjar is Pediatric Intensivist at Balabhai Nanavati Hospital.

to keep the SPO_2 95%. After 2 hours, the peak pressures are at 20 cm H_2O , without us adjusting any setting on the ventilator. We decrease the PEEP to 4 cm, and after 2 more hours the peak pressures have reached 16 cm H_2O and the nurse informs us that the FiO_2 requirement is 0.3. This is the beauty of PRVC mode, the child has practically weaned off the ventilator by himself without much intervention from our side. We check that the respiratory drive is good, and if there are no contraindications to extubation, we extubate the child and shift to nasal CPAP as a step down.

The technology behind this entire process, I know is phenomenal and extremely complex, but for me, the end user, things have been made so simple. I can now rely on my junior-most team member to manage the ventilated patients on PRVC easily. With years of working with the SERVO ventilator

platform, I have now reached the level of confidence in the systems, such that ventilation has become predictable and rote to perform in our unit.

This confidence also stems from the fact that the SERVO ventilator platform has the most sensitive trigger system as compared to other machines, and I have tried them all, even without the use of Y-sensor. Also the enormous sensing rates are unbelievable, the advantage is very clear at the bedside when we use the machines, and cannot be adequately described in words.

In your opinion, what are the most important parameters to look for in ventilatory performance to meet the specific needs of children?

Dr Biradjar: An uncluttered simple interface coupled with precise delivery

of smaller volumes per breath and the ability to minutely sense the child's efforts are the absolute requirements in any ventilator for pediatric and neonatal use. In addition, choice of modes, including non-invasive modes, and ones like ventilation graphics, ability to use the same machine in all patient groups, inbuilt ultrasonic nebulisation device, robust all-climate build, alarm memory, sensible algorithms for back-up ventilation, etc.

What in your opinion are the most important developments in ventilation therapy or procedures for neonatal and pediatric patients respectively, which have occurred in the last decade?

Dr Doshi: A paradigm shift in ventilation strategies and understanding the physiology of VILI are the two most important developments in the last

decade. I salute those who have done so much research in this area and then proven their theories in clinical studies. They probably have indirectly saved millions of lives after their lung protective ventilation strategies were adopted by clinicians all over the world. The industry has also given great support to this endeavour in three different ways; one by technological advancement that has remained in step with newer strategies, and making the ventilator interface more simple. Secondly, they have shown great foresight by being an instrument to spread this knowledge widely all over the world by various means; journals and training programs. Lastly, the industry's willingness to support purchase of ventilators in the developing and under-developed regions of the world has allowed us to remain in sync with the western world in terms of giving the benefits of newer technology to our patients.

I do not have any personal experience in using Neurally Adjusted Ventilatory Assist - NAVA, but from what I have read about it, I am eagerly waiting to try it out and incorporate it in our ventilation policies. Possibly, it is the answer to my doubts about the shortcomings of the present synchronous modes of ventilation.

Have there been any specific advantages in terms of education and training in regard to the new SERVO-i ventilator fleet?

Dr Doshi: I firmly believe that ventilation therapy can be taught only at the bedside. We have a system in place whereby we always have at least two senior and experienced faculty members in the unit at any given time. The learning process for juniors is a continuous process and involves discussion on daily rounds, hands-on working and observation. Before they are allowed to go near a ventilator, they are first trained in our infection control protocols. Once we feel that they have imbibed the importance of proper aseptic techniques, they are allowed to work bedside. They are then taught basic techniques of proper suctioning and chest toileting, and it forms the bulk of their duties in the PICU for the first 6 months. By this time they have started understanding the basics of ventilation, and start gaining confidence in decision making. They are being continuously assessed by us, and based on their abilities we allow them to take critical decisions in patient care, and shift our roles to mainly supervisory. This is a very rustic method of training, but works very well. All the graduates who have worked in our unit for a period of at least one year, are now spread all over the country and I am proud to say, manage their own small units and are confident to treat any challenge that comes their way, and reproduce the same fantastic outcomes that we do here. Our nursing staff are also trained in a similar fashion and are equally important members of the team.

Regarding training for the newer SERVO-i's, it was a natural transition and was quite hassle free as everybody used to working on the SERVO platform using the 300's and every team member had ample experience on using PRVC modes of ventilation.

Could you give us some general information regarding patient demographics?

Dr Birajdar: We had 360 neonates admitted to our NICU in 2006, and had an overall mortality of 3.6%, we were required to ventilate 170 amongst them due to a variety of reasons and had a mortality rate of 6.5% amongst this group. We had 401 pediatric admissions in 2006, to our PICU, and had a mortality rate of 3.24%

Our NICU (tertiary level care) has 3 beds, premature unit (secondary level care) has 8 beds and PICU (tertiary level) has 5 beds. Our pediatric ward has 16 beds, with an option to admit 6 to 7 more children in other parts of the hospital. Our pediatric general ward (free beds) has 12 beds.

The hospital has 450 beds and always runs with an average 90 to 95% occupancy.

Admission and ventilation statistics for 2006

Month	NICU			PICU				
	Total	Ventilated	Not Vent.	Cardi	Neuro	Surgi. & Trau.	Infec. & Ot	Total
Jan	25	15 / 1	10 / 0	8 / 0	5 / 0	4 / 0	22 / 0	39
Feb	35	12 / 1	23 / 1	6 / 1	8 / 0	3 / 0	12 / 0	29
Mar	25	13 / 0	12 / 0	2 / 0	7 / 0	5 / 1	12 / 0	26
Apr	25	9 / 0	16 / 0	5 / 1	6 / 1	2 / 0	14 / 1	27
May	28	14 / 1	14 / 0	7 / 0	6 / 1	4 / 0	10 / 0	27
Jun	30	16 / 1	14 / 0	7 / 1	10 / 0	4 / 0	14 / 0	35
Jul	27	11 / 1	16 / 0	5 / 0	2 / 0	6 / 0	12 / 1	25
Aug	32	18 / 1	14 / 0	2 / 0	8 / 0	4 / 1	18 / 1	32
Sep	39	20 / 2	19 / 0	4 / 0	8 / 0	6 / 1	22 / 0	40
Oct	38	12 / 0	26 / 1	10 / 0	10 / 1	9 / 0	12 / 0	41
Nov	28	16 / 1	12 / 0	11 / 1	12 / 0	3 / 0	15 / 0	41
Dec	28	14 / 1	14 / 0	8 / 0	9 / 0	7 / 0	15 / 0	39
Total	360	170 / 11	190 / 2	75 / 4	91 / 3	57 / 3	178 / 3	401

Biography

Dr Hiren N Doshi has over 11 year's expertise in pediatrics, neonatology, pediatric critical care and pediatric cardiac intensive care. He obtained his initial medical degree at the Krishna Institute of Medical Sciences at Shivaji University in 1994, and had his speciality training at Dr Balabhai Nanavati Hospital in Mumbai in 1998, and is board certified from the national board of examinations, New Delhi. Dr Doshi has conducted research in the areas of microbiology of otitis media in children as well as endocrine complications in thalassemia major with emphasis on diabetes mellitus. His current research plans are within the area of newer modalities and refinements

in ventilation in neonates and children, and decreasing morbidity and mortality in extreme low birth weight babies. He has organised workshops in India within the area of pediatric critical care and pediatric cardiac intensive care.

Dr Hiren Doshi presently works as Senior Intensivist and Pediatric and Neonatal Consultant at Dr Balabhai Nanavati Hospital in Mumbai, and has held this position for the past three years.

Dr Suresh Babruvhan Birajdar

received his initial medical training at Bharti Vidyapeeth's Medical College at the University of Pune, India. He obtained his degree in

pediatrics at the Seth G S Medical College and King Edward Memorial Hospital in Mumbai in 2005, and thereafter worked as registrar in the Neonatal Intensive Care Unit at King Edward Memorial.

Dr Birajdar has participated in numerous pediatric and neonatal workshops and conferences, and received first prize for Oral Award Paper entitled "Psychological Consequences in Pediatric Intensive Care Survivors: The Unsuspected Impact" at the First Asia Pacific Congress on Pediatric Critical Care in 2005. Dr Birajdar is currently employed as a Pediatric Intensivist at Dr Balabhai Nanavati Hospital in Mumbai.

References

- 1) Donahoe M. Basic ventilator management: lung protective strategies. *Surg Clin N Am* 2006; 86: 1389-1408.
- 2) Hickey RW, Painter MJ. Brain injury from cardiac arrest in children. *Neurol Clin* 2006; 24: 147-158.
- 3) Doyle L, Colletti JE. Pediatric procedural sedation and analgesia. *Pediatr Clin N Am* 2006; 53: 279-292.
- 4) Brown K, Lightfoot C. The 2005 guidelines for CPR and emergency cardiovascular care: implications for emergency medical services for children. *Clin Ped Emerg Med* 2006; 7: 105-113.
- 5) Berger St, Konduri GG. Pulmonary hypertension in children: the twenty-first century. *Pediatr Clin N Am* 2006; 53: 961-987.
- 6) Ramachandran Nair, R Sharma R, Weiss SK, Corez MA. Reactive EEG patterns in pediatric coma. *Pediatr Neurol* 2005; 33: 345-349.
- 7) Woods WA, McCulloch MA. Cardiovascular emergencies in the pediatric patient. *Emerg Med Clin N Am* 2005; 23: 1233-1249.
- 8) Wite MD, Zuk J, Gralla J, Friesen RH. Correlation of the bispectral index monitor with the COMFORT scale in the pediatric intensive care unit. *Pediatr Crit Care Med* 2005; (6)6: 648-653.
- 9) Coffin SE, Zaoutis TE. Infection control, hospital epidemiology, and patient safety. *Infect Dis Clin N Am* 2005; 19: 647-665.
- 10) Kattwinkel J, Niermeyer S, Nadkarni V, Tibbals J, Phillips B, Zideman D, Van Reempts P, Osmond M. An advisory statement from the pediatric working group of the international liaison committee on resuscitation. *Pediatrics* 1999; 103: 56.
- 11) Sarnaik AP, Daphtary KM, Meert KL, Leih-Lai MW, Heidemann SM. Pressure-controlled ventilation in children with severe status asthmaticus. *Pediatr Crit Care Med* 2004; 5 (2): 133-138.
- 12) Rosenberg DI, Moss M, Am Coll of CCM of the Soc of Crit Care Med. Guidelines and levels of care for pediatric intensive care units. *Crit Care Med* 2004; 32: 2117-2127.
- 13) Carcillo JA, Fields AI. Clinical practice parameters for hemodynamic support of pediatric and neonatal patients in septic shock. *Crit Care Med* 2002; (30) 6: 1365-1378.
- 14) Marino BS, Bird GL, Wernovsky G. Diagnosis and management of the newborn with suspected congenital heart disease. *Clinics in Perinatology* 2001; 28 (1):91-136.



Director of Respiratory Care Joe Dwan, RRT and MR technician Steve Johnson, RRT, MR.

Standardizing ventilation technology up to the MRI suite, in an expanding hospital environment

The award-winning Kaiser Foundation Hospital – Kaiser Sunnyside Medical Center, in Portland, Oregon, received the Joint Commission's Gold Seal of Approval in 2006. This award demonstrates their commitment to providing the highest level of quality care to their patients, in terms of compliance with state-of-the-art standards for quality and safety of care.

The respiratory care department at Kaiser Sunnyside focuses on standardizing ventilation technology throughout the institution, and is the first hospital in the United States to implement a new ventilator solution in the MR environment. The objective is to improve patient safety and provide more focus on patient bedside care. Critical Care News spoke with Joe Dwan, Director of Respiratory Care, who is one of the driving forces behind the standardization.

Can you give us a brief description of the Kaiser organisation and the services it provides?

As a Health Maintenance Organization (HMO), our healthcare is comprehensive covering all components and services, including medical, vision and dental care. Kaiser Permanente has other regions across the U.S. besides the Northwest Region, and nationwide has approximately 9 million patients. Our physicians are employees of the company, and we have a subscribed population to treat, about 470,000 Kaiser members in the northwest area of Oregon and southwest Washington. My hospital is currently just over 200 beds, which can be considered a small hospital in the U.S. But within Northwest Region, we have around 25 clinics and over 1500 internists and primary care physicians, who refer their patients to our hospital. Because of our HMO system, our hospital is often full, thus we are expanding. We have an increasing membership of patients and have to plan for the future growth as our population increases.

Is it a benefit to the patient, that the same institution is involved with their care at a primary level, as well as the entire way to specialist care and hospital care?

It provides seamless care from basic outpatient clinic care, to specialist care, hospitalization and to home care. We have an electronic medical record system in the outpatient arena that provides communication from the clinics 60 miles north and south of here, and the physicians in the hospital have access to the complete patient medical record of all outpatient and pharmacy care. This streamlines safety when developing care plans and prescribing medications in the outpatient and inpatient areas. In most hospitals, the patient is admitted, and your only medical history is often what the patient tells you. Our system is transparent, so all caregivers can see which interventions and medications are being given at any location in our healthcare system. Of course, we guard the patient's information very carefully.

Can you briefly describe your position and area of responsibility within Kaiser?

My role is that of Director of Respiratory Care for the Northwest Region, therefore all the respiratory issues for the entire region come to me. Currently in addition to managing the hospital inpatient respiratory department, I also manage the asthma COPD case managers in our outpatient departments who act as ER outreach care providers. When our asthma and COPD patients come into the ER, the follow up asthma or COPD care is managed by their case managers, with communication via the electronic medical record to their internist. We also provide a home oxygenation care management program that I manage. Since we are a comprehensive HMO, we have about 1500 oxygen patients at home. There are three respiratory therapists managing the oxygen needs of the 1500 patients. They do periodic evaluations of the oxygen care and evaluate new patients for home oxygenation, based on national guidelines. This provides improved value to the patients as well as the physicians. It also improves quality of care, since it allows the respiratory therapist more time to spend with the patient to meet their healthcare needs. Patients rely on their case managers for ongoing care and the electronic medical record facilitates communication between case managers and the patient physician.

Our two pulmonary function labs are also under this management scheme and provide services under protocols, as do our care managers and inpatient therapists. We have a total of 37 respiratory therapists, of which 25 are on staff in the hospital. I no longer manage the sleep department, but we expanded the sleep lab and now it is one of the biggest sleep labs on the West Coast with 16 beds operating 7 nights a week. For our respiratory therapy group, my leadership style could be described as "laid-back." I do not have a controlling style of management, but rather a participatory management style. Nevertheless staff input through our Labor Management Partnership, teamwork and communication is key in everything we do as a respiratory care department.

From an operational perspective, what is the size of the institution in terms of beds, ICU beds and patient occupancy turnover on an annual basis?

We just opened up a new tower to the hospital, as well as a new ICU. We've increased from 13 beds to 20 ICU beds. We also are opening up a new 20 bed cardiovascular ICU in 2008 and are transitioning to a full service hospital, as opposed to a smaller specialised community hospital. We are currently recruiting respiratory and nursing staff to cover the hospital expansion.

Can you give us some details in regard to your staffing situation in the ICU, at present and in terms of the planned expansions?

We have a very stable staff situation with under 3% turnover in respiratory therapy in the last four years. Three years ago, we had two day shift staff members and two night shift staff members on 12 hour shifts, but with our expansion we are currently running five staff members per shift. In addition to our ICU expansion, our ER has grown from 19 beds to 30 beds and will be expanding to 42 beds this winter. This is an amazing expansion rate but has been in the planning for some time. The ICU is typically operating on an average of 12 patients, with an occasional increase to 17 patients. Recruiting qualified critical care nurses, respiratory therapists and intensivists will allow us to utilize the new ICU capacity.

In our ICU, there is a mix of surgical and medical patients. I anticipate that we will need up to 45 respiratory therapy staff members on the inpatient side, when the current expansion is completed. In addition to the expansions of the ICU, ER, cardiovascular ICU, we are expanding our NICU as well, with a goal of 30 beds. We were a 182 bed hospital before the expansion began, and we will eventually be at about 350 beds.

I understand that you have standardized your ventilator fleet in recent years, right up to the MR suite. What were the reasons leading to this standardization?



New staff member Amber Reid, RRT, receives training in regard to the MR ventilator from Joe Dwan. She is employed at UCSD San Diego as well as Kaiser Sunnyside, Portland

Patient safety is very important for the hospital and the staff. New procedures were derived from the Institute for Healthcare Improvement (IHI), 100,000 lives program, and the JCAHO patient safety goals, including decreasing ventilator acquired pneumonia (VAP) rates, rapid response teams, and weaning protocols. The effort focuses hospitals on matching the safety record of the aviation industry. The data showed a typical ICU has an average of seven patient errors a day. If this were the aviation industry, the same ratio might result in a number of airline crashes per week. By following the aviation industry's systems, we are trying to eliminate errors and thereby improving patient safety. As a manager and a patient advocate, I support this effort.

Which types of activities or areas are you working in to maintain or increase patient safety for the ventilated patient?

In the ICU our therapists have many clinical privileges. They are highly skilled staff who have the trust of the intensivists. Therefore therapists pick

their own ventilator settings in the ICU, mode, rates, etc, and are able to make adjustments within a framework of limited parameters. We use a window order where the physician states to keep the PO_2 within a window of lower and upper limits, and CO_2 within a window. Therapists make adjustments within that framework. We also have an extensive weaning protocol. Our first weaning protocol was developed in 1993, and has gone through multiple evolutions, the last being 2 years ago and incorporated the IHI recommendations. We are also following the national weaning guidelines published in 2004. A nurse and a therapist complete a "Readiness to Wean" evaluation form every day on every patient on a ventilator in every ICU. This helps to focus on decreasing our ventilator length of stay. It ensures that we are clearly evaluating our methods of getting patients off ventilators. National weaning guidelines showed that there is no evidence to support doing vital capacity maneuvers and negative inspiratory forces, i.e. traditional weaning parameters. We are following these aforementioned guidelines, measuring the Tobin Index (RSBI), respiratory rates, hemodynamic

stability, sedation level, and proceeding to a spontaneous breathing trial. We also apply the ARDSnet protocol as our ventilation strategy for all patients, targeting low tidal volumes in the 4-6 ml/Kg range and keep the plateau pressures under 30 cm H_2O . We started using permissive hypercapnia in the mid 90's and have evolved with the evidence in the literature to apply ARDSnet protocols to all patients.

One of our outcome measures is length of ventilator stay. Last year ventilator length of stay was 2.2 days, which is very low. We have been tracking this parameter for the last 14 years, with our ventilator length of stay averaging 3 to 3.5 days. The recent decrease is due to new physicians, a much better job of applying the weaning protocol, better education for our respiratory therapists and critical care nurses and our medical director who is supportive of improving processes in the ICU. We have a semi-closed ICU, so one intensivist manages 80-85% of patients. In smaller hospitals, a variety of physicians could manage patients in the ICU. Ours utilizes a core group of intensivists and has hospitalists to manage floor patients.

In our daily hospital operations, we have SERVO-i in the NICU, in our intensive care units, in our ER and in the MRI, therefore our therapists use one type of ventilator in all settings. We have a total of 27 SERVO-i's mixed in these areas.

So to improve patient safety for our ventilated patients, we are reading the medical literature and applying the evidence through educating the staff and developing support systems; such as the Readiness to Wean form and we are measuring outcomes to confirm the changes had positive impacts on patient care.

How do you couple standardization together with patient safety? How has the standardization impacted on training and education of staff?

I am giving a presentation at the AARC this year about transitioning to a single ventilator platform. One of the best features of standardizing to one ventilator model is patient safety. In the past,

patients treated in the ICU were on a completely different ventilator than patients in the NICU, ER and PACU. Some hospitals used multiple brands of ventilators in their ICUs. When we had a TCPL machine in the NICU, the staff would stress over operating the ventilator, and not focusing on the patient. By standardizing, they now know the ventilator well, but are applying it in a different setting. They have to adjust their thinking to the neonatal patients, but they know the machine and can spend their time focusing on the patient and assessing him, instead of the equipment. Significant improvement in patient safety is achieved by standardizing and results in improvement by decreasing potential errors.



Joe Dwan and colleagues Brian Wartell, RRT and Emily White, RRT.

Which types of ventilation modes are most frequently used, and why?

We tend not to use Synchronized Intermittent Mandatory Ventilation (SIMV) alone because of the National Weaning Guidelines, which reported that SIMV works as a standard mode, but should not be used to wean patients. We have actually switched to Pressure Regulated Volume Control (PRVC) as a primary mode of ventilation. We will use Pressure Control according to the ARDSNet protocol, to target the pressures we are delivering, i.e. both the plateau pressures and the peak inspiratory pressures. Pressure Support and Volume Support are utilized as well, both as a primary mode of ventilation and in support of other modes.

What are your policies in regard to suctioning and oxygenation?

Through our Ventilator Associated Pneumonia (VAP) program, we reviewed and found variations in practice between the nurses and the respiratory therapists, as well as within the respiratory therapy and within the nursing groups. Therefore we have set up a collaborative effort with nurses and intensivists and respiratory therapists by sitting down and reviewing the limited literature that is available. We have then come to a standardized method of doing suctioning. This may have contributed to our change in ventilator length of stay outcome, as an

individual factor. We also changed how our therapists managed cuff pressures; we have looked at subglottal suctioning tubes, which have questionable evidence to support them. The four RCTs on subglottal suctioning endotracheal tubes showed extremely high VAP rates that were brought down to fairly high VAP rates, along with other changes that could have influenced the outcomes. We evaluated oral care as well. It is a collaborative effort and within Kaiser, there is a real teamwork approach in order to build relationships and improve patient outcomes.

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

We extubate quickly, thus our record of 2.2 days ventilator length of stay. Utilizing our Readiness to Wean protocol, respiratory therapists and nurses do standard assessment of patients' vital signs and hemodynamics, and RSBI, as well as a short breathing trial of no more than 30 minutes. Then either they come off the ventilator or they don't.

What is your average extubation success rate?

A few years ago I researched re-intubation rates and found there were no benchmark rates, although articles did describe rates from 10 to 20%.

So I looked at ventilator length of stay as a benchmark instead, finding from 1.0 days ventilator length of stay upwards to 24 days ventilator length of stay in the literature. Like most hospitals, we primarily benchmark against ourselves. Our reintubation rate is around 5-7%. Our usage of non-invasive ventilation (NIV) has increased significantly while our ventilator volumes have remained the same.

How is non-invasive ventilation therapy utilized in the ICU?

In the early 1990's we used the old Respiration STDs, and when the Respiration Vision came out we bought several. With the new SERVO-i, all have non-invasive capability on them. Many of our patients are no longer intubated at all, since we are able to manage more of them on non-invasive ventilation. We have completed training programs on VAP, and we achieved a 0 rate for ventilator associated pneumonia in non-invasive ventilation for the last quarter of 2006. We started by doing research in the literature. Part of our improvement was developing standards for ventilation care, oral care, managing the endotracheal cuff, and steering the patient to non-invasive prior to intubation, thus preventing the possibility of a VAP. During 2007 we had only one patient with a VAP, with about 370 ventilated patients for the time period. That is very satisfying. The feature of having non-invasive on the SERVO-i helps with

"marginal patients," thus we can start them off with non-invasive. The excellent monitoring capabilities that come with the Servo-i allow us to follow the patient closely.

How have you accommodated mechanically ventilated patients in the MR in the past, and can you share your experiences in implementation of the new ventilator solution in the MRI suite?

I believe ventilator manufacturers across the world have not done a good job of addressing ventilation in the MRI. I've complained to vendors that we are using 1960's technology in our MRI suites. As an older therapist, I was used to adjusting inspiratory time, flow rate and pressure to deliver tidal volume and respiratory rates. Our younger therapists have no experience with IPPB type devices. But that is the only type of technology that

has been available in the MRI for many years. We modified the SERVO 900C to use in the MRI out of necessity which meant that 1980s technology was a big improvement from the 1960s, but still inadequate. Annoying my vendors, I would ask them when would we get an MRI ventilator from this century? It was exciting to see the SERVO-i MRI application at the 2006 AARC Congress. This application allows us to standardize to one ventilator throughout the entire hospital providing the ability to maintain identical ventilator settings even in MR. Clearly, our sickest patients are the ones that are going to the MRI.

How has it been working so far?

The approach is good and we have learned valuable information about MRI. The SERVO-i is MR Conditional, meaning that it can safely be used in the

MR environment when specific stated conditions are met. It can be used in 1.0, 1.5 and 3.0 Tesla MR suites. Magnetic fields must be measured in each MRI suite prior to installation and protocol must be followed. Kaiser Sunnyside is the first hospital in the US to install the new MRI option on the SERVO-i. We have treated a limited number of patients so far. It has worked well in the patients that we have examined in the MR. These patients are the typical complex patients you have in a critical care unit.

Training and competency of the Respiratory Therapy staff is mandatory prior to use of the MR ventilator. We have found it worth the investment, since these are our sickest patients, and you want to match the ventilator settings to those you are using in the ICU or ER. You don't want the ventilation aspect to be a problem in transporting these patients, so for this reason alone it is worth the investment. This is why we will install the ventilator in the new MRI suite as well. The more we learn about ventilation, the more we learn that there is a connection to every moment the patient is being ventilated, the volumes, pressures, and rates delivered, including during transports and resuscitations, and the impact on acute lung injury and survival. So if you transport the patient to another site within the building, such as MRI, and you do not provide an appropriate level of ventilation and monitoring, you could be providing lung damage to an already critically ill patient. This may impact the length of time they are on the ventilator as well as the patients survival.

You have worked as a respiratory therapist for 30 years. In your opinion, which are the most significant developments in respiratory therapy during the past three decades?

In terms of respiratory care, there have been a couple of fundamental benchmark developments. In mechanical ventilation, bringing in Pressure Support and Pressure Control as modes of ventilation is significant. I gave my first presentation on Pressure Control and Pressure Support in 1984, when this was fairly new. I did some predictions then that in future we would have been using these modes as our primary method



Joe Dwan, MS, RRT joined Kaiser Permanente in 1984.

of ventilation. Technology helps drive some of the changes in respiratory care. Graphics are probably one of the biggest benchmarks in respiratory care in the past 20 years. Graphics, in terms of mapping flows, pressures and rates, and pressure volume curves, is a huge development that is often underutilized. Graphics have allowed us to fine-tune the ventilator to the patient, whereas in the past we were forcing the patients to do what the ventilator demanded. Now adjusting the inspiratory side of ventilation to match the patient, or having this done automatically with Pressure Support is common. We are now able to manage and adjust the expiratory termination criteria, to match the patient's needs and prevent patient asynchrony. Patient asynchrony is one of the major reasons it has been hard to get patients off the ventilators. Microprocessors have been a major part of these significant developments, including utilizing graphics at the bedside.

You will be making a presentation at the upcoming AARC meeting. Can you give us a preview of what subjects you will be speaking about?

My background is in education, earning a Masters Degree in education and having taught respiratory care for many years. I am going to present a process to train staff to become advanced respiratory therapists. Ventilator companies, and respiratory therapy department directors, accept the "knobology" level of training, or the "how to's" of making things work. The field of respiratory care is not only about how it works, but also how to apply this at the bedside. The second level of training is the application level. Learn the ventilator in-depth so you can maximize the technology at the bedside. Optimize what is happening to the patient by means of its monitoring tools. The third level of training results in creative applications in challenging situations. I will also talk about criterion based evaluation of equipment, which I learned as co-chair of Kaiser's national respiratory equipment committee. You need defined objective criteria when evaluating equipment. I see too many respiratory therapy department managers purchasing equipment on subjective

feelings and hearsay, not objective criteria. It is important to buy quality equipment that will make a difference at the bedside. We need to make a rational analysis and define criteria when making equipment investments. Cost can be a factor, but it is important to step back and define; what is important here? What is important is how well will I take care of the patient? What are the differences between this device and that device that will impact patient care? Having the same device throughout the institution means that the focus is no longer on the devices but on the patients.

What do you think will be the most significant challenges in mechanical ventilation in the decade to come?

The future I think will be revealed in research being done by John Marini, Arthur Slutsky, Marco Ranieri and Luciano Gattinoni on what changes happen in different types of ventilation. I believe in evidence-based medicine. However, in the field of mechanical ventilation and respiratory therapy, there is not a great deal of evidence in the literature. The ARDSNet articles have a few big holes in them, like not addressing autopeep, but still have made significant improvements in survival of patients and decreased lung injuries. Evidence based medicine will help drive changes. There are some enormous variations in practice throughout hospitals worldwide. There is also the debate on consistency in practice versus the art of medicine. Both have value. Look at patient outcomes, look at patient safety, which is moving us toward consistency in practice. There has to be some leeway in practice to individualize patient care, but evidence and safety will drive the changes in healthcare.

Another huge change in this country will be a shortage of nurses, respiratory therapists and intensivists, which might cause gaps in healthcare. Demographically, the average age within most respiratory therapy departments is approaching 50. In the near future, there will be too few new workers with the high level of skill of our current healthcare workers. We are looking at training new people or importing new workers who are not at our current skill

level. Another option is implementing really strong training programs. The patient population is growing older and surviving longer. The advances in the neonatal environment are resulting in more premature babies requiring critical care interventions. No doubt, the future will bring more advances and significant challenges in healthcare.

What do you think might be the most interesting developments or opportunities in respiratory therapy in the near future?

The field of Respiratory Care needs people who know not only how to work the device but how to apply it at bedside – the field of application specialists. Developments with significant effects on how ventilation is being delivered, such as NAVA, has piqued my interest so I'm watching it closely. Other developments, such as closed loop ventilation, are interesting as well. Technology of ventilation, how ventilation is delivered and monitoring advances will continue to come to the market. Our opportunity as therapists is not to only know how to operate machines, but to have knowledge of how to apply them at bedside. Respiratory therapists have a unique perspective in three areas – 1) learn the technology, 2) know the equipment, and 3) apply it at the bedside. And there will be more specialization in terms of clinical application and developments in terms of outcome and advances in patient care. We, as respiratory therapists, are really patient care managers, rather than technology managers. ■

Biography

Joe Dwan, MS, RRT, taught respiratory therapy at several colleges before joining Kaiser Permanente Northwest Region in 1984. He is active in the Oregon Society for Respiratory Care and the AARC Political Action Contact Team. He also is Co-Chair, Kaiser Permanente's Respiratory Therapy equipment committee.

MAQUET

JOIN US IN PRAGUE FOR THE SYMPOSIUM ARDS – PATHOPHYSIOLOGY, DETECTION AND THERAPY

CRITICAL CARE



MAQUET sets the global standard in providing clinical education and scientific programs. We are committed to helping our customers stay in touch with the latest innovations in treatment, practice, and research with support from the foremost experts in the field.

Our seventh MAQUET world-class Symposium will be held in Prague, Czech Republic on June 9-10, 2008 and will feature some of the world's leading experts including Dr Jesús Villar, Dr Rolf Hubmayr, Dr John Marini, Dr Marco Ranieri, Dr Vladimir Cerny, Dr Ivan

Herold and Christer Sinderby, PhD. The symposium will be chaired by Dr Arthur Slutsky.

Our intention is to create a stimulating and pleasant environment in which speakers and delegates can interact and engage in discussion. We wish you warmly welcome to this opportunity to meet and discuss with colleagues within the field.

For more information about the detailed program and registration, please go to: www.maquet.com/symposium

MAQUET – The Gold Standard.

MAQUET Critical Care AB
171 95 Solna, Sweden
Phone: +46-8-730 7300
www.maquet.com

MEMBER OF THE GETINGE GROUP

CRITICAL CARE NEWS is published by MAQUET Critical Care.

Maquet Critical Care AB

171 95 Solna, Sweden

Phone: +46 (0)8 730 73 00

www.maquet.com

©Maquet Critical Care 2008. All rights reserved.

Publisher: Leif Lohm

Editor-in-chief: Kris Rydholm Överby

Order No. MX-0393

Printed in Sweden

www.criticalcarennews.com

info@criticalcarennews.com

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

The views, opinions and assertions expressed in the interviews are strictly those of the interviewed and do not necessarily reflect or represent the views of Maquet Critical Care AB.

©Maquet Critical Care AB, 2008.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any other means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of the copyright owner.

The following designations are registered trademarks of MAQUET Critical Care: Servo-i®, Automode®, Open Lung Tool®