

Critical Care News

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New frontiers in ventilation therapy and respiratory care

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NAVA – a new generation in respiratory therapy

Research in the concept of Neurally Adjusted Ventilator Assist (NAVA).
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Acute Lung Injury – from basic science to bedside application

Symposium in Strasbourg, September 2005.

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The continuing development of neonatal and pediatric ventilation therapies

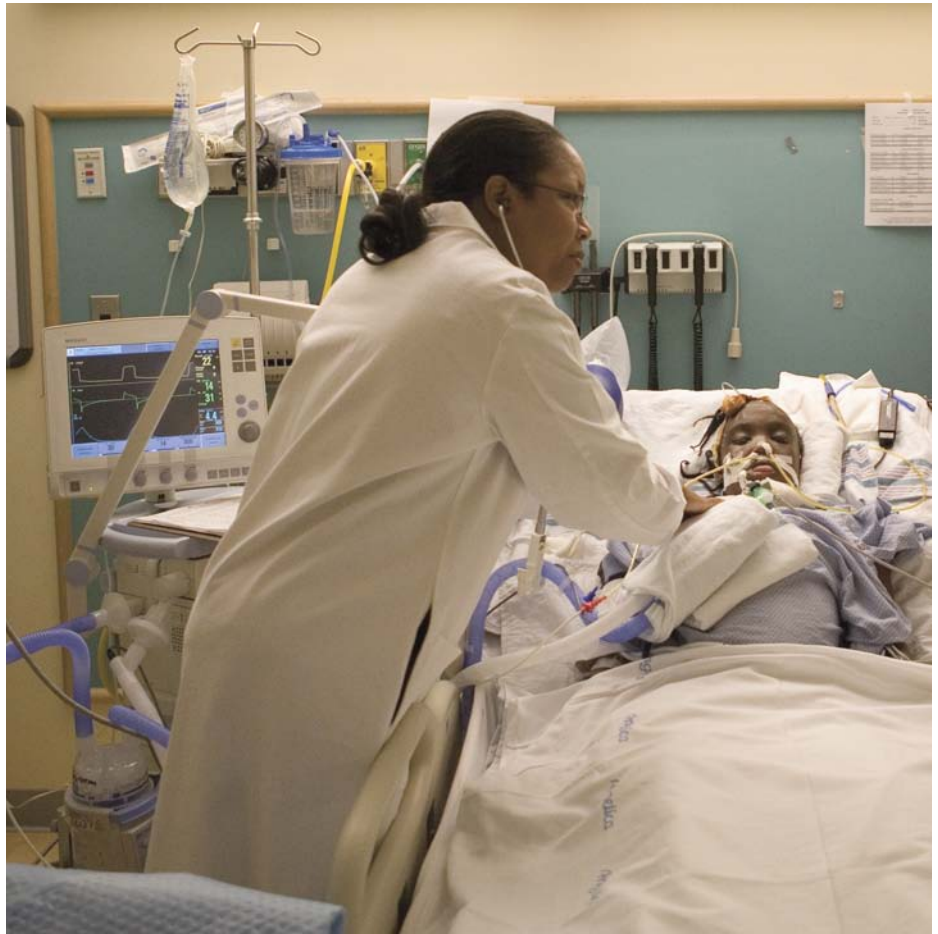
Dr Ralf G. Huth, Director of Pediatric Intensive Care at the Kinderkliniken of Johannes Gutenberg University Hospital in Mainz.

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Defining new procedures and solutions in ventilation patient transports

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Tailoring and improving respiratory therapies in an expanding university hospital environment

Robert Wood Johnson University Hospital of New Brunswick, New Jersey



Dr. Williams-Phillips of the Bristol-Myers Squibb Children's Hospital examines a 4 month old PICU patient.

In the past, each generation of health care professionals have encountered the course of changes in practice, originating from innovative research and development. In contrast today, medical communities and caregivers in almost every discipline around the world are facing similar challenges at a much accelerated pace: medical research and rapidly expanding technologies require healthcare professionals not only to keep pace with current and future developments, but to quickly adapt new research, innovation and treatment strategies to new clinical policies and therapeutic procedures.

New frontiers in ventilation therapy and respiratory care

In this issue of Critical Care News, we will focus on how clinical and technological developments have impacted on specific intensive care units, not only from a therapeutic perspective, but in terms of practical application as well. ICU staff members will share their experiences in the need for developments, and their solutions and adaptations in working procedures and clinical practice.

Streamlining ventilation therapy for patient outcomes

In the metropolitan university hospital setting, rapid and significant expansion of patient population and research, community and industrial growth require rapid expansion of facilities, staff resources and care procedures as well. The Robert Wood Johnson University Hospital of New Jersey has implemented

new technology, processes and procedures for coordinating critical care and managing ventilation therapies, and in the affiliated Bristol-Myers Squibb Children's Hospital as well.

The highly coordinated team effort within this award-winning institution have also contributed to efforts in a recent Top Level disaster preparedness simulation scenario, and future plans for hospital and research development.



Ullevål ICU staff with CT transport patient.

Advances in neonatal and pediatric ventilation therapies

The very first pediatric intensive care unit established in Germany has played a very active role in forty years of development of pediatric and neonatal intensive care therapies and practices. The pioneering spirit within this PICU remains undiminished, as they continue to evaluate advancing technologies and therapies to provide patient safety and comfort, and streamline work processes.

Cutting edge knowledge – Acute Lung Injury Symposium

A globally distinguished panel of speakers including many of the top profiles in intensive

care and respiratory research shared insight, developments and experience related to ventilator induced lung injury. The faculty interacted with over 200 intensive care physicians from around the world over the course of the two day symposium in Strasbourg.

A paradigm shift in ventilation therapy research: Neurally Adjusted Ventilatory Assist (NAVA)

Since the introduction of mechanical ventilation over thirty years ago, ventilation therapy has traditionally consisted of adjusting airway pressure, flow and volume. A group of researchers in Toronto have established the physiological concept of NAVA – Neurally Adjusted Ventilatory Assist, in which the



PICU head nurse Christine Reisling at the Kinderkliniken, University Hospital of Mainz.

patient's own neural control system adjusts ventilation pressure.

Overcoming challenges in transporting the ventilated patient

ICU patients and diseases are similar throughout the world, and ICU staff throughout the world share some of the most significant challenges in the course of their normal everyday routines. Transporting the ventilated patient, whether to the CT department, MRI, ultrasound or X-ray departments is one of the most difficult, time consuming and risk-filled routines. The ICU staff of Ullevål Hospital of Oslo, Norway is in the process of establishing an evidence based protocol on patient transport procedures, and have found new ways to simplify and standardize this process. ■



Christer Sinderby, PhD, discusses the background and concept of Neurally Adjusted Ventilatory Assist.



Some of the ICU physicians from many nations that participated in the Strasbourg symposium.

The award-winning Robert Wood Johnson University Hospital of New Brunswick, New Jersey has undergone rapid expansion in recent years to accommodate treatment of more than 200,000 patients annually. This academic medical center provides state-of-the-art care including cardiac care and transplantation, emergency medicine, neurosurgery, and pediatric and neonatal critical care. The institution is also home to The Bristol-Myers Squibb Children's Hospital, with the region's largest pediatric intensive care unit, and a Level One Trauma Center with a pediatric commitment.

The Respiratory Care Department at Robert Wood Johnson has encountered many challenges during this rapid expansion, and has developed and standardized work processes and protocols to meet these challenges. This team effort includes members of the respiratory therapy department, together with medical directors, intensivists, and nurses in the different critical care departments.

Tailoring and improving respiratory therapies in an expanding university hospital environment

How has the respiratory care department expanded with the institution in recent years, and how have routines and procedures been adapted to accommodate this expansion?

Gerald Schlette, MS, RRT, RPFT, Director

Respiratory Care Services: We currently have 66 staff members, and will hopefully be going up to 77. We staff seven ICUs, one step-down unit, our NICU and our level one trauma center as well.

Bernadette Lewis, RRT-NPS, Supervisor,

Respiratory Care Services: There have been some substantial changes. The institution had undergone a reorganization and re-engineering phase, which was subsequently abandoned, and we are currently going back to the way respiratory care was initially designed, in the late 80s and early 90s. We now have a structure with a Director, Supervisors and Coordinators, with the objective of improving patient care. The respiratory care department now clearly demonstrates its benefit to the institution by means of reducing lengths of

stay, developing and initiating various protocols, which help improve patient care and outcomes.

How do you manage education and training with such a large department and staff?

Bernadette Lewis: In the past, we have had an educator role, but now the supervisors and coordinators all take responsibility for education and training. We schedule, develop and implement all respiratory therapy in-servicing throughout the institution; not only for our own staff, but for the physicians, residents and nurses as well. In the past year, staff members have also taken an active role in in-servicing their peers and colleagues on various topics.

Gerald Schlette: We have redefined our professional roles and job descriptions; for example, we have combined specialty areas such as being certified for both pediatric advanced life support as well as cardiac advanced life support. Roles from that have



Gerald Schlette is Director of Respiratory Care Services at Robert Wood Johnson University Hospital.



Bernadette Lewis, Supervisor, Respiratory Care Services has worked for many years and seen many changes at the institution.

advanced to where we are offering different courses to the residents in both of the medical schools, teaching them not only about respiratory care but cardiopulmonary respiratory therapy, ventilation and weaning, right from the start. This makes our job now, three years later, much easier, and it has worked out very well for us.

Bernadette Lewis: This past year we instituted our first SICU residents' lecture. We in-serviced the residents on mechanical ventilation modes, ventilatory strategies, and the weaning process; we also conducted hands-on training. It was a series of two hour sessions over six weeks, and we received very good reviews from the residents. It improves patient care and outcomes, if we can get to the intensive care unit and there is no question about the availability of modes and technology. Everyone working with the patient will be versed in ventilator modes, strategies and weaning protocols.

The other important aspect in these new procedures is that respiratory caregivers actually go on rounds with the physicians, so we have a lot of autonomy in the units. They start their rounds by 08.00 am, and have their plan of action for the day, for each patient.

Gerald Schlette: We want to work closely in the beginning of the day with the physicians, nurses, residents and respiratory therapists, to deliver a plan of action and course of therapy for that day for each individual patient and set goals, that can be monitored over a twenty-four hour period. The next day, everyone can check whether we are achieving the goals on

schedule, or if we are ahead or have fallen back. The objective is transparency and teamwork, for the patient's benefit.

Louis Fuentes, RRT, Critical Care

Coordinator: One of the things we try to institute in rounds is clinical dialogue with the physicians. We want all of our respiratory therapy staff members to have clinical input regarding their patients in the ICU. Ideally, our goal is to decrease ventilator length of stay by passing pertinent information to each other as healthcare providers, and incorporating this information into a plan for each patient that needs our intervention on a daily basis. As coordinators and supervisors, we need to be a resource for our staff and show our support. We aspire to educate our therapists by looking at x-rays, interpreting hemodynamics, and utilizing different ventilator strategies so that we maintain a dynamic mindset towards patient care. Together with the nursing staff, the therapists are the eyes and ears of the patient, when the physicians are not in the ICU. So when the physicians are present, if there is a problem, we can address it as descriptively as possible for them and give our clinical opinion for these situations in these areas.



Louis Fuentes, RRT is one of four Critical Care Coordinators, with a pivotal role in standardizing and teaching respiratory therapy.

How did you start to change the way you had been managing ventilation therapy?

Gerald Schlette: We started having a lot of problems with our older ventilators. There was no battery back up, and there were a couple of instances where there was risk of danger. I had used the SERVO-i in another institution and it was something I thought was promising. I had

an overnight decision to make with minimal input from the physicians here. We had an opportunity to replace our old fleet of 29 ventilators and purchase 35 new units. We currently have 41 SERVO-i ventilators. That was the start of uniformity. We started to hire clinical coordinators, of which we currently have four; in the NICU, surgical ICU, medical ICU and PICU.

The coordinators play a pivotal role in our objectives for synchronization and efficiency. Our Critical Care Coordinator, Louis Fuentes, oversees everyone. We have instituted weaning protocols. Because each of the ICU departments is different, we have implemented protocols that are very similar, but somewhat customized to each individual department. Louis does this in collaboration with each of the Medical Directors for the individual units. Our objective is to establish an institutional database. We can now accurately track ventilator length of stay, which we were not previously able to do.

This lack of correct data became evident as an extremely important parameter that we used in a process with the UHC United Hospitals Consortium, which led us to discover that the data from the past was inaccurate. The charge initially came to us that our ventilator length of stay was a ridiculous number. Upon investigation, we discovered that their manner of estimating and accounting our ventilator days was first day on ventilator until day of discharge, which couldn't possibly be more inaccurate. So we decided to institute our own database, which Louis updates with the other coordinators every single day. Our ventilator length of stay is now marvelous for an institution this large.

What is your current ventilator length of stay?

Louis Fuentes: Presently in our trauma unit, our surgical unit and neurosurgical unit, our ventilator days average at 6 days, which is very satisfactory in these units.

In our open-heart recovery unit, the ventilator length of stay is efficient with our fast track extubation and weaning protocol. The average length of ventilator stay there is approximately 8 hours, post-surgery for fast-track patients. We are currently discussing protocols for the medical ICU and our long-term ventilatory unit, where the patients tend to be very complicated medical patients including renal dialysis issues. Sometimes they cannot be put in a long-term facility, since these facilities are limited in New Jersey, without dialysis capabilities. Those are some

of the projects we are working on now. In this department, we are considering implementation of a Volume Support/PRVC protocol, which we are discussing with our Medical Director Dr. Jagadeeshan Sunderram.

How has the ventilation technology supported the focused effort in this institution?

Gerald Schlette: Our therapists had some experiences of the SERVO 300 Ventilator, some with Automode and some not. An overwhelming majority of the therapists were reluctant to ever use Automode, and I feel this was a huge disservice to our patient population.

When we implemented the SERVO-i fleet with the new user interfaces and graphics, it was much easier to introduce and instruct about Automode. In our open-heart recovery unit, nurses were initially very reluctant and resistant to this change. But they realized the benefit of Automode - how fast it will help the patient get off the ventilator, the interaction with the anesthesia and medication post-op, and now they don't want anything else. And this has expanded from the open-heart recovery unit into the SICU heart department and other areas of the hospital as well. The physicians see the sequence of events and the benefits of them.

What other types of ventilation therapies are used in addition to standard therapies?

Bernadette Lewis: We have five nitric oxide units, two in the NICU, one in the PICU and the other two units are available for the additional patient population. We also provide high frequency oscillation (HFO) when appropriate, in all patient care populations. HFO should not be used as a last resort; its use is encouraged prior to the patient's decline. We have begun to educate physicians and staff to monitor certain physiological disease states, such as ARDS that is difficult to treat, and to implement HFO before the patient reaches life-threatening circumstances.

I understand that more expansion is planned for The Bristol-Myers Squibb Children's Hospital, as well?

Gerald Schlette: Yes, Children's Specialized Hospital in Mountainside will be part of our campus in New Brunswick, joining The Bristol-Myers Squibb Children's Hospital and The Child Health Institute of New Jersey. This acute care pediatric rehab facility is scheduled to open in 2008.

Can you describe the other ICU units here?

Louis Fuentes: Our neurosurgical unit is a seven bed ICU. Our trauma unit accommodates ten critical care beds. There we see everything from uncomplicated general surgery patients to ARDS. We have an active trauma helicopter service and land transport trauma service. The cardiac ICU comprises eighteen beds, where they care for post-op open-heart cases, valve replacements, aortic valve replacements, robotic surgery, and we have done transplant cases as well. Dr. Mark Anderson and Dr. Peter Scholz are the chiefs of Cardiac and Cardiothoracic Surgery. We perform rounds with the cardiac intensivists, and work closely together with them regarding patient goals. Our MICU has 16 critical care beds and incorporates a daily readiness to wean assessment on every patient requiring mechanical ventilation. Our MICU coordinator Mr. William Twaddle, RRT has worked intensely to help facilitate weaning in the MICU and CCU. Recently, we have approval on a new mechanical ET tube holder to help us prevent inadvertent extubation and potential pressure ulcers from having an artificial airway. The CCU consists of 15 critical care beds with patients suffering from a multitude of cardiac conditions.

Bernadette Lewis: The trauma unit keeps us very busy on some days. Just last week, we had seven cases come in within the period of one to two hours. It can be anything from stab wounds, to construction worker accidents, to traffic accidents with multiple

victims. Numerous highways surround us, and we are a heavily populated urban area.

Gerald Schlette: In terms of acuity, the institution is pretty much at the 100% mark. We have a total of 584 beds, but we have exceeded 600 on occasion. They are looking at redesigning our holding area for the ER to accommodate these patients, as a combined solution for medical, cardiac and surgery patients.

Robert Wood Johnson Medical ICU

Critical Care News met up with Dr. Jagadeeshan Sunderram between rounds at the Robert Wood Johnson Medical ICU to discuss new procedures for weaning and outcome tracking. Dr. Sunderram is a pulmonologist and Medical Director and Head of the MICU at Robert Wood Johnson University Hospital.

Can you describe the impact recent development has had on the medical intensive care unit and staff?

I have had this position since 2001 and there has been a lot of expansion since that time. The MICU has grown and is a state-of-the-art unit, with one nurse for every two patients and a pod system where the patients and monitors can be followed closely. There is a central nursing station, but this is not used as often since the pod system came into effect, which enables the nurses to be closer to the patient.



Dr. Jagadeeshan Sunderram is Medical Director and head of the MICU at Robert Wood Johnson University Hospital.

How is your cooperation with respiratory therapy?

It has been a fantastic coordination. The implementation of a Critical Care Coordinator function has enabled us to do a number of things to improve our outcomes. For example, we had very high rates of ventilator-associated pneumonia in the past, and what we have done is to institute something called multi-disciplinary rounds. This includes about thirty questions that look at prevention strategies for ventilator-associated pneumonia, for gastrointestinal bleeds, and so on as recommended by the Society of Critical Care Medicine. We do that three days a week and cover the whole ICU to make sure that these recommendations are in place. We have been able to reduce our rates of 10 VAPS per 1,000 patient ventilator days, which was about the national average, down to 3 to 4 VAPS per 1,000 patient ventilator days. This is a substantial reduction. We implemented this program only five months ago, so we have seen these dramatic reductions in a very short period of time. In fact, in some months we have had no ventilator-associated pneumonias at all.

Are you implementing a series of weaning protocols?

We have a series of standard questions that the therapists ask each morning. They ask if the patient is ready for a trial of spontaneous breathing, they conduct a rapid-shallow breathing index; they look at high FiO_2 levels and high PEEP levels. They establish whether the patient is on less than 8 cm H_2O of PEEP, if the patient is at less than 60% of O_2 concentration, and whether the patient is hemodynamically stable and has no contraindications to rapid-shallow breathing index. If the answer to those three questions is yes, they conduct a rapid-shallow breathing trial. If the patient passes, the therapists inform the physician that the patient is ready to come off the ventilator. The physician may determine whether or not a trial of spontaneous breathing should be done. We have that protocol in place, and it has become very streamlined, but everything depends on patient response. It is much easier for the patient and the staff.

Will you be looking at length of stay on the ventilator?

We will definitely be looking at that data. It is not currently available, however the respiratory department will be collecting the data in a

database for analysis. We have some preliminary data showing that almost 80-90% of the patients, who we thought were ready, did come off the ventilator. And about 50% of the patients who we did not think were ready actually came off the ventilator as well! I think it had to do with the issue of sedation. Once we examined sedation management, we changed the protocols and routines, and I think this group of patients will be reclassified in the future. That is what is so fascinating about implementing these protocols; you look at one or two aspects in detail, which may illustrate how a full change of events can occur. There are a series of links here, and at some point there is always a failure. So we are trying to identify where the failure happens, and with the data in hand we can identify that point and fix it. That is a benefit of standardizing our processes.

Robert Wood Johnson Surgical ICU and Neurotrauma ICU



Kumar DeZoysa and colleague with neurotrauma ICU patient.

Critical Care News spoke with Kumar DeZoysa, BS, RRT, Critical Care Coordinator, Surgical ICU and Servillano Derikito, RRT, Staff Respiratory Therapist, to discuss how the new procedures are impacting respiratory therapy in the Surgical and Neurotrauma ICU departments.

Can you generally describe some of the cases you are treating today?

Kumar DeZoysa: We have a patient who was involved in a motor vehicle accident. The

patient has a non-significant aortic tear, and is being stabilized for the OR. He has been at 70% O_2 concentration and 14 cm H_2O of PEEP for the last two weeks, and we have been waiting for him to be stabilized. He took a turn for the worse during transport to the CAT scan. After returning he went from SIMV/VC to AC/VC, and the patient continued to deteriorate. He was put on AC/PRVC, and the patient started to improve, which we hypothesized was due to the fact that the patient had an autoPEEP ($=+20$ cm H_2O) with PRVC. I am capturing the data, using the SERVO-i data retrieval, and it makes for an interesting case study.

Is your neurotrauma ICU running basically at full capacity most of the time?

Servillano Derikito: Yes, basically every day of the week is busy, but we tend to get the most patients on Fridays and the weekend, when the accidents are more prevalent.

What are your experiences of implementing the weaning protocol for standardization?

Kumar DeZoysa: We were introduced to the concept of lung recruitment approximately 8 years ago, via a Siemen's instructional video on lung recruitment, and we realized that this is a way to improve patient outcomes. Dr. Burchard Lachmann's contributions have formed the cornerstone to our lung recruitment maneuver philosophy, and we have been refining our technique since then. We are trying to



Kumar DeZoysa and Servillano Derikito with surgical ICU patient.

implement this philosophy into our ventilation management and weaning protocols to facilitate and improve the weaning process. Lung recruitment maneuvers include monitoring the PaO_2 : FiO_2 ratio and appropriate PEEP titration to maintain this ratio. We believe that once the lung is optimally recruited with noted improvement in ABGs and other indicators of pulmonary status, it will be much easier to facilitate weaning. The newly implemented protocol has its basis in routine weaning maneuvers, but emphasizes the need to have an improved understanding of lung physiology and the pathophysiology of atelectasis, and incorporates monitoring of the pulmonary status.

What about your post-extubation strategies for maintaining lung recruitment?

Kumar DeZoysa: We have started a research project incorporating biofeedback in conjunction with lung recruitment. Initially, we educate the patient about atelectasis and corrective actions to include incentive spirometry (IS) and deep breath and hold (DB&H) maneuvers. We provide each study patient with a pulse oximeter within the patient's visual line of sight, usually at the foot of the bed. We ask that the patient maintain a certain saturation level, such as $\text{SpO}_2 > 95\%$, by performing extra bouts of IS and DB&H exercises in addition to the requisite hourly regimen. We believe that once patients are armed with this information and a pulse oximeter, they should be able to follow their own progress and help themselves improve by means of this biofeedback. We started this research project about two months ago and we



Kumar DeZoysa and Servillano Derikito.

have captured data on approximately 20 patients so far, but our objective is 500 patients. It will be interesting to see a final analysis of the data from this number of patients. Anecdotally, I can state confidently that patients with compromised pulmonary status who are compliant with the instructions improve within hours of implementation of pulse oximetric biofeedback. As the institution grows, the respiratory therapy department has more opportunities to get involved in various aspects of research. We have a very supportive anesthesia department that has volunteered to guide us through the intricacies and subtle nuances of the processes of research and publication, in addition to our primary goal of improved pulmonary and patient care.



Doug Campbell, Assistant Vice President of Operations described disaster coordination activities.

Robert Wood Johnson University Hospital Operations

Robert Wood Johnson University Hospital is situated at the crossroads of New Jersey's chemical, biochemical and pharmaceutical industries, and is in proximity to the Northeast rail corridor, large international airports and New York City. Disaster coordination and preparedness is a significant consideration for this university hospital. Critical Care News spoke with Doug Campbell, Assistant Vice President of Operations.

You started at this institution in 1985. Have you seen considerable expansion since then?

It is amazing what has happened in the past twenty years, not only for Robert Wood Johnson but also for the city of New Brunswick. The hospital has benefited from the addition of the Children's Hospital, the Cancer Building and five new buildings are currently in the planning process. We have also benefited from our affiliation with the University of Medicine and Dentistry of New Jersey-Robert Wood Johnson Medical School, which has expanded on the New Brunswick campus as well.

What are the most significant developments in recent years?

The establishment and growth of The Bristol-Myers Squibb Children's Hospital is one of the most significant developments. When we built the Children's Hospital in early 2000, we shelled the top two floors for future use, thinking that we would not need them for

some time. However, due to the growth of programs we needed the resources of additional space much quicker than we thought, so all seven floors are now completed and occupied. That development has been enormous, with the addition of the NICU and Special Care Nursery and the growth of other pediatric units, as well as the pediatric oncology service. Additionally, the construction of the Cancer Building, the expansion of the Cancer Institute of New Jersey, all have been significant developments that have affected the hospital in a positive way.

Disaster coordination and preparedness must be a significant consideration for this university hospital, with your proximity to metropolitan areas and chemical industries in New Jersey?

That's correct, and New Brunswick is at the center of the State of New Jersey. We have a major university; the Northeast corridor train line runs along the east side of our campus, there are oil refineries, the petroleum industries, the chemical industries, and pharmaceutical production, all within a close geographical area to the hospital, which is only

30 minutes from New York City. Our sister hospital, Robert Wood Johnson at Hamilton, is 30 miles to the south. This facility dealt with the Postal Service Building anthrax cases that developed in 2001. Robert Wood Johnson University Hospital really is at the crossroads for the need for statewide emergency preparedness.

We participated in Top Off 3 last year, which was a congressionally mandated series of emergency preparedness exercises, lead by the Department of Homeland Security. We participated at the top level, what we call Level Three, and the drill was conducted over three days.

We had over 380 volunteer patients over three days come through our facility, while we were operating the hospital at nearly 100% occupancy. Our courtyard was transformed into a 125 bed surge capacity area, and an Incident Command Center was set up in our boardroom. The Respiratory Therapy department did a great job; since the scenario was the dispensing of plague, they were taxed beyond what they could imagine. We established a Victim Control center, and it was one of the toughest experiences the institution has ever undertaken, but an

extremely valuable experience to us. Participation in this drill was done at 100% occupancy, so we were busy treating our real patients as usual, in parallel with the simulation exercises. It taxed all of our resources but we are much better for having conducted this exercise.

It must be extremely valuable as an institution to have that experience in hand?

Yes, we know now that we can handle a certain number of extreme incidents: chemical, biochemical, and a surge of patients. These were all very important experiences in terms of reference for the future responses. The exercise went extremely well, and we continue to work towards being one of the leading facilities in the state. So much so that we received a grant of 1.5 million U.S. dollars to construct the medical coordination center on our campus. The Medical Coordination Center will coordinate the health care emergency response in a five-county area in central New Jersey. This facility is also established to assist with the coordination of responses to emergencies anywhere in the state.



Doug Campell, Assistant Vice President of Operations.



The mobile intensive care unit of The Bristol-Myers Squibb Children's Hospital covers a broad geographic area for patient up take.

The Bristol-Myers Squibb Children's Hospital

Mobile intensive care unit

The Bristol-Myers Squibb Children's Hospital operates a fully equipped transport service. Gerald Schlette described it:

The transport service provides a fully equipped mobile intensive care unit. Patients can be intubated or have chest tubes placed during transport. The unit provides compressed oxygen, a full range of IV therapy equipment, a crash cart including an aortic balloon pump, cardioverters, and two ventilators, one for the

incubator and one for older patients.

We have a broad geographical area for patient uptake – northern New Jersey, Albany New York, south New Jersey, Philadelphia and other points in Pennsylvania, Washington DC, and Virginia. These are planned emergency patient transports – the patient is usually stabilized but needs to come in for specialized care.

The critical care transport team usually consists of at least one critical care nurse from the appropriate unit, one critical care respiratory therapist, and one or two residents, depending upon the case. It is something we are proud of at this institution.

Pediatric Intensive Care Unit

The Bristol-Myers Squibb Children's Hospital has the region's largest state-designated pediatric intensive care unit, which is operated with a family-centered focus. Critical Care News spoke with Dr. Jacqueline Williams-Phillips, Director of the Pediatric Intensive Care Unit.

Can you describe your multidisciplinary team approach here in the PICU?

There are six full-time pediatric intensivists on staff, two additional pediatric intensivists who make rounds on a part-time basis as well as three critical care nurse practitioners.

On rounds we include the bedside nurse, nurse practitioner, attending physician and respiratory therapist, as well as a pharmacist. We also have a pediatric intensive care fellow, second and third year pediatric residents, and medical, nursing and pharmacy students on rounds. The team makes rounds twice a day and the attending staff are on site essentially 24 hours a day. We have a multidisciplinary ICU which admits both surgical and medical patients. Nursing coverage for some patients may be 1:1 while others can be 1:2. We also have a step-down intermediate care service within the facility for patients needing monitoring.

For a new facility, you seem to have grown quickly in terms of size and services?

We have a fellowship program as well as a nurse practitioner program in pediatric critical care. There are 14 beds in the ICU with provisions for up to 6 more if needed. We have an active transport service, which is run from the ICU, and we have just started a pediatric cardiac surgery program this past year.

We have almost 1,000 patient admissions per year, with almost 800 critical care transports. There were 215 mechanically ventilated patients in 2004 and 268 in 2005, representing 2,364 and 1,525 ventilator days respectively. This includes conventional, high frequency, and BiPAP/CPAP.

We used to be a children's hospital within the main hospital at Robert Wood Johnson University Hospital until 2001, when The Bristol-Myers Squibb Children's Hospital was established. A brand new state-of-the-art PICU was added, with sleeping arrangements for families, so parents never have to leave their child's bedside. We focused on family-centered care when the establishment was constructed and were honored with an award in 2005 for our PICU's family-centered care at the Society



Dr. Jacqueline Williams-Phillips is Director of the PICU at The Bristol-Myers Squibb Children's Hospital.

of Critical Care Medicine annual meeting.

Which types of patients and of ventilation therapies are most common here?

The ratio of medical to surgical patients is about 4:1. We take all critically ill children outside of the neonatal intensive care arena here. The types of patients requiring critical care include post-op general surgery, cardiac surgery, neurosurgery and other pediatric subspecialty surgery, as well as oncology,

respiratory failure, pneumonia, ARDS, RSV and other medical critical illnesses.

We use a variety of ventilation strategies depending on the individual patient and condition. For cardiac patients post-op we try to minimize volumes. For a trauma patient, the strategy will vary depending on the presence or absence of hemodynamic instability or intracranial hypertension. Most of us like to use PRVC with SIMV. Our respiratory therapists are very involved in the development and implementation of the treatment plan,

and generally attend rounds, providing input and sharing strategies. We teach not only residents and fellows, but also nurse practitioners and nursing students from the local nursing schools. There are respiratory therapists in training, and we have residents from other institutions who come by on rotation, and medical students in their third and fourth years. Everyone has input and there is a lot of bedside teaching on rounds.

A number of years ago our PICU was ranked number one for lowest mortality. We belong to a national database that matches severity of illness in the PICU, and we are able to compare our unit with other children's hospitals nationally, in terms of demographics, outcome and mortality. Family-centered patient care and outcomes are our main focus, and we are proud of our staff and facility. ■



Dr. Williams-Phillips with PICU patient.

Biography

Jacqueline Williams-Phillips, MD, FAAP, is Medical Director of the Pediatric Intensive Care Unit at The Bristol-Myers Squibb Children's Hospital at Robert Wood Johnson University Hospital. She is an Assistant Professor at Robert Wood Johnson Medical School and has been an attending physician in the PICU since completing her fellowship in pediatric critical care at Children's National Medical Center in Washington D.C. in 1994.

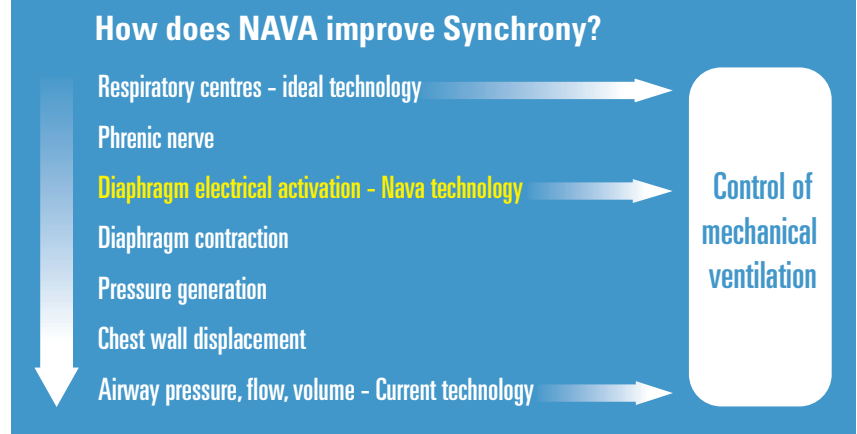
Intensive Care Units around the world have been providing their patients with mechanical ventilation for the past thirty years, ever since the first electronic ventilator technology appeared in the early seventies. And ventilation therapy, irregardless of mode, has been delivered in the same manner – a clinician has regulated the pressures and volumes provided to the patient.

A group of researchers in Toronto have established a new respiratory methodology, based on the neural signals provided by the patient. Research in the concept of Neurally Adjusted Ventilator Assist (NAVA) is rapidly gaining the interest of the scientific community.

NAVA – a new generation in respiratory therapy



Christer Sinderby, PhD, is on staff at the department of Critical Care, St. Michael's Hospital Toronto, Canada.



Adapted from Sinderby et al Nature Med 1999

Can you describe to our readers what NAVA (Neurally Adjusted Ventilatory Assist) is, and how it functions?

NAVA is a new mode of mechanical ventilation, where the ventilator is controlled directly by the patient's own neural control of breathing. Since the introduction of the mechanical ventilator over thirty years ago, ventilation treatment has traditionally been provided by means of adjusting airway pressure, flow and volume. With NAVA, the ventilator pressure is adjusted by the patient's own neural control system. The neural control of respiration originates in the respiratory center, and signals are transmitted through the phrenic nerve to excite the diaphragm. With NAVA, these signals are monitored by means of bipolar electrodes mounted on a nasogastric feeding

tube and positioned in the esophagus at the level of the diaphragm. As respiration increases and the respiratory center requires the diaphragm for more effort, the degree of NAVA ventilatory support needed is immediately provided.

This means that the patient's respiratory center is in direct control of the mechanical support required on a breath-by-breath basis, and any variation in the neural respiratory demand is responded to by the appropriate corresponding change in ventilatory assistance.

Besides being a distinct mode of ventilation, NAVA also offers a complete evaluation of the neural respiratory control in the context of a respiratory monitor. For example, if no assist is provided, the drive will be very large, but if the patient is provided with assist, the drive

decreases. These are rapid reflex loops that are constantly ongoing.

This provides both the neural monitoring signal and how much assist is to be delivered, at the same time. It also shows the extent of how the respiratory drive has been regulated, and the pressures used in this respect. There are no other modes that can provide these capabilities today. A pulseoximeter may tell us: "The saturation is going down to 80% and affecting PaO₂, and if FiO₂ is increased, the saturation increases back up to 91%". But that is only a monitor, and the clinician is in charge of making the required adjustments. With NAVA, the patient is "in charge" of adjusting the ventilation. We do not make any interventions; only observe how the patient is regulating himself. One interesting aspect is in emergency situations; we have found that it is



Christer Sinderby was the recipient of a Parker B Francis Fellowship in Pulmonary Research.

always safest when we apply NAVA. We seem to have much better control than by any other means. In fact, we have found that the sicker the patient is, the better NAVA seems to respond. Right now in Toronto, we are studying heavily sedated patients breathing on NAVA, with very few difficulties, blood gases are normal and the patients are stable.

This is of special interest, since it is a new area of research. What led to your research in this particular area, and how did you establish this concept?

It started with signal analysis of electrical signals from the diaphragm, a field where we had been doing research for many years. We started with something called spectral analysis, which is examining the diaphragm electrical activity in the frequency domain. The frequency domain can provide a great deal of information, for example when a muscle is fatigued, the number of motor units a muscle has, and how the muscle is recruited, which is the signal used when triggering breaths. We plotted the frequency spectrum to 1024 different points, and divided the points to evaluate the signal, so we made an enormous analysis of every little sample. This in turn led to

a practical solution, which a good friend of mine, Dr Paolo Navalesi, an intensive care physician, asked if we were interested in using this technology for evaluating ventilators. By this time, we were doing research on respiratory muscle fatigue during weaning.

We went ahead and evaluated the signals we had, and observed that the signals were very stable, and that there were significant delays with triggering with conventional ventilators, which made us think that we could do a much better job. So from that point on, with the signal processing research, which we had already developed, it was not very complicated to obtain algorithms for controlling the ventilator. The difficulties arise when attempting to apply these algorithms into current ventilator technology and existing platforms, where adaptations to already existing technology must be considered.

Will the biggest challenge with NAVA be that people will have to regard respiratory therapy in a fundamentally different and new way?

Traditionally, many physicians who have worked in the ICU have had a background as an anesthesiologist or an intensivist. With NAVA, this means that they may have to think in terms

of neurology as well. But a neurologist typically doesn't think in terms of respiratory therapy, either. But the potential benefits may outweigh these challenges, for example when we see neonatal patients being treated with nasal ventilation, and the CT scans confirming that their lungs are completely recruited.

It is not a matter of one group being able to do something a little better than another, rather that we are opening a completely new door. It is a significant paradigm shift, which may offer opportunities to do things we never felt possible before. But this requires a totally new manner of thinking. When we have the opportunity of lecturing to ICU staff, we try to communicate that this is new, this is pioneering, and we may be able to do things that were not possible in the past. But an entire group of professionals will have to start considering this new generation of mechanical ventilation as well, which is necessary with the introduction of a new methodology.

There has been a growing interest in asynchrony in recent years, however it is still perhaps not prioritized as it might be in daily treatment work. From your perspective, how frequently does patient-ventilator asynchrony occur?

I believe that there is a level of patient-ventilator asynchrony in every patient, and in every mode of pneumatically-driven ventilation. From my experience, it is rare to find patients with insufficient support. In most cases, patients are receiving too much support, and this means that the assist is prolonged beyond the neural cycle. In this situation, triggering the ventilator can become a problem for certain patient groups, for example COPD. But knowing when to terminate inspiration – there are no physiological cycling-off criteria available today. We have previously observed and shown that asynchrony occurs in intubated adult patients with mixed etiology (Beck et al, 2001, Spahija et al, 2005) and in intubated infants being weaned from the ventilator (Beck et al 2004). In particular, by having the ability to monitor the neural activity of the diaphragm during mechanical ventilation, opens the possibility to evaluate patient-ventilator asynchrony at the bedside.

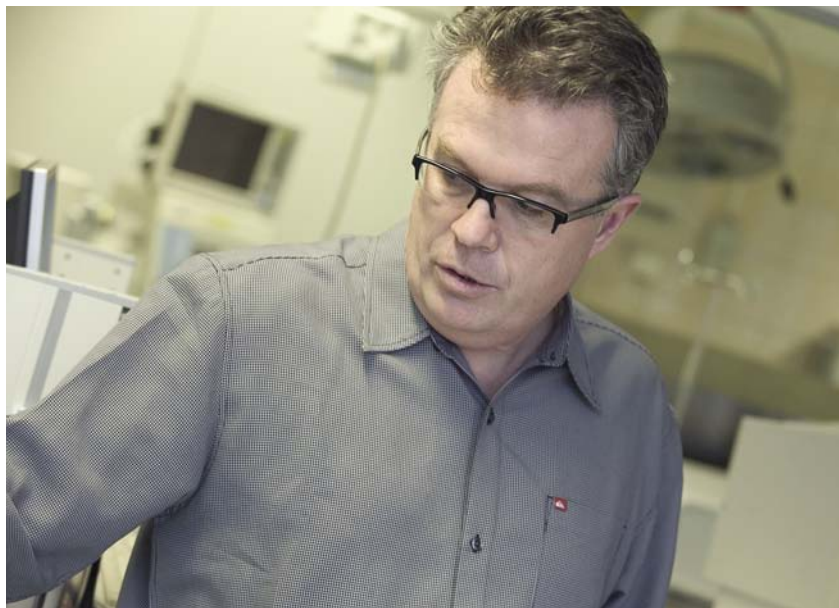
Ventilator asynchrony can be compared to other technologies: who wants a car that has a five second delayed reaction when you accelerate, and sometimes brakes, and sometimes does not brake at all?

Or a computer mouse that reacts long after you have clicked on it, or with lightening speed so you can not catch up at all?

Exactly – this is basic supply and demand. A methodology and system should deliver a support in the amount and time that the patient needs it, which allows the level of support to decrease over time. This is the support we are striving to obtain, which is why synchrony is important.

In terms of patient risks in connection with asynchrony, what do you believe is most significant?

One of the physiological effects of patient-ventilator asynchrony is that it interferes with the patient's natural breathing pattern. As we have shown in intubated infants, excessive delivery of assist (beyond the neural inspiration) prolongs expiration as compared to an unassisted breath (Beck et al 2004). In addition, if there is a delay to trigger the ventilator, this will prolong inspiratory time. With NAVA, the ventilator is cycled on when neural inspiration begins, it provides assist during inspiration proportionally, and it cycles-off when the neural expiration begins. It does not interfere with the natural breathing pattern, because it follows the natural breathing pattern.



Christer Sinderby has conducted extensive research within neurally controlled ventilation.

One of the greatest problems arising from excessive delivery of assist (delayed cycling-off) is that extreme pressures and volumes can cause lung injury. Our most recent experience in experimental research suggests that NAVA is lung protective (Brander et al, 2006). Our clinical data also indicates the potential for lung protection as the spontaneously chosen tidal volumes are low and similar to those recommended by the ARDSNet study for reducing ventilator-induced lung injury. In three pre-clinical studies and two human studies, we have tried to increase the NAVA assist to levels comparable to overdistention. And we have not been able to come up to these levels – there is a neurological reflex that regulates and closes pressures that are too high. Physiologically, when a volume increases to a certain level where you can no longer inspire, the body has a neurological mechanism that stops the process. This is a fundamental difference from mechanical ventilation, where a third party regulates volumes and pressures. But synchrony is two-dimensional: a time scale where it might be too late to start to inspire or too early or too late to cycle off, and the other dimension is amplitude. But the protective component is not only in amplitude. For example, when we have studied neurally triggered pressure support, and deliver high pressure support levels, in these cases the patient time scale cycles off so early that it is not possible to go over a certain level. If the volume is obtained too rapidly, it stops, from a neural perspective. This is the same pattern of normal respiration, you cannot inspire above a

certain level that the body does not accept. With NAVA, a ventilator would function in the same manner as the body in this case – you cannot prolong a breath. If a breath were prolonged, there would be excessive volume, resulting in lung injury. So NAVA covers both dimensions, the time scale and the amplitude. And the benefit is that you have a methodology that does not lead to a run away situation, but allows the body's physiological defense mechanism to regulate the ventilator. General asynchrony can be compared to an example: if a patient tries to breathe and get insufficient support, the inspiration is insufficient. If the ventilator then should start when the patient has stopped inspiring, they receive the wrong level of assist and become agitated. If I thereafter increase the support from the ventilator to supply larger pressures, the patient might miss a few breaths, and we have initiated the downward spiral.

If patient-ventilator asynchrony is so severe that the patient “fights” the ventilator, the caregiver usually resorts to sedation and/or neuromuscular paralysis of the patient. However, the current trend in mechanical ventilation is to give less sedation and to help the patient breathe spontaneously. If we consider spontaneous breathing to be a true objective in ventilation therapy, we must help the patient to receive a level of support that is adapted to spontaneous breathing, and interfere as little as possible. Respiratory support should only be delivered when the patient wants it. Traditionally, it has been a matter of supplying a ventilation support that

sustains a certain level of minute ventilation, but the ventilator must take care of the lung, chest wall and abdomen, and the work of breathing increases. The patient does not receive what he needs.

What considerations should be taken with NAVA in regard to intubated as well as non-invasively ventilated patients?

If you are treating an intubated patient, you have a patient who has lost some level of autonomous breathing control functions (you have blocked the upper airway defense mechanisms). Perhaps you want to protect the airways if the patient is very sedated. With neural control, it does not matter how you ventilate; we can ventilate with a mask, with a helmet, nasal prongs, a mouthpiece or an endotracheal tube. We see the same results however we deliver ventilation, the fact that we are delivering neurally controlled ventilation is not an issue. However, this difference between invasive versus non-invasive is a traditional way of thinking in regard to delivery of ventilation therapy. But for example, some patients must be sedated, if they are in pain or very ill, and NAVA can still support ventilation in these cases. NAVA delivers the support when the patient neural signals demands a breath, and NAVA delivers support that is proportional to the patient's neural request, and stops when the patient has received enough. It works if the patient is intubated or ventilation is delivered by other means.

This is a matter of disconnecting pneumatics in how we consider this: the tube, whether it is in the nose or in the throat, is only there to deliver ventilation. Today, physicians use pressure and flow as feedback for supplying support, which means a lot of information is needed from the same tube. With NAVA, we take the information from another source, directly from the brain, if you will, and that information comes directly outside any other routes.

Are any particular patient categories of special interest in terms of NAVA, at this point in time?

In regard to patient categories, I believe it is very important to gain experience in as many types of intensive care patients and disease categories as possible. Heart-lung transplant patients have many organs where the neural connection has been cut and replaced by new organs, and I do not think they would be good candidates for NAVA ventilation at this stage; it

is perhaps too early yet. In regard to other different patient categories – we are in the pioneering stages.

We are entering into a new generation in mechanical ventilation. For myself as a researcher and for the team I work with, we are doing as much as we can to obtain as much good information as we can at this stage. Our total focus right now is on safety. We hope that other intensivists and research centers with a pioneering spirit will want to join us in the development of a new methodology, something fundamentally different than everyone is used to. There is an exciting journey ahead of us, with experiences that we may have not expected, but also groundbreaking therapeutic discoveries in the near future. This will require an enormous amount of communication, and forums for clinicians to share experiences with each other.

Biography

Christer Sinderby, PhD is Assistant Professor at the Department of Medicine, University of Toronto, Canada, and Research Staff Scientist at St. Michael's Hospital, Department of Critical Care Medicine, Toronto. He received his MS degree from the Karolinska Institutet in Stockholm, Sweden, and Doctor in Medical Science degree at the Department of Neurosurgery, Sahlgrenska Hospital, University of Gothenburg, Sweden.

Christer Sinderby has had numerous academic committee assignments, including the University of Western Australia, as a peer reviewer for American Journal of Respiratory and Critical Care Medicine and Journal of Applied Physiology, and as a member of the American Thoracic Society/European Respiratory Society task force for the ATS/ERS statement on standardization of respiratory muscle tests.

He has won numerous research awards and grants including the Montreal Chest Hospital Research Institute Annual Award, the Parker B. Francis Fellowship in Pulmonary Research and Fonds de la Recherche en Santé du Québec Chercheurs Boursier Scholarship.

His research has been extensively published in peer review journals and monographies.

When we try something new for the first time, it may easily happen that we experience that it does not work according to our expectations, which means it is a question of diagnostics and translation, in the process of learning the patterns of treatment with a new methodology. What is important to note is that the initial physicians working with this will be true pioneers. We have a first solution how NAVA can be applied, but we will collectively need to share all of our experiences as we go forward.

A new way of thinking and a new perspective on ventilation means not only potentially new solutions, but potentially new challenges as well within the future in critical care. ■

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Cutting edge knowledge on mechanisms and therapy opportunities related to Ventilator Induced Lung Injury (VILI) was the focus of a two-day symposium sponsored by MAQUET Critical Care in Strasbourg, in September 2005. More than 200 critical care practitioners from more than 20 nations worldwide participated.

They had the opportunity to listen to and interact with a globally distinguished panel of speakers, including Professor Luciano Gattinoni, Professor Marco Ranieri, Professor Rolf Hubmayr, Professor Gary Nieman, Professor Michael Quintel, Professor Jesús Vilar, Dr. Fernando Suarez Sipmann and Professor Stefan Uhlig. Chaired by Professor Arthur S Slutsky of Toronto, the two-day symposium covered a broad range of current research and therapeutic topics related to VILI, ranging from molecular biology, to methods of bedside recruitment.

Acute Lung Injury – from basic science to bedside application

Professor Arthur S Slutsky opened the meeting as Chairman with the goals of the symposium: an in depth look at ventilator-induced lung injury in terms of basic mechanisms and clinical approaches, in a series of didactic lectures with a collegial and interactive atmosphere. He also presented the first lecture, entitled “Ventilator Induced Lung Injury (VILI): From Barotrauma to Biotrauma”



Symposium overview.

Professor Slutsky emphasized that ventilator induced lung injury by no means is a new entity. In fact already in 1745 it was speculated that mechanical means of ventilating the lungs may induce lung injury and that the pressure applied during resuscitation should be limited to “as much as a man could bear”. Current concepts of ventilator induced lung injury are closely linked to repetitive opening and closing of the lung, as is the administration of high lung volumes. This will lead to a mechanical damage either as atelectrauma or barotraumas. He further explained how these well-proven mechanisms may lead to activation of pro inflammatory substances, with subsequent migration to other organ systems and risk of secondary organ failure. As the lung receives all the blood volume and contains 50% of the marginated neutrophil pool it is strategically situated for such a scenario. The huge surface area of the lung and its connection to the environment makes it apt to serve as a portal entry of pathogens, which may subsequently be spread to other parts of the body. As the lung is metabolically highly active with production and conversion of substances like NO and Angiotensin it can be speculated that

inhibitors of some of these substances may be complementary to the ventilatory strategy, either as markers for development of ARDS or additions to the therapeutic arsenal.

Professor Slutsky emphasized that all these features make the lung extremely suitable for translational research, where a hypothesis starting in the laboratory can be confirmed by animal and human research, and new questions can go back to the lab in a cyclical manner.

Professor Slutsky concluded by presenting novel non-ventilatory approaches to VILI including a rabbit study where intratracheal anti-TNF-antibody attenuated VILI. Critical Care News spoke with Professor Slutsky after his presentation:



Professor Arthur S Slutsky,
Symposium Chairman.

What, in your opinion, is the most significant development in mechanical ventilation in the past five years?

I think an increased belief that the way we ventilate patients, using lung protective strategies, can save lives. I think that is the most relevant development. The ARDSNet study really got people thinking that if we do it right, we can actually decrease mortality in ARDS. For a number of years, many people thought that it really did not matter how we ventilated, as long as the patient is kept alive. Turning knobs on the ventilator is not going to save more lives.

So in the past, there was not the current level of consciousness of the potential damage that could be done by a ventilator?

That is correct. There were animal studies that showed the potential damage, but the fact that you can now actually translate that into increased lives, is really significant.

There seems to be an increasing awareness of the relationship between bio-trauma and ventilator induced lung injury, as in regard to cell damage, inflammatory response and the sequence of events, as we heard in your lecture and from some of the other speakers. Do you think that there is a need for more studies in this area, and that this will intensify in the future?

I definitely think so. If you look at the paper we published that started off the bio-trauma hypothesis in the Journal of Clinical Investigation in 1997, it has been cited about 350 to 400 times. That means that as many studies have been conducted and published since this concept was introduced. I think it provides a reasonable hypothesis why patients die on the ventilator, in terms of multiple system organ failure. It is not the only hypothesis, but it is a very reasonable hypothesis for why that happens. So I do think

it will continue to drive more and more research. There are a number of centers that are clearly addressing this issue.

In respect of multiple organ failure and kidney failure, you referenced the rabbit model by Imai et al. Do you anticipate that there will be more of these studies as well?

Yes, I do, since people want to know – there is an intellectual interest. People are asking themselves, “Well, if I do something with the lung, it actually has an affect somewhere else.” We know the obvious, that ventilators can damage the lungs. But scientists like that which is not obvious. That the ventilator-lung damage can affect other organs is perhaps not obvious at present, and this is where scientists want to investigate. It is intriguing to think of what is going on, what is being released, and the role of the central nervous system. What the mechanism is for how one organ affects another is quite interesting, and has very strong clinical implications for future applications. So that combination of intrigue, and the possibility for new clinical applications or therapies to influence patient outcomes is a pretty attractive area.

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Early markers of alternation in lung mechanics in ARDS, and what a difference a PEEP makes |

Professor Ranieri emphasized the mechanical characteristics of VILI in his presentation:

- Cyclical opening and reopening of the airways, leading to shear stress on a breath-by-breath basis.
- Overdistension due to tidal volumes.
- The presence of mechanical stress is related to the dynamic interaction between respiratory mechanics and ventilator settings.

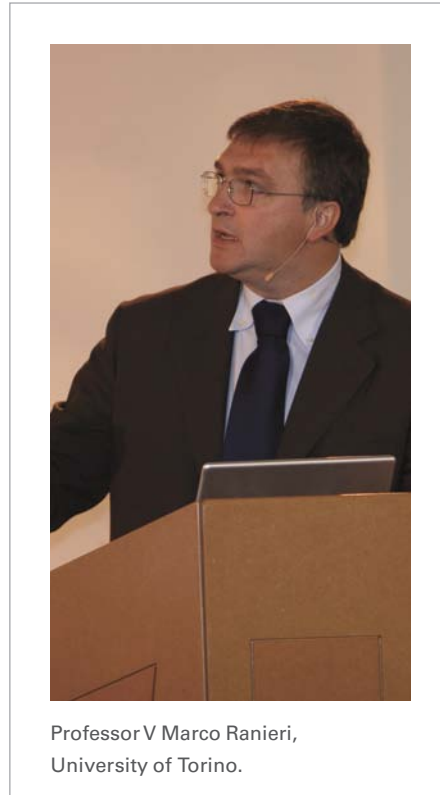
The pressure-volume curve has been proposed as a tool for avoiding imposed stress to the lung by mechanical ventilation. However, Professor Ranieri argued, even if settings have been optimized at a certain point in time, the characteristics of the lung may change, invalidating previous assessment by suctioning, position changes and other interventions.

Ranieri called for a measurement that could be applied in real time to continuously assess the imposed mechanical stress on the lung. In a series of publications, he has shown that if compliance is kept constant during tidal inflation, stress is avoided and proinflammatory markers are decreased. The Stress Index, which gives a mathematical interpretation of the shape of the pressure-time curve, could be such a tool. A Stress Index above 1.0 indicates overdistension of the lung and can be seen on the pressure-time curve as an upward concavity. A downward concavity on the pressure-time curve indicates intra-tidal recruitment and will result in a Stress Index below 1.0. The Stress Index proposed by Prof. Ranieri should be regarded as an easily applied, breath-by-breath indicator of imposed mechanical stress.

He emphasized the value of the index, citing a just completed study including 60 patients with ARDS, where CT images and the stress index were compared during low tidal ventilation according to the ARDS net protocol. 50% of the patients showed no overdistension or intra-tidal recruitment with the protocol (SI = 1.0), but he stated that even with a low-volume strategy, a large fraction of patients will show overdistension as judged by the Stress Index. The finding was validated by CT image evaluation. Additionally, patients with a Stress Index = 1.0 showed a lower concentration of IL-1 in Broncho-alveolar lavage compared to the group with Stress Index different than 1.0, further strengthening the value of the index.

Professor Ranieri concluded by giving a strong recommendation for the use of the

NIH protocol, as this is the only strategy, which has proven to save lives in patients with ARDS. However, everyone should be aware of the fact that the NIH strategy does not protect all patients from mechanical stress. Critical Care News spoke with Professor Ranieri following his presentation:



Professor V Marco Ranieri,
University of Torino.

Reading between the lines, I think you suggest that the patients on the ARDSnet protocols who do not benefit from this strategy as much as they might, perhaps receive too high PEEP rather than too low PEEP and you imply that hyperinflation, based on your stress index, was more likely to occur. Can you comment on this?

Yes we were quite surprised to see that the most important phenomenon in the percentage of patients in the NIH lung protective group is not tidal recruitment but is tidal hyperinflation. That is somehow consistent with the picture that the ARDS network published in the blue journal to obtain mortality versus plateau pressure. The higher the plateau pressure they had, the higher the mortality. If you go down to zero, zero plateau pressure is zero mortality, which obviously makes no sense but in some cases can explain the finding that even if you are using a tidal volume of 6 ml/Kg body weight, you may overdistend the lung.

On this subject what do you think is the most significant development in mechanical ventilation over the past ten years? It is the growing realization of the dangers and the extent of Acute Lung Injury?

No, I think it is more the fact that we were able to apply to the development of mechanical ventilation, the evidenced based medicine, the randomised controlled trials, and we were able to set up these kinds of studies. And we were able to transfer to mechanical ventilation the concepts from basic science and applied physiology, and merge them together. I think that mechanical ventilation is one of the few fields in medicine, where the effort that is done in other disciplines in medicine is combined: basic science, applied physiology, clinical research has been performed and been successful. So I think this is an important development in the discipline in the past ten years.

Your message about tidal volume of 6 ml/Kg body weight, that everyone seems to hear but not everyone is applying. And as we heard from you, this is not systematic, how should this be addressed?

First of all, we have to be consistent. The opinion leaders must give this take home message clearly without exception. Secondly, we have to get a message from the audience. Eggleston said, "If it is real, it is rational!" So it is real, and there must exist a rationale for this. The rationale is that a tidal volume of 6ml/Kg body weight is a tool implemented in a clinical trial. The clinical trial is close to real life, but is not real life. Real life is the physician at the bedside with a ventilator and a patient. So I think the next step is for research to provide tools that can be used at bedside for the physician to fine-tune the ventilator settings, in order to minimize VILI.

You mean practical clinical applications?

Yes, the studies are the theoretical component but not the real life. In the real life you don't treat the patients with numbers, you treat the patients with knowledge. In order to get this knowledge, research must provide some tools at the bedside to help the physician to fine-tune what the physician believes is the best tidal volume for the patient, and to be able to replicate this.

What do you hope to see as significant developments in the next 3-5 years, and what you think is needed in terms of future clinical trials?

Primarily, tools that can help the clinician at bedside to determine the presence or absence of mechanical stress. Secondly, the development of new modes of mechanical ventilation that take the full amount of information from the patient, and to be able to provide support in total agreement with what the respiratory physiology is. These I think are the two future steps that can be translated into clinical trials, and eventual outcomes.

[CLICK FOR ABSTRACT](#)

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| Molecular biology for the intensivist and micro array analysis in VILI |

Research in mechanical ventilation is usually associated with the description of events related to pressure and flow. However, Professor Uhlig illustrated that events on the molecular level are important to evaluate, as these may be fundamentally associated with secondary or systemic effects of disease and treatment.

Professor Uhlig presented a model of how a stimuli is received at a receptor on the cell membrane, the stimuli is then transduced, upon which transcription is induced in the cell nucleus. This also constitutes the response by the cell.

The main constituents of the cell membrane are phospholipids, distributed primarily in the outer layer of the membrane bilayer. Lipid rafts are occurring in the plasma membrane and serve as anchor points for the cytoskeleton. The lipid rafts also bring together many signalling substances and are thus very important for the cell response to stimuli. Special forms of rafts are the caveole. The endothelial cell line is full of caveole. Although caveolae have been known for a long time, their function is largely unknown, but it is believed

that they are associated with the transport of protein from the vascular to the interstitial compartment, thus raising the oncotic pressure in interstitial fluid. It seems further that regulation of certain enzymes; most notably eNOS is inactivated by the binding of caveolin and will not become active until the binding to caveolin is released. It seems that this may be one of the mechanisms resulting in ventilator induced lung injury as lung stretch will release eNOS and result in production of NO.

The phosphatidylcholine and sphingomyelin in the plasma membrane further serve as important precursors for many biologically active substances, these molecules may significantly contribute to disease exemplified by apoptosis, edema formation and emphysema. Professor Uhlig also described how pressure and stress can activate metalloproteases through the EGF-receptor pathway. He also gave a brief description of the Western Blot analysis, ubiquitous in publications associated with molecular biology. Most bioactive molecules are directed to elicit a response in the cell nucleus. Professor Uhlig

gave an overview of the promoter architecture and how this may be relevant to the intensivist. New assays are now available which determine cell nucleus activity. As nuclear factor-kappa B is activated in alveolar macrophages from patients with ARDS these assays may be important for the understanding of VILI.



Professor Stefan Uhlig, Leibniz Center for Biosciences, Borstel, Germany.

| Quantitative analysis of gas/tissue distribution in the lung. CT and other techniques/Is ventilator strategy affected by abdominal hypertension? |

Professor Quintel introduced the concept of functional CT image analysis of the lung, which was pioneered by Luciano Gattinoni in the late eighties. Since then the technology has evolved with semi automatic analysis made possible by software calculation of the image. The Maluna software is the tool that has been developed and used in his institution for the purpose.

The functional CT analysis is based on the density of the individual voxel of the CT image. The analysis will give a measure of air and

tissue content. By performing a regional calculation, the amount of hyperinflation, normally behaving and collapsed regions can be identified and quantified. The technique has been a very important scientific tool, allowing insight into the mechanisms of pulmonary dynamics and verification of other new technology. The CT image is a useful clinical tool in that it may serve to identify the nature and degree of pulmonary disease and clearly identify recruitment, overinflation and

consolidation of the lung. The main limitation is of course that it cannot be used repeatedly due to radiation.

Professor Quintel gave a short introduction to Electrical Impedance Tomography (EIT), which in the future may serve as a bedside alternative to the CT image. EIT injects a small current, which is picked up by electrodes around the thorax (16-24). By measuring the difference in conductance between the electrodes, an image can be produced representing the

varying densities in a segment of the lung. It should be kept in mind though, that EIT does not give a true image of the lung, but it will be possible to discriminate areas of air and tissue. The technique is relatively specific and has a good correlation to PEEP induced decrease in non-aerated lung volume.



Professor Michael Quintel, University Clinic of Göttingen, Germany.

Critical Care News spoke with Professor Quintel following his presentation.

The thorax CT discussion was fascinating, and the benefits of CT from a thoracic point of view. The limitations you spoke of – do you see more development in future to provide more practical clinical adaptation?

Clinical adaptation might play a role by means of, for example, computer tomographs can be directly transferred to the ICU – the mobile CT's. This will have an impact for staff and might be easier to perform CT scans. However it doesn't change anything with regard to radiation. If we look at CT development over recent years, what has become more and more apparent is higher speeds, and higher time resolutions for CT scans going up to 20 Hz. This makes more breath-by-breath analysis possible, and the opportunity of looking deeper inside each individual breath, with a higher frequency of slices on the same place in the thorax. And this gives more detailed information on breath-by-breath changes in regard to any kind of ventilation.

Can there be other types of lung related areas in the future where EIT can be of interest in pulmonary dynamics?

EIT is a very fascinating technique, but the problem is that we are not aware of any standardized procedures to analyze it. EIT

allows you to get a picture of regional ventilation and perfusion, and we can carefully look at changes over time. But right now we have no tools available to make comparable interpretations of what we observe. CT is based on an anatomical structure. EIT is more complex and is oriented on an anatomical structure, but it gives you a picture of the impedance changes over time, and you have to interpret the course of the changes also.

So CT and EIT should be seen as a complement to each other, at the present time?

Yes, and the big advantage of EIT is that it will be more of a bedside procedure; it can be performed at any time and can be repeated as often as we want to. If we can establish how to interpret the data, it may have huge advantages over CT scans.

Your second lecture at this meeting presented the concepts of how intra-abdominal pressures affect the dynamics of intensive care practices is something not many are aware of in critical care?

For reasons I am not sure of, intraabdominal pressures is an area where there has been little interest within the international intensive care community for a long period of time. The first congress with focus on this subject occurred only two years ago. So it is nice to see that there is growing interest in the concerns of intraabdominal pressures, which may be due to the fact that there are more means of measuring around the abdominal cavity. We have observed changes to abdominal pressures related to hemodynamics and to respiratory mechanics. What we have been missing is to take care of the venue of the changes responsible for the observations we make. That is why intraabdominal pressure is coming more and more into focus. This is facilitated by our increased knowledge, and by some definitions about how to measure, and that we are achieving consciousness worldwide in this respect. We are becoming more aware of how important this factor is, and we are learning how to measure, and how intraabdominal pressures influence other parameters, and to use it as a tool to control therapeutic approaches, as we use other tools in this respect.

I remember when I was giving the first talk in Germany about intraabdominal pressures, about two and a half years ago. The response was as if you were talking about something

that had never been a problem before.

But if you look at some fundamental studies by Frostell and Hedenstierna in the eighties, you will see the physiological basics and significance were already established at that time. For whatever reason, for twenty years, no focus has been put on this area. But thankfully, it is becoming more generally established as a significant area in recent years.

[CLICK FOR ABSTRACT](#)

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| Impact of alveolar geometry on lung injury distribution |

Professor Nieman described how alveoli are usually depicted as grapes on a vine with no connections between them. Histologic observations however, indicate that alveoli are highly interdependent where maintenance of their interlinking structure is extremely important for stress distribution. Disturbances in this geometrical pattern with collapse or overdistension of individual alveoli will lead to increased stress in adjacent tissue and alveoli. Although not fully understood how, surfactant plays a crucial role in distributing stress among alveoli. The current perception of alveoli as a bunch of grapes opening and closing with tidal volume is actually based on surfactant research.

While healthy alveoli will move very little and hardly change in size, surfactant depletion will lead to gross abnormalities in alveolar dynamics. Alveoli will start to collapse during expiration and recruit during inspiration. Professor Nieman's research group has established the acronym RACE-Repetitive Alveolar Collapse and Expansion, as a measure of pathologic alveolar behavior. Professor Nieman presented several impressive film clips exemplifying the differences in alveolar behaviour between healthy and injured lungs. He emphasized that recruiting the lung and keeping the lung open by a proper setting of PEEP, will minimize RACE and restore the dynamics seen in the healthy uninjured lung.

Critical Care News discussed the lecture subject with Dr. Nieman following his presentation.



Gary F Nieman, MD
Adjunct Assistant Professor of Surgery,
SUNY – State University of New York,
Upstate Medical University, Syracuse,
New York, USA.

The participants were fascinated by your presentation and many like me are wondering, do you think it is a common misconception among the majority of clinicians that there is a balloon-like expansion of the alveoli during inspiration?

It is universal throughout the profession, if you look at any standard medical school textbook, which is how alveolar mechanics are taught. They teach mechanics in the way the surfactant biologists describe the alveoli, as a "soap bubble" at the end of the capillary tube. A lot of the anatomical books depict the alveoli as resembling a bunch of grapes. That is just the way it is being taught.

This concept of shared walls and shared structures within the alveoli – it must really represent a challenge to change the general mindset about this aspect of lung mechanics?

You are right, that point has come across throughout this meeting, from my basic science outlook of changing people's minds, to the investigators doing clinical work with the objective of changing people's opportunities on how to better treat the patients. Professor Ranieri talking about tidal volume of 6 ml per kilo body weight— this is one direction. At his hospital, they have changed, due to his research and force of will. How do we get the rest of medical community to change deep-rooted traditions may be a very difficult task.

We actually don't really know yet about the normal dynamics of the alveolus. There are about four different concepts. There is evidence to say that balloon-like expansion does occur, the folding and unfolding, normal recruitment-derecruitment, or the alveolar ducts changing size. There is some evidence for all four concepts, but the predominant physiological basis is yet unknown.

So further studies are needed to better establish alveolar dynamics. Do you foresee continued and accelerated research in this area?

We surely are continuing our research. Do I anticipate a breakthrough in the near future? Probably not, however I am very excited about the work I am doing with Dr. Kitioka within her concept of the alveolar mouth moving, and by changes in the alveolar mouth affecting the opening and closing of the

entire duct system. That is potentially a breakthrough concept, although it is still too early. It must be validated by biological data and go through peer-review, but from an intellectual point of view, it is very intriguing. It might help us move a little bit forward in our understanding of alveolar dynamics.

The fact that alveolar ducts appear to remain patent longer than the alveolus during ventilator induced lung injury, do you have any theories on what that might be due to?

We have only recently discovered this behavior, which by chance we have found by looking in the corner of rat lung where it is very thin; we can actually see the entire length of the duct so we get a real three-dimensional look at alveolar mechanics. That is the first time we noticed that the ducts appear to be patent while the alveoli collapse. Suggesting that since we know that this does cause injury, as I have presented today, it suggests that the alveolar collapse and not the duct collapse may be the major mechanism of the tissue trauma in alveolar mechanics.

I think we are generating more questions than answers right now, since it is such a new topic to look at what is going on at the alveolar level with each breath, and the impact of mechanical ventilation on those breaths. Surely there is a big difference in the mechanics of the acutely injured lung and the normal lung, and there is growing data looking at the type of injury and how this affects alveolar mechanics, and data I am presenting can show that depending on the type of injury, the mechanics can be markedly altered. Endotoxin does not seem to cause unstable alveoli, where other injuries do, so this suggests that the type of disease that individual patients have may have markedly different altered mechanics, and of course the question to the clinicians, how do we protect one lung versus another? And how do we know what mechanics are present in each individual patient? I think that in order to intelligently pursue protective mechanical ventilation, we really have to know what is going on at the alveolar level. We have to know physiology. We have to know pathophysiology. Then we can make intelligent decisions on how to adjust our ventilation to protect the lung, so hopefully what we are doing is investigating and learning the physiology of acute lung injury.

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| ALI and ARDS in Europe and the US, and gender and genome in ARDS |

Prof. Villar reported that ARDS was first described by Petty et al 1967. It may be debated if all patients included in the study would be considered as having ARDS, but Professor Villar pointed out the value of the paper as it was the first to call to attention that this was not really a disease, but a syndrome where the patient ended up with dyspnea, tachypnea and cyanosis, and that ventilator treatment may be life saving.

Over the years there have been several attempts to obtain a universal definition of ARDS, but it appears that consensus in study criteria is lacking, which leads to a situation similar to comparison of apples and pears, as described by Prof. Villar, when examining publications reporting the incidence of ARDS. From this perspective, it is hardly surprising that ARDS incidence is reported ranging from 3.4/100.000 inhabitants to 75/100.000.

Although frequently cited, the last figure is very hard to believe, taking into account that several studies report the incidence of acute respiratory failure to be about 135/100.000 inhabitants, as presented by Prof. Villar.

Studies on mortality from ARDS may also be very hard to analyze in this respect, as inclusion criteria may be substantially different. Professor Villar pointed out the risk of including distinctly different patient categories if inclusion criteria are evaluated only at one point in time.

Professor Villar also summarized that patients fulfilling the American European Consensus Conference criteria on ARDS day one but not on the subsequent day had a mortality of 22%, while patients fulfilling the criteria on two consecutive days had a mortality of 68%, and that other centres have later confirmed this difference.

Critical Care News met with Professor Villar following his presentation.



Director of Research Prof. Jesús Villar, Santa Cruz de Tenerife, Spain.

I was not aware of the fact that in the 1960s that the textbooks explain that tidal volumes are the same in all mammals, 6.3 ml/kg?

Yes, that information came from American physiologists and zoologists who studied respiratory physiology in animals. They established a striking finding in mammals, regardless if it is an elephant, bear, rat or mouse, that when they plotted those measurements, the values were different, but when they calculated body weight, they established a normal value. Since obesity is not a factor with wild animals, they found there was a line, and all the mammals were on the same line, and the tidal volume value was 6.3 ml/Kg body weight, exactly the same regardless of the size of the animal.

This is fundamental anatomy that perhaps not many people are aware of?

Exactly, it is a standard value that can be compared to normal body temperature

measurement. The common tidal volume value has been there but we have not been aware of this. And additionally, to really demonstrate that the value is 6.3-ml/Kg body weight, you don't need a randomised controlled trial to test nature! It is physics. If I were to measure your tidal volume right now, we know what it would be.

Another fundamental aspect you presented in your lecture is that there is no standard definition of ARDS. Despite all of the research in this area over a number of years, many people are probably unaware that a standard definition is lacking?

It is difficult to believe, I know, especially in this day and age. Back in 1972, there were very few experts in this field, in this discipline, and modern mechanical ventilators appeared first in the early 70's. I think what happened was that those people in the first panel recommended to establish studies to set a universal standard definition. And here we are, over 30 years later, discussing what the definition of ARDS is. Where do we set the values? How can we define what is acute respiratory failure, what is ARDS and what is acute lung injury? I think that many people don't follow the recommendation of many consensus conferences as they disagree completely: without inclusion of several parameters in the definition, you do not get a homogenous population.

Do you think there is need for another consensus conference in regard to ARDS?

There is a need, definitely. Ten years after 1994, it is time to reassess this situation from a patient / treatment perspective. I was part of the American-European consensus conference, and at the end, there was unanimous definition. The vote where PEEP

was considered the most important parameter won, but this perhaps mirrored regional preferences. If a consensus conference on ARDS is held in the future, I think it is better that an equal number of European and American experts meet together and discuss issues to find a common denominator and preferences, and hopefully find agreement, and then establish the definition. Specifically, an equally balanced number of experts, to find agreement on basic parameters such as age, hemodynamics, and oxygenation. For example, to find a standard ventilatory setting to say "ok, under the tidal volume of xx, and the inspiratory/expiratory time of xx, and an FiO_2 of XX, and a peak value of XX, if the patient has PAO_2 less than yy, this can be defined as ARDS or ALI."

But in addition, something that is missing in the definition is time. If we make the criteria of only half an hour, is it ARDS? This may be something that is apparent in the OR or in the intensive care unit, but eight hours later, the patient is extubated. Logically, a situation of acute lung injury or acquired respiratory distress syndrome is a serious condition that will not disappear in a few hours. To define the time constant is very important. Another aspect is drug development. Manufacturers of drugs are developing substances for use in clinical situations like acute lung injury or ARDS, but if we do not have an established clinical definition, we have the risk of a good drug being tested in the wrong patient populations, without obtaining the expected positive results. The investments of the drug manufacturers in many years of developing a substance to be a very good drug, can be wasted if the disease definitions are not standardized and in place.

Does this mean a potential risk of suboptimal treatment for these patients?

Exactly—for example, administering a good drug to the patients who might not even need it.

These vast differences in definitions of ARDS, with consequentially vast differences in applying treatment to ARDS patients seems to require an educational effort to the critical care community around the globe. How should this be addressed?

For example in regards to tidal volume, there are still physicians who apply no more than ten, or no more than 14 ml/kg bw. So I think the transition to go back where it should be will be very difficult. That is human nature. It took 12 years for the gastroenterologists to accept that the gastric ulcer was a result of the helicobacter bacteria! But today, if a gastroenterologist does not prescribe an

antibiotic in connection with a gastric ulcer, it is considered malpractice. So maybe in the future we have to consider that it is not "ventilator induced lung injury" but perhaps "physician induced lung injury." The ventilator itself does not produce injury; it is what the operator does with it that produces injury to the patient. I don't increase blood pressure to 170 in patients; I don't allow patients to go below 90. The need for standard definitions is increasingly important as we go forward. But changes in treatment traditions are possible, we only have to look to the example with the gastroenterologists to see that this is true.

We will need to continue to be able to customize therapies for particular patients and individual patient conditions. But if we do not have universally standardized disease definitions, or standard ventilatory treatments for these patients, clinical studies and data become of less value, as we are comparing apples, bananas and oranges with each other.



Dinner entertainment at the Symposium.

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How to assess recruitment at the bedside, and prone positioning in ARDS |

From animal models, we have learned that recruitment is a continuous phenomenon. Professor Gattinoni challenged this concept, claiming that he hardly ever sees sequential opening in patients. Instead he urged the audience to use the stethoscope and listen for the presence of crackles to set PEEP. He stated that, although the pressure–volume curve is an interesting research tool, setting PEEP above the lower inflection point on inspiration does not make sense as collapse is an expiratory phenomenon. He went even further in the discussion posing the question, if there are regions in the lung where the tissue is collapsed all through the respiratory cycle, there will be no opening and closing of these areas. Ventilator induced lung injury, as we know it will not be possible in these areas.

Some years ago Prof. Gattinoni and colleagues introduced the concept of using PCO_2 to avoid overdilation when recruiting the lung. If compliance improves and PCO_2 is decreasing, recruitment is probably beneficial. If on the other hand PCO_2 increases with increasing PEEP, hyperinflation is probably the main effect by the increase in PEEP. To illustrate this, Professor Gattinoni cited an observational study (no specific intervention after the findings) where patients who had the highest potential for recruitment also had the highest mortality. Patients with low potential for recruitment had very low mortality. It can be speculated that this group had a higher FRC hence having less substrate to recruit.

Professor Gattinoni concluded his presentation with a summary of the multicenter study by stating that higher potential for recruitment is associated with CT scan lung severity, the more impaired physiological variables and higher mortality rate. He also stated that in the group of patients with lower potential for recruitment, a high PEEP level had no physiological significance.

Critical Care News discussed some of the ideas and issues in his lecture topics with Professor Luciano Gattinoni

As a world-known researcher who has studied so many aspects of lung dynamics and respiratory therapies, what in your opinion are the most significant recent developments in regard to mechanical ventilation?

I think what we are learning in recent developments is to do exactly as we learned



Professor Luciano Gattinoni, University of Milan, Italy.

for twenty or twenty five years ago, but to do even less. We have learned that less is more. We use less tidal volume, we use less PEEP, and we use less nutrition, less antibiotic therapy, less of everything. We are learning to respect more the nature of evolution, and the processes of nature. In mechanical ventilation, basically we now have the course of gentle, lung protective ventilation, and this I think will prevail. Personally I don't believe in any benchmarks or courses of ventilation, but I respect the basics of stress and strain. So the less stress and strain you apply, the better it is. And this is the gentle ventilation I am talking about.

There has been a lot of discussion and enthusiasm about PEEP and lung mechanics the last five years or so, but I still think we have a lack of knowledge, in my opinion. We still do not know precisely what conditions we should call ARDS, what is optimal treatment and what can cause possible harm. I think I am convinced clearly that we need to renew our current vision of these matters.

As you stated, there is an increasing understanding of the natural physiological process in the body during recent years, and with increased studies on VILI, there seems to be a growing awareness. This general increased understanding must also include the natural process of prone positioning in mechanical ventilation?

If I said nothing else about prone positioning, I would simply say it is a condition in which the process of mechanical ventilation is possibly less dangerous. I want to avoid any misconceptions and state that there are no miracles in prone positioning. Prone

positioning may help in terms of distribution of pressure, because of the different shapes and compliance of the chest wall cavity, in conditions for which the same mechanical ventilation applied supine, prone positioning may be less dangerous. If there are standardized studies in this area, there may be the risk of taking the wrong conclusions. It is not possible to standardize anatomical aspects of chest wall shapes and compliance.

What do you think could be the most significant development in mechanical ventilation in the next five years?

I think if ventilators could be incorporated into more physiological respects, with regard to determination of lung volume and transpulmonary pressures, this could be a significant development. For example, the stretch maneuvers: many companies incorporated the volume-pressure curves, and now it is ten years later. What is the benefit and impact of pressure volume curves, from a therapeutic aspect? It is debatable.

These two measurements of lung volume and transpulmonary pressures, which are linked in some ways, are of future significance. They are quite constant, I believe, even in ARDS. Even one of these parameters of itself could be a significant development. Not to look at tidal volume, but at volume per unit of blood. This is the real ratio, which measures the strain. And it is physiologically based. The tidal volume is a sort of surrogate.

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Cellular and tissue stress failure and new insights into the pathology of acute respiratory failure

Professor Hubmayr reminded the audience that depending on the view, injury might mean different things, from the general overview of the clinician to the reductionist view of the molecular biologist. He referred to work done by Dreyfuss, West and Slutsky on hyperinflation models and emphasized that although the tidal volumes delivered to animals may seem exaggerated, it is very plausible that distribution mechanics in the injured lung will lead up to areas that will be ventilated at vital capacity with every breath. This has also led him on to research focused on alveolar cell reactions elicited by deformation.

In general terms, cells are spotwelded to their matrix, as presented by Professor Hubmayr. As it is impossible to uncouple pressure from deformation and force from strain, there is no pressure sensor or strain sensor signalling in the cell. The way a cell senses anything requires some conformational change of some molecule in the cell. The focal adhesion proteins can be regarded as a strain gauge, so when tension increases or the basement membrane alter its shape, the adhesion proteins will alter their shape and induce signalling molecules. If a round cell is forced to stretch until it's flat as a pancake, the lipid membrane may be stretched until it bursts. Before the cell membrane breaks it may trigger a variety of signalling proteins. If a cell membrane breaks, two main scenarios may be seen according to Professor Hubmayr. One which is cell death and necrosis, or the cell will repair itself and continue to function. The cell membrane break will activate stress genes leading to a proinflammatory signalling. The cell may turn into a very angry cell leading to intense signalling, which is perpetuated and intensified by neighboring cells. In other situations, according to Professor Hubmayr, even a large wound may be sealed and the cell will live happy ever after. The clinical correlation can be seen when elevated troponin levels are found. This does not mean that a patient has a myocardial infarction but simply signals that there is stress failure in the cardiac myocytes, which subsequently has healed.

In summary, Prof. Hubmayr stated that plasma membrane stress failure is an important mechanism in the pathogenesis of ventilator induced lung injury, and that most injured lung cells repair plasma membrane wounds, if we estimate that for the lung about 60% of cells repair plasma membrane wounds. He also concluded that failure to repair plasma membrane wounds results in cell necrosis and

successful repair of plasma membrane wounds is associated with a pro-inflammatory gene response. He stated that wound repair occurs through trafficking and fusion of vesicular organelles with the plasma membrane and deformation induced vesicular trafficking as a cyto-protective mechanism, which serves to maintain plasma membrane tension at sublytic levels.



Professor Rolf D Hubmayr, MD, Mayo Research Foundation, Rochester, MN, USA.

Critical Care News discussed the topic of cellular and tissue stress failure with Prof. Hubmayr following his presentations

It was interesting to see the relationships between successful membrane repair and failure of membrane repair, which are probably not commonly known to intensivists at this time?

No, I think our intensivists at Mayo Clinic are the only group that is working on that problem. However, there are groups in other organ systems, such as muscle research. In muscular dystrophy, paralysis might result from a lack of reparative potential, and their repeated cell injury sets up a chronic inflammatory state.

I believe that many of the manifestations of ventilator induced lung injury that people are talking about here: cytokines, mechanics, gas exchange – all of that at the end of the day can be traced back to a deformation event at least in some cells which causes injury, and either cell death or repair. We are looking at a very

early event, which then sets up an immune reaction and a repair reaction. By the time the clinician sees that there is something wrong, the clinician sees the consequences of the cell injury, such as edema, inflammation, abnormal mechanics. In my presentation I have attempted to put this into more clinical and physiological context, with data on the effects of pH and PCO₂ on these repair processes. It is interesting that in a hypocapnic environment, cell repair is impaired. So you end up with more necrotic cells than if you injured the lung in a hypercapnic state.

What do you feel is the role of thrombins in cell repair and cell damage?

We have not particularly looked at thrombins. Thrombins change the mechanical properties of cells; they cause essentially a cell contraction, at least in endothelial cells. We do not really know if a contracted cell, or one that is stiffer, is more or less likely to undergo deformation injury. There is no unitarian relationship between cell mechanics and the likelihood of the cell being injured.

There seems to be an increasing awareness currently among intensivists that more needs to be known about inflammatory cell processes, but there are no clear clinical applications at this point?

I think it is of increasing interest for intensivists, but at this stage there is really no practical clinical application. By understanding the determinants of cell injury, you can influence and manipulate those so that the chance of cell injury is less. Essentially, everything that we are talking about at this meeting can be traced to a signal transduction event that is communicated by cells. The tissue is not signalling anything. The hope is that rather than treating the problem at the stage where there is inflammation, which is already downstream in the process, it would be nice if we could prevent it upstream instead, and pre-empt this process.

The audience regarded your film on lipid-tether mechanics in fascination. How to spread the educational value of these mechanics?

The whole idea is this: think about a cell as a network structure that is covered with lipid film. You can imagine that if you deform the

structure, the film will burst. If the cell can produce more film at a rate that is greater than mandated by the deformation, the film will not burst. In some way, I am simulating a deformation event, but pulling on the film. If there is enough lipid film flowing into the

structure which requires molecular traffic of intracellular organelles, that I can manipulate with pharmacologic agents, by enhancing it or retarding it. I have a read-out of the trafficking, the repair, the reorganisation machinery, and I have a read-out of the tension in the lipid film.

There is a critical tension, if reached, that causes the film to break, and the cell has mechanisms to prevent that from happening. By measuring the recoil of the tether, we can look at these mechanisms.

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Difference in recruitment strategies, and does circulation have an impact on ALI and ARDS? |

Dr. Suarez Sipmann cited a paper published by Marcello Amato et al in *New England Journal of Medicine* 1997 as the first time that a study demonstrated that the ventilator settings may have an impact on patient outcome. The study showed a reduction in mortality, and it introduced the concept of recruitment maneuvers in the treatment of ARDS patients. Dr. Suarez Sipmann stated that recruitment maneuvers are physiologically sound but highly empirical interventions and as of yet there are neither clinical outcome, nor safety data, so it is difficult to determine what the best recruitment maneuver is. One of many definitions of recruitment maneuver is "the re-expansion of previously collapsed lung units that results in an instantaneous change of the lung morphological and physiological condition". One single maneuver can improve lung condition, and we should take advantage of this, according to Dr. Suarez Sipmann.

The objective of a recruitment maneuver is to place the tidal volume on the deflation portion of the pressure volume relationship. To do this, Dr. Suarez Sipmann recommends that driving pressure should be increased to a level that can open up the collapsed areas of the lung; simultaneously PEEP should be

increased to be safely above the collapse level of the lung - keep the lung open. PEEP should then be lowered in small decrements to find the collapse point. The final endpoint of a recruitment maneuver is not oxygenation or other parameters, but to administer a gentle ventilation pattern, which will keep the lung in a zone that avoids the mechanisms of ventilator induced lung injury.

Dr. Suarez Sipmann emphasized that as the lung gets sicker, the requirement for higher pressures for longer periods of time to achieve the same results in terms of recruitment, is obvious. It must also be considered that ARDS is a heterogenous disease with healthy, flooded and collapsed areas. One of the objectives with recruitment is to remove these regional differences and obtain a more homogenous gas distribution.

The hemodynamic effects in connection with recruitment maneuvers are usually related to the cardiac preload. However, pressure controlled ventilation at a pressure sufficient to recruit the lung seems to have the least hemodynamic side effect. An important aspect of hemodynamic tolerance is the lung condition; the sicker the lung, the lower the transmission of alveolar pressures to vascular

pressures. Lung protective ventilation is composed of many interventions that have to be used in combination, according to Dr. Suarez Sipmann, and as we are gaining more information about the response to recruitment, and the time is approaching where he believes that we will start seeing outcome studies based on recruitment.



Fernando Suarez Sipman, MD, Madrid, Spain.

Critical Care News spoke with Dr. Fernando Suarez-Sippman following his presentations.

With regard to the panel of speakers at this symposium, you are probably the research profile that is the youngest in age but a pioneer in terms of experience in stepwise recruitment. If you go back ten years, when you started doing this systematically, what are the biggest changes that have occurred in terms of lung recruitment and VILI?

I think that we started with this strategy believing it was useful, following the physiological patterns that demonstrated that it was useful, and knowing and acknowledging that it is a very difficult strategy to apply, because of the dynamics involved and the expertise that is required to apply it in a proper way. What has changed under these years is that, even with many bends in the road, I think we are still on the right path. What we have learned here the last few days is the importance of finding the correct ventilation mode for a particular patient, to individualize treatment, and not to take a standard "recipe" for treatment, but to use the options you have. By taking all of these measures we are learning that protecting and improving the condition, is the right way to continue. Recruitment is one of these tools in this regard, and to me it has its place in the treatment of these patients. So, the judicious use of recruitment in a lung protective strategy is still something I recommend based on the very positive feedback I see from the results in my patients.

What has also changed in recent years is that we have much more information, much more data, and many more physicians are using this recruitment approach in their clinical practice. We are reaching a point where we can finally launch a study in which we can test if using a recruitment strategy has an impact on patient outcome.

If you look to the aspect of pulmonary circulation and effect on tidal volume, this is perhaps another area where more general awareness is needed?

One of the problems in research is that for the sake of science, scientists can pick one aspect and go into very deep detail of that aspect. But in doing so, it is easy to forget all other aspects and dynamics of treating that particular patient or disease category, for example, the discussions about tidal volume that have been held at this meeting. I am not saying that I disagree, but this is one element, and we should not forget perfusion, we should not forget other aspects that dynamically affect the patient. But there is more information that is available to us. One good thing about the global strategies is that you keep on learning from the patients, you are continuously challenging traditional methods, and this challenging process gives us a huge amount of information to continue to improve patient care. One of the key issues in future I believe will be better monitoring options. But we should continue to move in this global direction, as long as we take consideration to the alveoli as a complex structure. ■

[CLICK FOR ABSTRACT](#)

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Some members of the distinguished global faculty.

Critical Care News spoke with a number of participating clinicians at the Symposium on Acute Lung Injury in Strasbourg. We posed the questions 1) **What were your expectations coming to this symposium?**, and 2) **What is the most valuable thing you have learned here at the symposium that you will be taking back with you?**

ALI Symposium – participant feedback



Anna Batcholar, Royal Victoria Infirmary,
President Intensive Care Society, U.K.



Reimar Riessen, University Hospital,
Tubingen, Germany.



Carlo Alberto Volta,
S Anna Hospital, Ferrara, Italy.



Massimiliano Sorbello,
Policlinico di Catania, Italy.

Anna Batcholar: I didn't know quite what I was expecting, actually. The fact that it is being organised by an equipment manufacturer, you do wonder whether it is going to be particularly aimed at the products that are produced. In fact, it hasn't been. It has been very good science, which is impressive, because the

temptation is always there to push your own product. In fact, I think this is a really good collection of people who know about the subject, telling us what they know.

Generally, picking up on what is up-to-date. Thoughts on how lung injury is actually produced. The models have changed over time, and there has been quite a lot that I have heard here that I never heard before. There is a need for more practical clinical application at the bedside for future. It is certainly important to have the background, and I do think it is interesting that if we go back ten years, we would all have said that we see a lot of patients with badly damaged lungs who were difficult to ventilate. I think we are seeing less of that now, as I believe the ventilators are more sophisticated, and we have a little bit better idea of how to ventilate them. It is a very positive development.

Reimar Riessen: To get an update on ventilation strategies and to hear more evidence about recruitment strategies. I also hoped to learn more about diagnostic strategies to identify certain patient groups that benefit from certain treatment strategies. After the symposium, I can say that I see many open areas where questions have not been answered yet, but there seems to be many interesting developments and studies that will be perhaps taking place over the next few years.

I think I was especially impressed by Dr Gattinoni's presentation, about the significance of selecting certain patient groups that benefit from certain interventions. The "lumping" strategies of the past, where we have found therapies for large groups of patients, and the need in future to define specific patient groups that will benefit from particular treatments, to customize more. It has been a very valuable two days.

Dr. Volta: To have a new vision of ARDS and ALI. For me, the most important thing is to have new knowledge on clinical practice. New studies about strategies in this area are always of interest.

In regard to high level of PEEP every patient is different from the other, so the level of PEEP should be high enough to avoid the cycling reopening of the alveoli.

Dr. Sorbello: All my expectations were fulfilled, just by the names of the speakers. The qualities of the lectures were excellent, but what is most important in this type of symposium is the debate between the speakers and participants, so you can compare information and knowledge and find solutions with other people. It is an opportunity to share across borders, from the high level of the speakers to the doctors at the bedside, bringing everything to the patient.

Depending upon if you look at ARDS from a clinical point of view or a scientific point of view, the difference can be quite big. At this symposium, we have learned a lot about mechanisms that can lead to ALI or lung damage. To apply this in a clinical application is too early yet in many respects, but it is important to know what research is going on. In order to compare data, you need to have fixed and clear definitions of ARDS, and that need was identified.

I think that this symposium is a wonderful model of meeting between science and clinic, and in many cases we do not know enough yet about precise guidelines for clinical applications. But it is important for us at the bedside to know of the research going on, so we are familiar with the developments as they proceed to bedside applications. Right now, I feel a biological approach to ARDS patients is the best one. Microbiology may seem to be very futuristic. But to know something about microbiology helps us to know where we might be in the coming years in future. This symposium was also valuable in the aspect that we could have interchange with the speakers; in the sessions and between the lectures, and that we could have interchanges with the other physicians, from our own countries and other countries as well. This is very valuable to us.

There is one other aspect from this symposium that is also very valuable, and that is the message that the lung is tightly linked to other organs and systems. The dynamics of the other systems and organs, and the complexity of these interactions, means you cannot have only knowledge of the lungs, but of the other major organs and systems as well. ■

The very first pediatric intensive care unit in Germany was established at the Children's Hospital of the Johannes Gutenberg University in Mainz in 1965. Ever since that milestone, the center has been involved in great advances in neonatal and pediatric research and patient treatments, which has led to rapid expansion and the establishment of the current interdisciplinary pediatric intensive care facilities. The institution recently celebrated its 40th anniversary by means of a two-day symposium with international experts. Critical Care News met with some of the staff members of this remarkable ICU, including Ralf G. Huth, Director of Pediatric Intensive Care.

The continuing development of neonatal and pediatric ventilation therapies



Dr Ralf G. Huth, Director of Pediatric Intensive Care.

Can you tell us about your 40th anniversary celebrations?

Ralf Huth: The background story is quite simple: in 1965, the Director of Pediatrics had a job offer at the University Hospital in Frankfurt, and in the negotiating period, he established an emergency department here. This building was only intended as a provisional solution for five to ten years, but it grew and became well established over the years. This was the first pediatric intensive care unit in Germany, and the fifth in Europe. Our recent anniversary symposium was not only a celebration, but also an overview of what pediatric intensive

care is all about, from disease and therapeutic perspectives. We reviewed not only disease situations but also the therapy options we have today, compared to the past and with a view to the future.

What has been your experience of ventilation therapy, in regard to past history as well as your future requirements?

Ralf Huth: If we review our own experiences in mechanical ventilation, we always used as a standard ventilator the old SERVO 900 device. But the problems with weaning meant that ventilation with infants was not that easy with this device. We were looking for another device. At that time there were only the old Draeger Babylog devices available. We then tested other ventilators; such as the Infant Star, the Engström ventilator and the Sechrist. We decided to go with the Infant Star, which in those days had the combination of flow-interrupted neonatal ventilation with the possibility of High Frequency Oscillation (High Frequency Flow Interruption HFFI). We had four devices aboard for neonates, and for older children we had Servo Ventilator 900 C.

This worked well in the early days. But when we moved to this new facility, we needed to redesign and that was the time that the Servo 900 C was getting older, and the Servo Ventilator 300 came on the market, so we would have a combination of treating even neonatal patients with the Servo Ventilator 300. The issue of weaning was important, especially when we started with pediatric cardiac surgery here in 1985. At that time it was necessary in

controlled ventilation to start up with the Servo 900C, and when it was time for spontaneous ventilation we would switch to a neonatal ventilator. This subject was almost solved with the Servo Ventilator 300 as a very good device covering a large range of patients.

Non-invasive ventilation was not regularly in use at that time. We were the first center in Germany to try out HFO with the Sensormedics 3100A. Oscillation came for neonates, as well as high frequency jet ventilation. It was transferred to Europe, and increasingly used in neonatal and pediatric ventilation, but never connected with the adult patient population. As there was some interest in our anesthesia department, I tried to show the benefits of oscillating flow. At that time, we had a sophisticated system that provided nitric oxide in combination with HFO. In the adult departments, we came to help out with our equipment for the especially difficult cases, like the ARDS patients. I had an opportunity to take part in one of the first scientific and education symposia on HFO, and convinced some of my colleagues in the adult department to come with me. In a workshop with a lung lavage model in a big pig, HFO was initiated and you could see improvement and we almost understood how HFO could work. Normally technology comes from the adult sector to the pediatric, but in this case it was the other way around.

After this experience, we were then focusing on the neonatal and pediatric non-invasive ventilatory care. We found one device that was ready to do this at that time, the Hamilton Gallileo that offered non-invasive ventilation and also automated ventilation or

adaptive support ventilation (ASV) for bigger children, for weaning after operations for instance. A little later, we started looking at SERVO-i since this device offers the possibility of non-invasive therapy in addition to controlled ventilation, even in the neonatal age group. Different ventilation treatments for all age groups combined in one device was the goal. Currently we have a problem with too many models for different therapies. We need to define how to reduce to fewer devices, but providing the same treatment performance.

How large are the children's intensive care units, and how many staff do you have to run them?

Ralf Huth: We have up to 150 patients in the pediatric department, including 10 pediatric ICU beds, 10 neonatal beds and up to eight intermediate care beds, all arranged on the same floor, in two wings. For nursing staff, we have 33 regular full time positions which means 44 persons including part time staff. Many of our pediatric ICU nursing staff have longstanding experience. We have very high standards in terms of professional intensive care nursing education. Over 90% have not only pediatric specialty, but also pediatric ICU nursing certifications. So this is a very special background, which contributes to a true team effort together with the physicians.

In regard to the number of physicians here, we share the facilities between neonatology and pediatric intensive care, and all together we have 18 fulltime physicians, including consultants. Some of the consultants working in cardiology and neonatology have also duty during the night shifts here, which comprises a total of 22 persons. We have a focus on

pediatric intensive care, especially the surgical cases, and a focus in neonatology on the perinatal problems.

Our patient occupancy is roughly 90%, with a changing turnover of nearly 500 a year.

What types of patients do you most frequently encounter?

Dr Jan-Helge Höpner, pediatric intensive care physician: Our main focus is on pediatric post-cardiac surgery, or post-neurosurgery. We do have general surgical cases, and everything that comes otherwise: infections, oncology patient with ALI or ARDS, trauma patients (fortunately decreasing rates over the past years), orthopedic surgery, urological surgery, oro-facial deformities, and other birth defects. We have a separate burn unit for two patients.

How long have you been doing nasal CPAP therapy here?

Ralf Huth: Since the introduction of this therapy. Nasal CPAP therapy had a big impact on controlled ventilation with all the complications. We were among the first to introduce transcutaneous CO₂ measurements and transcutaneous O₂ measurements. Being early involved with nasal CPAP therapy, we then gathered additional information by non-invasive monitoring to know when to reduce invasive ventilation therapy and change to non-invasive ventilation. Previously, we were flying blind. I can remember in the past how we did blood gas analysis. I started at bed number one, finished at bed number ten and went back to bed number one again. What has changed from that time is the add-on information from non-invasive monitoring; like saturation monitoring and CO₂ monitoring. This gives us a sense of security when it's possible to reduce invasive ventilation therapy and go over to non-invasive support.

Based on your experiences, when is nasal CPAP therapy best indicated? Which types of patients and which types of situations?

Ralf Huth: I think the question is rather when do you indicate invasive ventilation? Ventilatory support is something that is needed if you have an additional oxygen requirement, if you have exertion and exhaustion. In the early years, we would say, "this child needs ventilatory support" which automatically implied invasive ventilation. We were not secure about interfaces: masks, nasal prongs and the like. Gradually we got experience and saw that it

could work. By introducing PEEP and opening the lung, we could also give these children support that was feasible by non-invasive measures, with less oxygen requirement, fewer ventilatory problems, and less exertion.

So is non-invasive ventilation therapy generally always preferred over invasive therapy?

Ralf Huth: Yes, generally we go for non-invasive when we can, and if this doesn't work, we apply invasive therapy. In some cases, such as post-op patients, they are intubated anyway and need invasive therapy to start out with, but in other cases we want to avoid invasive ventilation when possible, for example oncology patients, patients with chronic respiratory problems, or patients with pulmonary problems needing support due to oxygen requirement and CO₂ retention.

In light of some of your experiences with nasal CPAP, is there an advantage of being able to provide nasal CPAP and invasive ventilation therapy with the same equipment?

Ralf Huth: Yes – right now we have too many devices, and the storage rooms are too small. Offering combined therapies with the same ventilator is an advantage.

Susanne Frey, pediatric intensive care nurse:

When there is a new patient coming, we have to decide which ventilator to use. If you have too many devices, you almost have to decide before you see the patient, which is difficult because we need to know if they will need non-invasive or invasive ventilation. If you have too many machines, it is difficult and time-consuming. Now we see the chance of choosing one device and doing pretty much everything with it. In Mainz we are looking for everything in one unit, from the newborns to the ninety kilo children, for the non-invasive and the invasive support.

Dr Höpner: It's an advantage to have a unit mounted behind the bed, with the interface at the head of the bed. You can start with non-invasive and go to invasive if needed, or scale down from invasive to non-invasive without having to move the whole unit.

How many different ventilators have you had in inventory, and as a nurse what are the challenges in training on these different devices?



Dr Jan-Helge Höpner, pediatric intensive care physician.



Susanne Frey, pediatric intensive care nurse.

Susanne Frey: Plenty of models: the Infant Star, the Servo Ventilator 300, the Hamilton Gallileo Gold, the Sensor Medics 3100 A and B with HFO, the Breas transport ventilator LTV 1000 and a CPAP device Vital Flow. This is a problem because if you get new staff members and you have to teach them on all different devices: Each model functions a little different, in terms of modes, and user interface. It is a challenge for the nursing staff. And each device model has special tubing, which requires training and logistical management as well.

Dr Höpner: It is also a challenge for the doctors. We need to decide which therapies the nurses should monitor. The other thing is that we physicians have to rotate between the different wards as well, which means that it is easier if there is some standardization - not only within the unit, but in our neighboring units, too.

Ralf Huth: The difference between the devices is a problem, which we are trying to overcome by finding one device that suits all. There are not only the technical aspects, but also how the user interfaces for these devices are designed for easy understanding and operating.

What are your experiences of combined invasive ventilation and nasal CPAP in the same ventilator? Can you share some of your patient experiences?

Susanne Frey: We have treated neonatal patients with ALI or respiratory distress using nasal CPAP and we have treated pediatric patients with muscular disease. We have treated post-op surgical patients with atelectasis, which have started out on invasive ventilation, before we have switched them over

to nasal CPAP, as well as oncology patients with pneumonia. Different types of non-invasive therapy have been provided, depending on the situation. For instance, in some cases we only needed CPAP to maintain PEEP, in another situation we needed Pressure Support too. There is much that can be done with non-invasive therapies, and we have different patient interfaces available; nasal prongs, nasal masks and full-face masks.

What are the most important practical aspects for nasal CPAP therapy? Is it early application, fixation, or the fitting of the patient interface?

Susanne Frey: The system should be easy to use. The patient interface should fit the patient comfortably but avoid leakage as much as possible. We used a helmet in one girl with chronic myeloid leukemia, who in the course of chemotherapy had leukopenia and ALI/ARDS due to pneumonia with PEEP up to 15 cm/H₂O. Initially she had an oxygen requirement of up to 100%, recovering under NIV. Oxygen was reduced to 30%. The non-invasive therapy with the helmet worked quite well in the acute situation.

Do you have a preference for the types of patient interfaces you are using with nasal CPAP?

Connie Sander, pediatric intensive care nurse: For the small patients (up to 5-6 kg), we use the prongs, which work very well in combination with the pacifier, which manages leakage nicely. For the larger children (bigger than 6 kg), we prefer to use a nasal mask, and in some



Dr Huth and Susanne Frey with a patient soon to be discharged. The baby was born a metabolic birth defect requiring enteral nutrition and pneumonia.

cases a full-face mask is needed, depending upon the individual facial morphology. Or in cases where they are not fully awake and can keep their mouths closed, we use a full-face mask. We have used the Fisher Paykel nasal CPAP interfaces, and they worked very well since you have different sizes to fit the actual patient, no problems with long or short nostrils.

Susanne Frey: We did have one tricky interface problem with a patient on the SERVO-i. She had been intubated for a very long period, and after extubation, we saw a big difference in the size of the nostrils. This was one specific case that was a little tricky to manage, but we did it.

Ralf Huth: It may not be a matter of which of the interfaces to use, but whether we have the right interface for this new kind of ventilatory support? I would say that a center might want to re-investigate which types of interfaces they are using, since this new combined device for invasive and non-invasive therapy probably gives you some new necessities and possibilities.

I think that we are not yet at the end of discussions how the patient interfaces between ventilators and children are designed, but hopefully we will see continued interface development. Having a new ventilator on the market, providing different kinds of support, from invasive to non-invasive therapy and back again, may challenge development of interfaces with quality and ease of use, alarm management and patient comfort in terms of application for neonates and small children.

Dr Höpner: I think patient comfort is a very important issue equal to the ease of use. If it is easy to start up a device, but you need to go back and readjust it every half hour because the patient is awake and moving, you have really gained nothing.



Bernhard Schmitt, PICU nurse, and Dr Jan-Helge Höpner with a post-op patient after completion of ventilation therapy.



PICU nurse Connie Zander and volunteer Frau Diehl, with a 5 month old heart failure patient, treated with nasal CPAP therapy.

How long have you had the latest combined ventilator for invasive and nasal CPAP therapy?

Ralf Huth: For about six months, in the recent version which we have been evaluating. We have just decided to purchase these units, which we consider an investment into the future. In my point of view, the development of SERVO-i was a straight line in development from the Servo Ventilator 300. It offered the same type of ventilation opportunities, but it was not a re-introduction of ventilation concepts; rather you could see a natural continuation in development. It was significant to us that SERVO-i included the combination of PRVC with SIMV, so that you have the possibility of this mode, which was not available before. This was something we were really looking for. I think the user interface was straightforward, with the easy access knobs to the most interesting parameters. The calibration of the O₂ cell facilitated ease of use. So I think that the development was going in the right direction, and it was very easy to introduce this device after long experience with Servo Ventilator 300, compared to other devices we had been testing before. It was a logical continuation of development, which eased the acceptance of introducing SERVO-i into the ward, compared to other models.

We have one infant patient here who has been extubated after an operation. He was treated with SERVO-i for a long time. He has spinal muscular atrophy with pneumonia, which needed long term support. I think without the SERVO-i we would have had to intubate him, but we were able to easily switch from nasal CPAP to non-invasive ventilation. So we were able to keep him totally on non-invasive support, which is unimaginable with any other device we have had so far. ■

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Liselott Järvinen och Dr. Kjell Olafsen.

In-hospital transportation of the ventilated patient is usually one of the most difficult and challenging situations that ICU staff may encounter. The Intensive Care Department of Ullevål Hospital in Oslo, Norway experienced a significant increase in ICU patient transports to the CT when it took over responsibility for neurosurgical ICU patients one year ago. Critical Care News spoke with registered nurse Liselott Järvinen, who has worked with establishing Quality Assurance standards and practices.

Defining new procedures and solutions in ventilation patient transports

How did ICU patient transports become a significant consideration of focus for defining your work routines?

We have always had patient categories that must go for diagnosis and investigations; CT scans, ultrasound, MR investigations and X-ray examinations, so patient transports are a big part of our daily challenges in the ICU. One year ago, we took on the neurosurgery patients as well, which contributed to an increasing

number of ICU patient transports as compared to the past; we went from one CT transport a day to up to five times a day, a significant increase. So we have extensive experience of the challenges of transporting patients.

Some of these patients are extremely unstable, so a doctor may accompany them. However for the most part, it's the nurses that accompany the patient. We have two nurses, and a medic that coordinates arrangements for the elevator and other details within the facility.

What was important when you started defining your requirements in transporting ventilated patients?

In the past, we did not have respirators to do the job. We hand-bagged the patients for many years, and we observed that the patients' respiratory capabilities became diminished after transport. We had an older fleet of ventilators in the ICU at that time, and we were given permission to renew our ventilator fleet.

We had one ICU ventilator that was dedicated for transport patients, but this had limitations from a practical perspective. When the neurosurgical ICU patients came to us a year ago and we were allocated additional funds, we started looking at SERVO-i, and decided to purchase for transport purposes. It has been a great support to us and facilitated the patient transport situations. It enables us to use the same ventilator unit that the patient is treated with, simply connecting the O₂ gas trolley, without interrupting treatment. A complete system without any disruptions; you don't need to disconnect or reconnect anything, and the patient treatment can continue as usual.

What other ICU patients do you have, in addition to neurosurgical?

We are a trauma ICU and an all-around ICU, and we support a broad spectrum of ICU patient categories.

One main group is multitrauma patients. We also have patients from the heart/thorax surgery, gastroenterology, oncology and occasionally children down to 12 years, when the PICU needs to off-load.

We have a capacity of 11 patient beds, with a high acuity. There have been discussions about a need to increase to 17 beds in total. We have a staff of 70 ICU nurses, primarily full-time, and

9 ICU physicians. We welcome family members here 24 hours a day, especially during the acute phases.

What are important aspects from a practical perspective, when transporting ventilated ICU patients?

That it works, that it is safe. We need to provide stability in ventilation of the ICU patient, or trauma patient. That there are alarms that let us know if the gas supply is interrupted, that it has an extensive battery capacity, that it is simple to use and we can see quickly what the patient situation is. This enables us to focus on the patient, and not on the ventilator, from a more holistic point of view. We have trend information that allows us to go back and see if there were any events during the transport situation.

How does the ventilator transport solution today compare to hand bagging in the past, in terms of the patient clinical situation?

We are working on an evidenced based protocol, where we have seen the negative consequences of manual ventilation. We are in the process of this work, and have not yet made a summary of all of the negative consequences of hand ventilation. However, we have tracked patient blood gases

throughout the years and have noticed that blood gases are stable in the current transport situation, and comparable to the levels we have measured before the patient has been transported. My own observation and experience is that patients who were hand-bagged required higher O₂ concentrations over a day or two after the transport had taken place, and often the lungs seemed to be more atelectatic. In certain cases, some very ill patients seemed to develop ARDS after the earlier transport situation with hand bagging.

The new solution with SERVO-i also enables us to monitor the patient in transport more carefully. It is easy to connect an additional capnography module, and the installation of the CO₂ module is an easy and simple procedure. We use this often with patients with head injuries, where it is important to have carefully regulated PCO₂ levels by means of stable tidal and minute volumes and expired CO₂. Patients in the weaning process in pressure supportive modes can also be transported with the ventilator, to maintain stable ventilation and to avoid extra work of breathing. This is helpful for patients in pressure-supportive modes, to see that there is no extra work of breathing, and to monitor tidal volumes without interruption in ventilation therapy.

What is the most frequent disease or patient situation that you encounter in transport situations today?

The most common situation is transports of neuro patients to the CT scan. In the periods where the patient is being monitored, with a control after three days, we can have up to five transports a day from the ICU. Two nurses always accompany the patient. The extremely sick intensive care patients require a certain amount of preparation before we can transport, and we always have a physician accompany us if the patient is unstable. We disconnect any infusion pumps that are not needed, for example TPN, but leave the necessary pumps including analgesia, if required.

But in an acute situation, with extra help we can prepare the patient and load and transport very quickly, within a few minutes if needed. As a final measure, we connect the oxygen trolley, set 100% oxygen on the machine, check battery status and alarm status, and take off with the patient in a safe manner in the acute situation. In these types of stressful acute situations, it is extremely important that we have followed the quality assurance transport protocol.



Liselott Järvinen, RN, has been working to establish an evidenced-based hospital transport protocol.

You are in the process of establishing an evidence-based protocol for transport of ICU patients. What are the most important aspects you have defined in this process?

We have learned that preparation is of utmost importance, along with a good communication with the treating physician. Any eventual complications during a transport of an ICU patient can be handled much more easily, if the preparation and communication work has been done in advance.

Transporting ICU patients is one of the most critical procedures. The risk for complications is evident, and when things go wrong, they do so in a hurry. For example, tubes can be dislodged, leakage may occur. Mental preparation of the staff accompanying these patients is therefore also very important. The protocol is focused on what steps to prepare for prior to a transport, and how to prepare the ventilator. We have established this protocol together with our ICU Director, Dr Kjell Olafsen.

How much time does it take to transport an ICU patient to CT?

A controlled, follow-up neuro CT of a stable patient doesn't take long, since there are fewer infusion pumps. About 10 minutes for us to prepare, then a few minutes in the elevator, and the CT procedure takes a couple of minutes, or a total of 20 minutes.

We have another CT that is on the other side of the hospital, and that takes much longer. We need to mentally prepare ourselves when we transport the patients to the other facility. We

usually have no waiting periods at the CT, when they know that we are coming with an ICU patient. However, the few times we have had to wait for some reason or another, it usually is not a problem, we have two oxygen cylinders with us, and plenty of battery power, where we can load 6 batteries in the SERVO-i ventilator. This is a big advantage.

Patient transports for X-ray examinations require other types of preparation. Will it be necessary to suction the patient? Is there oxygen, electrical supply for the infusion pumps if needed? The newer volumetric pumps are thankfully starting to have better battery capacity than in the past, but this is always a concern.

If you summarize your current situation and solutions, what is important as you move forward?

The arrival of SERVO-i in the ICU for patient transports is really an advantage, in our perspective. We save time and we ventilate safely in a closed system and without interruption to the patient. It is simple to use and clean. We feel from a nursing perspective that many of these details are important and were well designed.

In terms of our evidence-based protocol, it will be exciting to examine these main aspects of communication, safety, and treatment strategies, and to summarize the results. We are also examining radiation levels in our staff members from patient transport situations. We want to challenge ourselves to continual improvement, in order to provide the best and most effective patient care in the transport

situation. It is always better to act from a position of safety, than to end up in a situation where there are unnecessary risks. Patient safety and staff safety are foremost, and through preparedness, it is much easier to minimize potential risks.

Critical Care News spoke with ICU Director Dr Kjell Olafsen about the background and the need for the evidence-based protocol:

How did you come to support the evidence-based protocol in ICU patient transports?

I think that transporting the ICU patient is a big component of our every day challenges, as the technologies and opportunities for examining patients grow. It can be a risk-filled procedure if not done properly. The purpose of the evidence-based protocol is to examine all pre-requisites and conditions prior to transport, in order to plan and standardize, with the objectives of minimizing risks for safer patient transports, and offering more security for the staff in these conditions.

Are evidence-based evaluations an increasingly important priority for this institution?

Yes, if there are risks, we want procedures and routines to be standardized, in order to do them effectively. These evaluations will require a large amount of time, effort and resources to map out procedures in this respect, but we think it is an investment and significant in the long term to have this data in detail in the future. Evidenced-based material is an important means of identifying the most effective routines, illuminating risk factors, and identifying the resources needed to carry out those procedures safely and effectively. ■

Biography

Liselott Järvinen is a registered nurse, with specialization in intensive care medicine and anesthesia. She has been working at Ullevål Hospital since 1996, and is responsible for medical technology within the ICU. She has worked with establishment of Quality Assurance procedures for many years.

Dr Kjell Olafsen received his degree in Intensive Care Medicine at the University Hospital of Tromsø, Norway. He has been the Director of Intensive Care at Ullevål Hospital since 2004.



Kari-Mari Tjelmeland, ICU nurse with a post-op cardiac patient on dialysis for kidney insufficiency. He has just returned to the ICU after transport for CT examination.

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