

Critical Care News

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Children's Mercy Hospital, Kansas City, USA



Critical Care News started as a peer-to-peer journal within intensive care in 1990, and celebrates its 20th anniversary this issue

20 years of Critical Care News

This issue celebrates the 20th anniversary of Critical Care News. The magazine, which was introduced in 1990 by Siemens, had the objective to support the sharing of peer-to-peer insight and experiences with innovations in clinical application of SERVO ventilators. The history of this magazine continued when Siemens Life Support Systems and the SERVO ventilators were acquired by the Getinge Group and transferred to MAQUET Critical Care.

In this issue of Critical Care News, some of the difficulties twenty years ago in ventilating infants in the MR are shared by members of Children's Mercy Hospital in Kansas City, as well as their current experiences with new ventilatory MR solutions for infants and pediatric patients.

We also have the honor and privilege of an interview with Dr Marcelo Amato, who outlines his landmark research and current and continual efforts in defining lung protective strategies in the ICU, and his experience of treating H1N1 patients.



Ventilation of infant in MR, Children's Mercy Hospital, Kansas City



Dr Marcelo Amato

A cultural and generational shift in treatment with mechanical ventilation occurred over twenty years ago, with the introduction of pressure-related modes to a singularly volume-related respiratory care environment in the ICU. That another great shift into new aspects of ventilation therapy is currently ongoing is evident in the features in this issue from Rio de Janeiro, where Dr Felipe Saddy shares his experiences in treating COPD patients with Neurally Adjusted Ventilatory Assist, or NAVA. It is also reflected in the interview features with Dr Liisa Lehtonen of the NICU of Turku University Hospital, Finland and Dr Peter Nordlund of the general ICU of Ryhov Hospital, Sweden, where clinical evaluation of the latest development in non-invasive ventilation, NIV NAVA, is being conducted.

Anesthesia for the obese patient: what ventilation aspects are specific to this patient group and what are the anesthetic considerations? The anesthesia feature of this issue highlights the reflections of three anesthesiologists, two of whom are in the United States, and one from Europe. They share their experience with respect to the obese patient group, all from airway management to ventilation practice and give their ideas concerning

the specific anesthesia considerations.

Lastly, this twentieth anniversary issue of Critical Care News marks another anniversary in the history of the magazine, as it is my last issue as Editor-in-Chief. I started working in this position in 2004, when MAQUET became manufacturer of SERVO ventilators, and reinstated the magazine to continue to promote the peer-to-peer effort and to mirror the ongoing and extensive clinical and product development. I also had the pleasure of starting up the magazine website, www.criticalcarenews.com in 2007. As I now go to other responsibilities

within MAQUET Critical Care, I will continue as a contributing editor to the magazine as well as producing the patient case library on the website. I have enjoyed meeting so many interesting and dedicated intensive care physicians and profiles from around the world, resulting in over 90 features and interviews in the past five years, and I sincerely thank our thousands of readers around the globe for their support of magazine and website. In the next issue of Critical Care News you will hear more about the new editorial crew, and I wish them the best of luck in future.



Editor-in-chief Kris Rydholm Överby on one of her first assignments, Kagoshima, Japan, 2005



Rachael Dameron, Manager Respiratory Care Department and MRI Safety Officer Dan Smock with infant patient and MR compatible ventilator

Bedside quality ventilation of neonatal and pediatric patients in MR — a multidisciplinary approach

The 100 year old history of Children's Mercy Hospital in Kansas City evolved from an act of compassion from two sisters in 1897. Dr Alice Berry Graham and Dr Katherine Berry Richardson heard of an abandoned, 5 year old crippled girl, and arranged for surgery and therapy for the child, which enabled her to walk again.

The current state-of-the-art 314 bed hospital with almost 15,000 admissions per year provides care to children from birth to 18 years of age from a six state wide area in the central United States. The compassion and clinical expertise of the two founders still resonates among all of the current hospital staff members, who work together in a multidisciplinary effort to provide the best care to each child.

This multidisciplinary collaboration among members of the Respiratory Care department, MRI department and PICU and NICU staff members enabled the introduction of new ventilatory solutions for neonatal and pediatric patients in the MRI environment. The new solution provides benefits for patients and staff members.



Respiratory Care Clinical Specialist
Kim Stevenson

Twenty years of ventilation challenges in neonatal and pediatric MR patients

Providing children with respiratory care during MR examinations was problematic from the implementation of the very first MR scanner at Children's Mercy Hospital many years ago.

Kim Stevenson, Respiratory Care Clinical Specialist for the PICU has worked at the hospital since 1984, and has seen a lot of change during the past 25 years. She describes the situation of ventilation in the MR, and the limitations of previous MR ventilation solutions: "We performed less MR. We hand bagged our intubated patients when we got our first scanner. A self-inflation bag with 15 feet of aerosol tubing and an additional exhalation valve at the patient connection was our method of ventilation. There was a different level of safety, the procedures were extremely long and it was tiring to hand ventilate during those entire lengthy procedures. You were physically right beside the scanner, and sometimes you were halfway in the scanner yourself if you could not reach a patient."

"We later had a pneumatic non-synchronous ventilator. You had to

establish an inspiratory time and set your expiratory time to establish a breathing rate. There was a large exhalation valve with a lot of deadspace, and the only flow for a spontaneous breathing patient was a reservoir bag 6 feet away with free flowing 100% oxygen. There was a limited display on the ventilator that could not really be seen. This type of ventilator really limited the type of patient we took to the MR. The other limitations from a work perspective were that we had to use two respiratory therapists and a couple of other staff members to transport in the past, compared to our current solutions and situation."



Respiratory Therapist Loren Dundee

Respiratory Therapist **Loren Dundee** concurs about limitations with the previous solutions: "When I first came here, we had the non-synchronous pneumatic ventilator in the MR. The rate was set by dialing in the inspiratory and expiratory times, and you would hook up a long piece of tubing to the patient and turn the flow up. For most patients, it worked better if they were not spontaneously breathing. There was transition time, you had to set up the ventilator first at bedside and fiddle with the settings to make the patients comfortable. Some of the patients would need more sedation to not spontaneously breathe. The transition was hard on some patients, and some patients simply could not tolerate the pneumatic ventilator and these would be bagged throughout the procedure. The

long tubing would mean a lot of dead space, just to get the MRI done, and you would never know what their blood gases were with manual ventilation. Smaller patients were not possible or would not do well in these circumstances."

Identifying, planning and investing in new MR compatible solutions, after a switch in ventilator fleet

Patrice Johnson, who is Director of Respiratory Care at Children's Mercy Hospital, was from the start one of the drivers of the process to identify and find a better solution for ventilation in the MR. She has seen a lot of change in her 13 years as Director, and is responsible for a staff of 100, including a Manager of Respiratory Care, four clinical specialists and an educator. The staff is spread among two campuses with a 27 bed PICU and a 67 bed NICU and nursery. She describes her perspective of the transition process: "The decision to switch from SERVO 900 to SERVO 300 happened before my time here, but the transition from SERVO 900 to SERVO 300 to SERVO-i was exciting, with so many of the new features that were available. There was a lot of attention from the manufacturer to incorporate user feedback and involvement, so the end users really have ease of use in setting modes, finding trending data information and incorporating data."

"Some of our physicians felt that the SERVO 300 had too much information on the display, but the new SERVO-i changed the way we view information. We have been able to present the SERVO-i as an option to intensivists, neonatologists and surgeons, not only for ventilating smaller patients but also moving patients from bedside to bedside or to MR or radiology. The patients are able to be maintained on their ventilator during in house transports. There is satisfaction, not only among our respiratory therapists but also in our nursing staff. When we transitioned to SERVO-i we were using a pneumatic ventilator in the MR, but we knew that the SERVO-i was going to include an MR compatibility package in the future and that would further benefit our patients."



Director of Respiratory Care Patrice Johnson

The right thing to do – the collaborative effort to look at what is best for the patient

Patrice Johnson stated that the older pneumatic ventilator being used in the MR was just not meeting the needs of the patients nor of the staff. "From a staff perspective as well as a care perspective, we needed a better option, and when we implemented the SERVO-i it was wonderful for us to have the same bedside ventilator as an MR ventilator. It allowed us to keep the patient on the same settings, and does not create any added stress for the patient, so investing and implementing the MR compatible ventilator was the right thing to do. It was not difficult for me to request administration for the purchase of two new MRI ventilators – indeed it was a natural step – this is the best way to care for these MRI patients. Our MRI Safety Officer and Lead Technologist Dan Smock and his department appreciate any time we can move a patient in and out of the MR smoothly, and they don't have to worry about ventilator safety issues, which enables them to focus on taking care of the imaging process and taking care of the patient."

"The respiratory care department and the MRI department have truly had a partnership in this respect, from the very beginning. We started looking at this alternative and we shared information and involved all team members in the evaluation and testing and that was appreciated by all - the collaborative effort to look at what is best for the patient, and how to achieve that."



Dan Smock is lead MRI technologist as well as MRI Safety Officer

The MR technologists' perspective on the implementation of the new MR compatible ventilator

Dan Smock, who is the lead MRI technologist and MRI Safety Officer at Children's Mercy Hospital, has been working within the field of MRI for over 23 years. He was well aware of the limitations and struggles with the old pneumatic ventilator in the MRI suites, and describes his perspective of the collaborative effort to implement the new MR compatible solution. "Patrice Johnson and Rachael Dameron of the Respiratory Care Department had heard about the MR compatible SERVO-i being available and brought it to our attention. I had seen it in some of the radiology literature. We all knew we needed other options for ventilation in the MRI. While it may be hard in some facilities for departments to work together – the therapists goal is to maximize their capabilities and the MRI department is just trying to make sure whatever they get is safe – it requires very good interdepartmental communication as well as a spirit of teamwork and willingness to work together to achieve a more positive patient environment."

The validation process

Dan Smock states that the MR compatible SERVO-i ventilator was initially tested in their old 1.5 Tesla MRI suite, prior to designing and implementing an entirely new 3.0 Tesla MRI suite in the hospital. "Once we got the ventilator here, we tested it in our old suite for a short time. The MRI department and clinical engineering department worked together with the respiratory care department to trial this new machine. We set aside an hour or two initially to figure out where we would place the ventilator in the old suite, and running the ventilator to see if it generated any artifacts. That took about a half hour, and after that everyone said, "When can we get this?"

"The MRI units are on call 24 hours a day, 7 days a week, and it might be hard to carve out that hour for validation, but certainly if hospitals are not able to image the kind of patients they need to because



MR compatible SERV-i ventilator, with infant in MedVac Immobilizer product

of their acuity, then that short test hour is golden.” Dan Smock outlines the need for interdepartmental discussions to take place early in the process, and that it may be a question of budgets: does the MRI department allocate for the new MR compatible ventilator, or is it the Respiratory Care department that makes the allocation? He states “Cooperation is needed to sort through that and similar logistical details. We work together with a strong multidisciplinary approach, and try to avoid being mired in internal politics, but work together as a team to focus on the patients.”

Safety and the MR conditional SERV-i ventilator

Two MR conditional ventilators have been in use at Children’s Mercy Hospital for the past two years. Dan Smock estimates that they are being used about 3 or 4 times per week on average, although on any given day they might be in use on 3 patients per day, depending on the types of patients being treated in the PICU and NICU. He anticipates that several hundred patients have been treated with the SERV-i MR compatible ventilators so far, with no safety incidents.

“As hospital safety officer, I have to keep on top of these matters. When we designed the two new MRI suites, we arranged so that we would have the tools we needed, with gas outlets on two sides of the room, and suction on both sides as well. Essentially we designed it so that the ventilator would enter the room and have a minimum of distance, without needing to go around the magnetic field and avoiding hazardous situations in this respect. Essentially, what we do is pass the IV lines through our conduit, bring them in, and hook up to the patient. If the baby is on the ventilator, we have their IV lines already in the room and coming back out, and the therapist takes the ventilator, the technologist takes the baby and positions it where it needs to be in the scanner. The floor is marked to define the ventilator distance to the scanner and the wheels are locked at that point, so it is pretty seamless for us and has worked very well.”

“One of the areas that we are performing more imaging with the MR conditional ventilator is with neonatal patients. In the past, these babies required a lot of sedation to stay perfectly still for 45 minutes during the imaging procedure, and with the pneumatic ventilator, we sedated those patients between the movement of the ventilator and the movement of the babies, and it was very difficult and time consuming to procure any proper images. It was a nightmare, and one of the other new solutions we have implemented is the Immobilizer infant product by MedVac. It can be used on infants up to three months, and you essentially vacuum “shrink wrap” the babies with this device, so that the air surrounding the babies is removed and they are swaddled comfortably. The combination of our neonatal immobilizer and the ease of using the SERV-i MR conditional ventilator mean that we have reduced the time the patients are away from the critical care unit by 50% of what it had been previously.”

Dan Smock emphasizes that the importance of MRI safety has increased, as 3 Tesla and even 7 Tesla scanners are becoming available, the machines are getting stronger than ever. This highlights the need for increased safety

requirements and education, in his opinion. "All of our respiratory care therapists must go through MRI safety training, to foster their understanding of what we are trying to accomplish in the MR and to involve them in our processes as well. I am the educator for the hospital, and we provide Level II MRI safety training annually, which is a requirement by the Joint Commission for anyone in working with direct patient care in the MRI suite. The Joint Commission has become very proactive in requiring safety training in recent years." Dan Smock states that elements in MRI safety training of therapists include not only magnetic attraction but awareness about certain surgeries and procedures that can be dangerous in the MRI suite, as well as certain devices. He outlines other safety issues as well: "Heating patients up with radiofrequency, for example – it is important to educate how a stable patient could become very ill very quickly due to the effects of the MRI scan. That may change how the patient breathes and should be treated. We can induce loops of electrical conductivity from the gradient changes in the magnetic fields. These can cause burns or peripheral nerve stimulation. Routinely, we safeguard the patients with a variety of different things, such as placing blankets between their legs and other measures to counteract conductivity, insulation between any electrodes that may touch the patient, and so on. Anything that is metal that must be on the patient is wrapped with a cold compress. We also train about what measures to take in a coding situation in the MR, so that anyone in the environment knows what safety elements to be aware of. Most of the MRI scanners around the world are superconductive magnets filled with liquid helium. In a worst case emergency scenario, these could spontaneously leak helium in extreme situations, which is an extreme risk that we must be prepared to take on."

No image artifact difficulties

"We have had no problems with noise or artifacts at all related with the SERVO-i MR conditional ventilator, with either the 3 Tesla or the 1.5 Tesla suite, no issues at

all to my knowledge," says Dan Smock.

Dan Smock states that when designing the new MRI suites, the 3 Tesla scanners were an unknown entity for the department and that they were fairly new to the field. He relates: "The very first child we took into the 3 Tesla scanners was actually on the MR compatible ventilator, and we had some severe artifacts, which in retrospect proved to be artifacts for the 3 Tesla system itself. They were actually from our head coil, which does head imaging. We were new to the 3 Tesla system, and we did not know where the artifacts came from, and were trying to go through the list of what could be the source of the artifacts by the process of elimination. At first we were concerned about plugging devices into wall outlets with AC current, most lighting is DC current and previous devices were set up with DC current, and the ventilator runs off AC power. We tried to eliminate a variety of things and realized it was the head coil, since we had issues even without the presence of the ventilator. We realized that these artifacts were not ventilator related."



Biomed Pat Tiehen

Biomed-friendly machine

Biomed **Pat Tiehen**, who is stationed in the Respiratory Care Department, takes care of the fleet of 45 ventilators within the department. He was involved in the integration process for the MR conditional SERVO-i ventilator. He shares his experience: "To be able to use the same ventilator at bedside and in transport was exciting. I was involved in the testing process, there were a few challenges as where to put our medical gases – we started using the aluminum-based tankholder/gas trolley and changed the straps to plastic clips. We figured out solutions to make things work, like aluminum tanks with non-magnetic brass yokes on them and MRI compatible regulators. The ventilator originally comes with two locking MR compatible wheels. We installed all four wheels to be MR compatible and lockable. Within a few months, we had put it all together." Pat Tiehen states that in the two years that the two MR compatible ventilators have been in use, there have never been any occasions where there were any significant problems or events with the SERVO-i MR ventilator. He says: "It has a clean record and interaction between departments here is excellent, communication is good, and everyone is focused on patient care." He also shares that the SERVO-i ventilators in general have an extremely good service track record within the hospital: "Of all the equipment I have taken care of, the SERVO-i is a joy to work on. The design is a biomed-friendly machine; it is straightforward and easy to work with. It is one of the best machines that I have worked on."

Education and implementation of the solution to 90 staff therapists

Rachael Dameron is Manager of the Respiratory Care Department and has been working at the hospital for 12 years. Her areas of responsibility include personnel management and staffing and the day-to-day workings of the department. She describes the workflow: "We have about 90 therapists on staff here, with a core team for the PICU, and everyone rotates between the medical and surgical floors, the



Respiratory Care Manager Rachael Dameron

emergency department and the NICU, so all therapists get some sort of critical care. We do have a department educator and specialists for each area, so they do most of the education."

"As soon as we had implemented the SERVO-i as our ventilator fleet, we knew that the MR solution was coming and were anxious to implement it here."

Rachael explains that PRVC in general has been the mode of choice in the PICU for many years, and that the RT staff in general feels that maintaining the same modes in the MR is one of the benefits of the new ventilator solution. "We had cases before when we would always take the pneumatic device up to bedside to see if the child would tolerate it, especially the neonates. It was always a concern but this is no longer the case with the new SERVO-i MR ventilator. With SERVO-i we match the modes at bedside and everything goes well and the patients are much more comfortable."

Rachael Dameron does not feel that the new MR solution was difficult to educate and learn from a staff member perspective: "Since we are such a strong SERVO institution, we basically could just roll out the MR compatible solution and use it in the scanner. The factory design is a regular, everyday SERVO-i ventilator, that happens also to work in the MR. It

is completely seamless and we use the functionalities to their full potential. It is so flexible so we can match it to the patient – you can use it everywhere."

Seamless transition of a 28 week neonate to SERVO-i MR ventilator

Respiratory Therapist **Nathan Carman** has been working at Children's Mercy Hospital for the past 5 years, and is currently Dayshift Coordinator. He transports both PICU and NICU patients, to the MR and other imaging departments. He relates the immediate benefits he experienced with the new MR compatible ventilator, from a work perspective: "In the past, we transitioned the patients to the pneumatic ventilator for about 10 minutes, and they would always fight the ventilator and require more sedation, so that we could not synchronize their ventilation as we can with the SERVO-i. We transport both PICU and NICU patients. Neonatal patients were previously always a big problem in the MR, since we could not sedate them as heavily as pediatric patients, as they do not metabolize drugs as well. It was a lot more hectic to go to the MR with a premature baby in the past. In addition to the SERVO-i MR conditional ventilator, we now also have the Immobilizer, which keeps the babies completely stable and snug.



Respiratory Therapist and Dayshift Coordinator Nathan Carman

The MR process is much easier now in the neonatal population. We match the ventilatory parameters of the SERVO-i MR unit to what the SERVO-i ventilator has been performing in the NICU, and it makes for a very nice seamless transition. The smallest neonatal patient we have treated with the SERVO-i MR was about 28 weeks old."

Patient benefits and decreased sedation

Nathan Carman believes that he has observed positive patient benefits with the SERVO-i MR ventilator, and feels that more patients are being managed in the MR on the SERVO-i – both pre-term babies and PICU patients. "Once we leave the nursery, the patient is in the care of the respiratory therapist, and if we see fluctuations on end tidal CO₂ values in the MR, we make adjustments during the process. Our NICU department is more comfortable now with us accompanying the babies on the SERVO-i compared to handbagging and risks of pressure spikes in the past."

"Our use of Fentanyl, morphine and some of the other sedation drugs I believe have been reduced significantly, thanks to these new solutions with the Immobilizer and the SERVO-i MR ventilator."

In terms of differences in patient benefits and values, Nathan observes that he and his colleagues definitely see improvements in terms of vital signs, heart rates, blood pressures, and saturations with the MR compatible ventilator, compared to the former pneumatic ventilator that was used in transport and in the MR. "Our patients do not lose any values with the MR compatible ventilator," he says. "We simply match the settings to the bedside SERVO-i ventilator."



Charge Therapist Kristen Zell

An average MR transport procedure – consistency and safety in ventilation

Kristen Zell has been a Respiratory Therapist since 1995, and has been a Charge Therapist for the last 5 years. She is involved in special procedures such as going to CT and MRI, and works in all areas of the hospital, with neonates and pediatrics in ER, general floors, PICU and ICU. She has seen the learning curves



PatTiehen, Rachael Dameron, Education Coordinator Lyndsy Wolfe, Patrice Johnson, EquipmentTech Kelly Romeiser, and Clinical Specialist Kristin Smith

related to each new ventilator model and the new MR conditional ventilator. She shares: "We were using the SERVO 900 when I started here, and they were just coming out with the SERVO 300. I liked the SERVO 300s, but the SERVO-i ventilator tells you more information you learned in school in theory but did not ever really get to utilize."

"Knowing the SERVO-i ventilator before we had the MR conditional SERVO meant that there was not much inservicing necessary to start using it. We were very excited when it was finally implemented a couple of years ago. I feel we can see many more patients in the ICU now as candidates for MR that previously could not tolerate the old transport/MR ventilator. They may not have tolerated manual ventilation. Now we can provide optimal bedside quality ventilation in MR. The most significant new populations are the neonates and patients with congenital heart defects that have required much more support in the past than we could provide in MR. Our only choice was to use either 100% FiO₂ or 21%. Now the transition is much smoother from bedside to MR. We can dial in the FiO₂, and the settings can be

exactly what is set at the bedside. The entire procedure is more user-friendly as well as patient-friendly, with the new solution. It has been wonderful, you can go up to a patient room and bring the SERVO-i MR ventilator, put in the identical settings as bedside, they transition well and you can transport them easily. With extra batteries, we have over 300 minutes of run time which leaves ample time to transport to MR, obtain the study and return to ICU."

"The continuity of care that the MR conditional vent provides enables us to focus on patient needs, not equipment. I feel that patients are safe and ventilated as well in MRI as they are in the ICU."

Kristen Zell states that the babies were a particularly challenging patient category in MR in the past: "In general, our babies typically never had enough sedation or paralytic, making it very challenging to ventilate effectively or obtain good pictures in the MR. We have been doing more MRI examinations on these patients since we have had access to the SERVO-i MR compatible ventilator. The Immobilizer swaddling system has been a big help as well. The babies



The Children's Mercy Hospital, Kansas City

need much less sedation and seem to tolerate both elements extremely well. The imaging goes faster and the whole process is streamlined. Our new MR suites are larger and were designed with ventilated patients and the respiratory therapist taking care of them in mind."

Better prognostic information based on MR scans

Stephen Klem, MD is Associate Director of the 27-bed Pediatric Intensive Care Unit at Children's Mercy Hospital, and Assistant Professor of Anesthesia and Pediatrics. He has been working at the hospital since 1991. He shares a description of the PICU activity and uptake area: "We have between 1700 and 1800 admissions per year, and patient uptake from a region of states: Missouri, southern Iowa, a corner of Nebraska, and part of Kansas, and a few from Arkansas and Oklahoma that are transported up here. We have a very active pediatric transport team that are working from 4 ground ambulances, 2 helicopters, and one turboprop plane to cover this area, so we transfer about 3400 pediatric patients a year, and 2000 neonatal patients per year."

Dr Klem states that PRVC is the mode of choice within the department; however some of the older intensivists still use SIMV for the average post-op patient with decent pulmonary function. "PRVC works great and is our default mode, for patients with more respiratory muscle issues, we kick over to SIMV for a trigger mode but we also do SIMV-PRVC since it is easier."

Dr Klem shares his impressions of the new MR compatible SERVO-i ventilator: "In the past there was handbagging in the first generation, and after that we had an MR-compatible pneumatic ventilator that made strange sounds and made us feel insecure about the ventilation, for better or worse. With the new solution in SERVO-i, we are sending sicker patients down to MR than we ever dreamed of sending 5 or 10 years ago, because of better information and better images nowadays. We are getting better prognostic information for the families, and sometimes life and death decisions are made based on MR findings."

"Our bravery threshold has shifted over time and the patients are more comfortable. We are very comfortable about using the SERVO-i for transport

for consistent controlled ventilation with SERVO-i than the previous pneumatic ventilator, and certainly more so than handbagging. With a lot of these children we don't want to see their CO₂ levels fluctuate too much. Ventilation is one less thing to worry about, the constancy of ventilation is no consideration any more.

Dr Klem gave his opinion of the main challenges and requirements for ventilating pediatric intensive care patients in the MR: "Fluctuations in intra-cranial pressures meant that a big priority is constancy of ventilation. More sophisticated ventilation that can provide monitoring capabilities and feedback if there are secretions requiring suctioning, changes in compliance, etc. Something that is reliable and the biggest convenience is that it is the same ventilator as at bedside. And by adding the gas tank you have a mobile ICU grade ventilator.

Dr Klem does not see any limitations with the current SERVO-i ventilator with MR functionality, from a ventilator point of view. "The MR is just a threatening place to send our patients and we constantly have in mind if the benefit of having the scan justifies the risk of sending our patients in order to do it. MR is still our preferred neuro-imaging technology, and for patients with MRSA getting abscesses and going down to MR to image so the surgeons know what to do next. It is the least invasive technique that is available for recurrent abscesses."

Respiratory Care Director Patrice Johnson summarizes the general opinion of the MR compatible ventilator from the multi-disciplinary perspective: "It is nice to state that after 2 years, the MR compatible solution has been totally seamless with no incidents. It is a normal part of the patient care environment for staff from all levels. From the first day when it went into place, it has been great."

"We had a smooth transition process, and the MR compatible ventilator has been a benefit to us and we are thrilled to share that. Not everything we do has gone as easily or been as well-accepted. This MR solution works well."



Dr Marcelo BP Amato is an internationally known intensive care profile for his many years of research regarding lung protective strategies

Two decades of ongoing progress in lung protective strategies in mechanical ventilation

The Hospital das Clínicas in Sao Paulo, Brazil is a university teaching hospital as well as one of the largest hospitals in South America, serving a population of around 3.5 million inhabitants. The institution has a medical staff of over 600 physicians, and provides comprehensive intensive care facilities for adult, pediatric and transplant patients.

The institution is also well-known for its research, and Dr Marcelo BP Amato of Clínicas has maintained a high global profile in intensive care for over two decades, combining research and bedside practice in his ongoing search for defining and refining lung protective strategies and tools. Critical Care News interviewed Dr Amato to obtain his reflections of the research milestones of the past that led to his study in NEJM 1998, the recent advances in clinical trials and his views on future opportunities in lung protection, as well as his current experience and opinions of the H1N1 virus.

Your dedication to clinical work and research within the areas of mechanical ventilation and pulmonary monitoring has become world famous. What has been your personal driving force for this total commitment?

I think it is the quest for the truth, and the work with post-graduate students, which has been very rewarding. I like this environment where we are trying to really understand what is going on. Let me give an example. I still take care of patients, and you are always learning from them; but once you finish your case, you always have a question in mind "was it enough?" "Could I have done something else or something more?" By doing research, we can address this uncomfortable feeling. It is a natural process: the attempt to solve such questions that come to your mind at the bedside. I am very lucky that the structure here at Clinicas hospital has allowed me to go in that direction. I have seen many researchers around the world, even in well developed countries, and I know it is very unusual that someone can be so focused in research. For instance, nowadays physicians usually have a heavy clinical load, but I can spend 70-80% of my time with research, which is great. This whole environment of research, and being among the post-graduate students, is what I really enjoy, much more than the atmosphere of congresses.

Your unit in Hospital das Clinicas in Sao Paulo has always had an extremely high rate of severely sick patients already upon admission compared to other ICU's around the world. In several published studies you have reported improvements in outcome and mortality for these patients. As a comparison, how would you estimate the overall numbers for outcome and mortality have changed if you look at all admitted ICU patients for the last 20 years?

Absolutely, just for comparison even today the average percent of patients under mechanical ventilation is 35% in any ICU in general - if you take an average ICU around the world, 35% of patients that day are going to be



Dr Amato in research laboratory with Erick De Camargo, software engineer, and Susi-meire Gomes, scientific researcher and biologist

undergoing mechanical ventilation. In our hospital, this average is close to 50%, which is significantly higher. We have more patients with severe disease and on mechanical ventilation, and among these patients in mechanical ventilation, the average mortality is around 40% and here at our hospital it is close to 50%. Obviously, we all have to improve our care, and this hospital is very heterogeneous, so it means that some units have a better outcome than others.

We don't have reliable numbers from the past in terms of outcome in absolute terms, but only from the past 2-3 years. But it is absolutely obvious that in the past, a patient with ARDS had a very bad prognosis, but nowadays we see many patients surviving in many units of this hospital and this is related to lung protective strategies.

In your endless endeavor to improve how to apply true protective mechanical ventilation in the ICU you have explored various methods how to accomplish this. What was the starting point for your research concerning lung recruitment procedures?

The starting point was when I was a resident and we were taking care of patients with Leptospirosis. This is a disease that can occur in Brazil and other poorly developed countries, when you have a lot of flooding in the rainy season, and you have high levels of water that people must walk through. If they have tiny wounds or scars on

their legs, a certain bacteria from the urine or stools of rats can be present in the flood water, and may enter into the patients' circulatory system and cause severe hemorrhage within the lungs. When I was a resident (1987-88), it was very common to see these patients under mechanical ventilation with the ventilator circuits full of blood, and we had to frequently disconnect the patients, remove the blood, and then re-connect. Usually, when this happened, we could anticipate a 100% mortality. My colleagues Dr Carmen Valente and Dr Carlos Carvalho and I realized at that time that depending on what we were doing with mechanical ventilation, the bleeding could be stopped. The first thing we realized was that increasing PEEP was good, and decreasing tidal volume was good. But how did we have this intuition? I think it was related to the fact that we started to read experimental studies on ventilator induced lung injury at that time, for instance the famous Webb and Tierney study in rabbits (1974) was regaining some attention through the works of Dreyfuss (1985) and Kolobow (1987). I was not familiar with Professor Lachmann at that point, I got into contact with him 2 or 3 years after we started our protocol of increased PEEP and decreased tidal volume in these patients. Thus, it was a very nice coincidence that two people in different parts of the world came to the same concept. This was about in 1989-1990. Professor Lachmann came to Brazil in 1992, and it was a good convergence.

This is how it all started: because of

Leptospirosis. Let me tell you something interesting, think about this: imagine that you are taking care of a patient, and that you are changing ventilator parameters, trying to apply a protective lung strategy. The first thing that you see is a drop in oxygenation, provided that you don't use PEEP, I mean, provided that you just decrease the tidal volume. Imagine this drop in oxygenation and the subsequent increase in carbon dioxide: how could you (or any physician) do this for the first time, at the bedside? It seemed impossible, non-intuitive and causing an immediately bad result. The only reason we could withstand such "apparently" bad effects of hypercapnia was because we could see the immediate stopping of bleeding in patients with Leptospirosis. We could see a positive result in terms of the bleeding process. Then we wanted to check the same procedure in ARDS patients, to see if it provided the same beneficial effect. That is how we started, and that is how we expanded the treatment strategy from patients with Leptospirosis to patients with ARDS. We decided to use the same protective strategies: high PEEP and decreased tidal volumes, which finally became the NEJM study. It is interesting to note that when Prof. Lachmann came to visit us, in 1992, he told us that our permissive hypercapnia strategy was a mistake. He was in agreement with the recruitment strategy, but not with high CO₂ levels, which he believed to be bad.

Your landmark study "Effect of a protective ventilation strategy on mortality in acute respiratory distress syndrome" was published in the New England Journal in 1998 and investigated a combination of concepts at that time: reducing tidal volumes and plateau pressure, allowing CO₂ to rise preventing overdistention and higher levels of PEEP based on the lower inflection point of the PV curve. This led to a host of other studies, including the ARDSNet trial. Which lung protective ventilation studies published in recent years do you find to be of special interest, and why?

I think that in terms of big changes in our perceptions, I would list experimental

studies. I consider that the recent PEEP studies - LOVS, ALVEOLI and Express, the three studies testing high PEEP strategies - form together an important theoretical and critical mass of background data, according to which we can now say that using high PEEP is safe, and eventually can decrease the length of stay in the ICU. I consider these three studies to be very good, as they are now telling us that even if you apply a very rough or simple, non-elaborated strategy of PEEP, you can still have some positive results, like decreasing progressive respiratory failure and length of stay. But obviously, I still believe we can do much more by applying physiology at the bedside. In this regard, these studies are important, but they are not capable of answering the main questions – we still need more studies. I still believe that the most important studies are the physiological ones, for example the study from Fernando Suarez Sipmann showing us that we can use compliance to titrate PEEP, or the theoretical study of Keith Hickling, when he showed in a mathematical model that we can use compliance to titrate PEEP, and also some other experimental studies about ventilator induced lung injury. In humans, we have 2 recent clinical but physiological studies, from Terragni and Grasso, showing that the titration of PEEP based on PEEP/FiO₂ tables is evidently suboptimal. However, according to my personal perception, they do not point to an appropriate alternative to that. I also like very much one study from Matthay et al where he shows that decreasing tidal volume further from 6 to 3 ml/kg can cause a further attenuation in the VILI process.

To summarize, in my opinion the most important studies in recent years are the combined multicenter PEEP studies and some of these experimental studies quoted above, which means that we know a little bit more about where we are in terms of lung protective strategies. However, I hope that, in the next few years, we will have even nicer studies about PEEP.

What about the ARDSNet trial?

The first ARDSNet study focusing on low tidal volumes was a very interesting

and important study – in fact a relief for us after two years alone, being the only group showing significant effects of protective strategies - but this study only focused on one aspect of our concept of lung protective strategy. The second study from the ARDSnet group, the ALVEOLI study, used a kind of "recruitment" that was a simplified maneuver, with results that were theoretically suboptimal. It is very hard to do recruitment at the bedside. This is why a good PEEP approach at bedside requires better monitoring tools. When I first visited Professor Lachmann in his lab at Rotterdam in 1997, I was convinced, before going there, that we could use lung mechanics to determine the optimal PEEP. But after my visit in Rotterdam, it was obvious to me that we needed better monitoring tools. He had an online blood gas monitoring system, and there, for the first time, I saw electrical impedance tomography, EIT – a very rough prototype that did not work online, and which had terrible images. But offline, the results were amazing: we saw detailed information about regional mechanics which was a revelation to me. I came back to Brazil and I felt I had to construct an EIT device. I was 100% sure that, even having nice tools - like we have today to measure online compliance- we still needed more. It became also obvious that we needed to use the concept of compliance on the descending curve, but regionally, not globally.

Lung recruitment procedures have today been acknowledged by many physicians around the globe to be helpful in preventing injurious pulmonary stress by keeping the lungs open at lowest possible pressures. However, there are still quite a few "disbelievers" and "uninformed clinicians" that need to be recruited to fully extend the clinical use of lung recruitment procedures. In your mind, what have been the most difficult hurdles in establishing lung recruitment as a general practice in the ICU?

We have to create tools to provide a better feedback to physicians. A better monitoring of the physiological effects of recruiting maneuvers. That



Dr Amato outlines an EIT image

must be our target. It is our mission in terms of software for the ventilators, interfaces, and also for the combination of compliance and EIT monitoring.

You realized early in your lung recruitment research that there is a need for an extended real-time pulmonary monitoring at the bedside to be able to see the changing dynamic process that takes place during a lung recruitment procedure. When and why did you start investigating the possibility to use EIT for this purpose?

I realized at my visit in Rotterdam that, during recruitment, you have a complex lung system with many different parts, each one behaving differently. When you analyze conventional mechanics, you have a single output, which is trying to measure and represent this complexity. It is a kind of impossible mission: for this complexity to be described by one single parameter. I had this very strong feeling in Rotterdam that we needed something to track regional changes.

I think the best alternative we have at bedside - at the current time - is to use compliance on the descending

curve. But this is still not fully optimal, it is a global parameter with all intrinsic limitations – and we always have room for improvement and development.

Your EIT project has now had several units internationally distributed for research and clinical use. Can you say something about the initial experience from this so far, and share your thoughts on future clinical applications?

I think I have received two important feedbacks from the field – the first has been very positive: whenever someone gets used to perform PEEP titration with EIT, the results are remarkable and looks like we are on the right track. On the other hand, I have received some feedback that we have to improve the EIT interface and the clinical significance of the information that goes with EIT, since it is not easy to interpret the images, at the current stage of the technology. That is the challenge for us: to provide an easier and more user-friendly version. But in terms of the clinical information you can gain after doing PEEP titration (with EIT), I'm really amazed, and this has been a consistent feedback. I have been personally doing PEEP titration

with EIT in ARDS patients at Hospital das Clínicas, a few dozens, also some patients with swine flu, and we have now results from Spain, Uruguay, in addition to some more animal studies in Uppsala and here in Brazil that have been very interesting. In Brazil, the EIT is also being used in treatment of horses, which is quite interesting – as horses present lots of atelectasis during anesthesia, due to their anatomy. Thus, EIT has been valuable and interesting to study the animal physiology under this situation.

In general, the feedback has been very good and I can anticipate that we have a big challenge in front of us, which is to transform this technology into a user-friendly technology: a long pathway.

Your contribution to the development of the Open Lung Tool has been extremely valuable. Did it meet your expectations of clinical usefulness? Is there additional functionality you would like to see in this tool in future?

Certainly, in the same way as we have a compliance tool, we need a better recruitment tool. I think we should create a much better tool to use at the bedside. An example: I do recruitment every day, I go to many patients around the world and I always see the same difficulty, which is to perform many operations at the same time during the maneuver. Also, you have to track and check at the same time if nothing is going wrong with hemodynamics, air-leaks or plateau pressures. You have to be sure that the ventilator does not go to backup modes, which is very dangerous: if the backup ventilation is activated during the recruitment phase, you have a high backup tidal volume on top of a high PEEP!

We have to create better recruitment tools where one could program some parameters and operations and then you press GO: and then you just focus on monitoring complications, like bad hemodynamics, excessive pressures, and so on, enabling you to see the whole behavior of the system. We need this type of facility in the ventilator, which we do not yet have at the present time. By making a more user-friendly recruitment maneuver

process, you would give to the physician more opportunity to just focus on the patient, on the side-effects and also in the physiological benefits during the process. With some smart calculations, you could give information if you were successful or not with your recruitment maneuver – some feedback during your recruitment process and just afterwards.

Automated servo control systems have been implemented in ventilators for decades now. Closed or semi closed loop system for user pre-set ventilator management has also been implemented for dedicated limited functionality in modern ventilators. With currently available technology do you think it would be clinically useful and safe to further develop this type of automated ventilator management in the near future?

I think that this is an extremely slow process. When you think about the old times, when I started to study mechanical ventilation, I was pretty much involved in the process of transitioning from volume-controlled ventilation to pressure-controlled ventilation. This was the precise reason why we created dual modes, called VAPS at that time – volume assured pressure support- or PRVC – pressure regulated volume control – both to be used as a bridge between volume-controlled and pressure-controlled. As soon as we started to work with the bridge, we could see that it was no longer necessary, and I gradually stopped my research in this field. I could envisage that we could jump directly to pressure-support, without fear. Think about the different perspective today: if you take an average patient from any ICU around the world, approximately half of them are under pressure support ventilation. We learned that giving some freedom is not bad.

Now we have a new challenge, which is jumping from Pressure Support to NAVA or PAV, another big transitional step. If you think about NAVA or PAV, they are both a kind of closed loop method, to a certain extent, since they are using as inputs some direct information from the patient. They are not completely controlled by physicians. There are some

clinical studies on NAVA and PAV which have shown that we can give this next degree of freedom to patients without too many problems. It is very preliminary, but we are learning that giving a little more freedom can be good, under special circumstances. We are starting to do some research on that here, and in particular, for me, I am interested in a very simple question: if you give a lot of freedom to the patient, will the patient use it in a good way? For example, if you have a patient with acute lung injury, if you give him too much freedom, will he promote too high levels of tidal volume or driving pressures to be applied on himself? We don't know yet. We are starting some research in this area, and it is a very interesting topic for me. I believe that, under certain conditions, the patient will not choose the right tidal volume. There are some preliminary studies on NAVA that show that the patients do choose a proper physiological level of tidal volume for themselves, but I am a bit skeptical about this point yet. We have to look at different patients and disease categories to check the consistency of such behavior.

In summary, closed-loop is something that has to evolve. Today we are starting to use some neurological input as in NAVA, or some mechanical inputs as in PAV, to feed the closed-loop system. It is likely that EIT will also be used in the future as an input to closed-loop ventilation. Like in a plane, the more inputs you have, the better your controlling system is, and the safer your system is. If you rely on only one parameter, and there is a problem with the reliability of that parameter, the whole system is at risk. I think we need a multiplicity of inputs in future for a reliable closed loop system.

The leap from volume to pressure in past decades was very radical at that time, and I think we are facing the same challenge today, going from pressure to NAVA or PAV. When we jumped from Volume Control to Pressure Support – suddenly the patient could control the flow, which he could not do before. Now, from Pressure Support to NAVA or PAV, suddenly the patient can control pressure coming from the ventilator – it is a big step.

Maybe too big. We do not know yet.

The decades of research you have conducted within lung protective strategies and lung mechanics includes a focus on physiology as well. What general opinions would you like to share in regard to your clinical experience of Neurally Adjusted Ventilatory Assist (NAVA) at the present time?

Besides investigating how much freedom we can give to the patient in acute lung injury, there is another question that I am interested in, related to the fact that some experimental studies have shown that monotonous ventilation can cause problems, and that some variability in tidal volumes or pressures are good for the patient's system, since they work like a recruitment maneuver. There are some good studies about noise ventilation that I like very much. It seems that noise ventilation is even better than intermittent sighs, for some reason that we don't understand very well. But maybe if we find a very good pace or repetition, or size for the sighs, it could be as good as noise ventilation. But the fact is that noise ventilation, with a random variation of tidal volumes, seems to be a good recruiting maneuver. I have seen patients that we have recruited, in which we found the optimum PEEP, but in which you could clearly see some slow derecruitment over time. I feel that if we keep such patients in a mode in which we have a little more variability, like NAVA or PAV, maybe we could maintain the recruitment in a more efficient way. This is a hypothesis, but I would like to investigate this and I have seen some cases that have called my attention into this direction. There is a theoretical trade off though: more variability also means a looser control over the VILI process. There are plenty of evidences showing that spontaneous ventilation can be as deleterious, or even more deleterious than controlled ventilation in terms of VILI production. Everything depends on the driving pressure applied on the respiratory system. It does not matter if it comes from the diaphragm or from the ventilator.



Dr Amato at Hospital das Clinicas, Sao Paulo, Brazil

As a summary of our discussion, can you point out some historically important landmarks and milestones which in your mind constitute the basis for the development of protective mechanical ventilation and lung recruitment strategies that are in clinical use today?

As I mentioned in some aspects earlier, I think in addition to our early research and experimental studies on VILI, we must start with Professor Lachmann and his open lung concept; the initial accumulated experience of Gattinoni, when he was promoting the venous-venous CO₂ removal and giving the lungs some rest; the concept of permissive hypercapnia promoted by Hickling for the first time in ARDS patients; Professor Hedenstierna and his concepts of atelectasis - early during general anesthesia and during high FiO₂ use (he was calling attention to the fact that atelectasis was much more prevalent than we initially thought, even in patients with normal lungs). I would like also to quote the recent studies from Kavanagh in Canada showing that hypercapnia can be protective in terms of lung injury - I think this is a very important development in recent

years. And obviously, the three clinical studies that showed that protective ventilation improves survival: the low tidal-volume ARDSNet study, our study at the NEJM and the recent Jesus Villar paper. These are particularly important ones, as they create a bulk of evidence that we should really pay attention to protective strategies. I would like also to not forget the tremendous evidence created by experimental studies, like Dreyfuss, Marini, Slutsky, Taskar, Tsuno, Kolobow and others. I would conclude with the PEEP studies I mentioned earlier, as we can now say that high PEEP is not damaging, which is a very important result.

Your expertise and know-how of the frontier within the area of advanced mechanical ventilation and pulmonary monitoring is well known on a worldwide basis. What quantum leap in technology would be required in order to significantly improve efficacy and safety in ventilator management for the future compared to what is available today?

I strongly believe in EIT, I strongly believe in multiple inputs to improve safety,

because then you can have closed loop systems. Without multiple inputs, it is hard to have closed loops, because you cannot rely on one single parameter; if it fails you are in big trouble. I think there is lots of work to do with the interfaces of ventilators. I have participated in the development of interfaces of some ventilator products and I have seen the challenges the manufacturers have with some regulatory agencies. They are always a conservative force in this process, as the regulatory authorities try to keep the interface at the very simple level, but we have to push hard in the opposite direction. It is like the invention of the joystick in planes - we all know that this is a remarkable invention, especially for complex missions and difficult targets for the pilots. I think we have to create something similar for the ventilator - a tool that makes the whole mission much more simplified and intuitive. This is a challenge, but I strongly believe in that.

In terms of specific tools that can be improved, one is EIT, that should be linked to the ventilator - this has been my dream for many years. I would like to integrate it into a ventilator. I think we should improve the use of capnography - it is still very complex. The technology per se is simple but the way you give information to the physician is still very complex - we should have a concept that would make the physician more comfortable with the results. For example, we should use capnography during PEEP titration and in a smarter way to make it easier for the physician to understand what is going on. I believe that EIT will be used one day to analyze the perfusion of the lung, and this is something I think will add information at bedside, in terms of hemodynamics and lung perfusion necessary to optimize V/Q match at the bedside.

I think some technologies to have online blood gas analysis are needed urgently. The old Paratrend project was very valuable and I learned so much from that. Obviously, we are evolving to non-invasive technologies to do measurements of blood gases in real time. I have also some insights that we need better substances to infuse into the lung that are better than surfactant.

Surfactants theoretically should work, and the neonatologists love it. But for adult patients we need something better. I am starting to understand about what is problematic about the surfactant trials we have seen, a hypothesis about what has gone wrong, and I see the need for a new substance to fill into the lung, promoting better air ventilation. Lots of work to do, and we need all of these monitoring tools to get more data.

Lastly, the subject in everyone's mind in intensive care: the H1N1 virus – what was your experience during the past year, and what are your concerns and preparations for the coming new flu season in Brazil?

I faced the worst cases of acute respiratory failure that I have ever seen in my life with the H1N1 virus in the past year. During the peak of the flu season, I received 5-10 calls a week from all over South America, asking me to recommend what to do or what not to do. ICU physicians became lost in treating these patients, since the reaction of the blood gas to the pressures applied with the ventilator, were completely disassociated in these patients. For example, if you do a recruitment maneuver, you usually don't expect too much improvement in oxygenation during the maneuver, but you can expect some improvement afterwards. However, with these viral patients – there was no response like this in most patients. If you increase PEEP in these patients, oxygenation frequently drops. Sometimes if you decrease PEEP, oxygenation improves. So weird things are happening frequently in the H1N1 patients. I realized that this behavior is caused by the fact that this H1N1 disease is very heterogeneous, associated to some poor hypoxic pulmonary vasoconstriction. You may have areas of the lungs of these patients that are completely preserved, and areas that are totally damaged. This is not common in ARDS, where you have a more diffuse disease. When you have a more impaired hypoxic vasoconstriction in this disease, any degree of pressure you put within the normal areas is going to divert blood flow to the bad areas: if you increase pressures, you will have more shunt. Then the physicians get lost in the vicious

cycle. I monitored some of the patients with EIT and CT, and I realized that in some respects these patients are like any other patients – they recruit, and if you decrease PEEP they collapse. But the output in terms of blood gas is a disaster, and this is what is causing confusion to the physicians. When you get lost with PEEP, tidal volumes and CO₂, it is hard to manipulate these patients at the bedside. We spoke about the topic of improved monitoring tools. Here at Hospital das Clinicas we are advising the clinicians to only focus on lung mechanics for these patients, and to forget blood gases in treating these patients.

As an interesting episode, I was called in to give advice for a patient and the patient had been ventilated with a PEEP of 24 cm H₂O. It was the first time in my life that I came to the conclusion that I had to reduce dramatically the PEEP, based on his mechanics and EIT data – this patient only needed 16 cm H₂O. It was an interesting experience for me.

I am starting an experimental study with the support of Maquet to study ECMO with the Cardiohelp device. I believe that, in the case of future H1N1 patients, we will need to keep these patients alive for one month, to allow them to recover from their tissue injury. If you look at the lung tissue of these patients, it is completely infested by the virus. It takes a long time to recover, the vessels are destroyed, the bronchi are destroyed, and it is a big mess. In the most severe cases, you have to

keep the patient alive, not causing more harm with the ventilator. And in these specific cases, ECMO is needed. This is how we are preparing ourselves for the next flu season with this device.

I had experience with ECMO during the 90s and I surrendered, due to the bleeding the technology caused in unstable patients. For me, it is clear that the least invasive and the lower the flow rate (blood flow entering the external oxygenator), the better for the patient. This is why I am doing some research to establish the lowest level of blood flow that I can induce with this device to have a reasonable result. I am also interested in using this Cardiohelp device together with some ultra-filtration in series, which could eventually enhance CO₂ removal: with less blood flow you could further improve CO₂ removal. I am interested in looking at these matters in preparation for the next H1N1 flu season, which I am very concerned about. If it is the same or even less than last year, we can perhaps save many more patients with this system. We lost many of these patients due to progressive respiratory failure in this last year. The Cardiohelp device may give us time to keep the patient alive to resolve these problems.

In summary regarding the H1N1 virus, my advice is that if the H1N1 patients are on a ventilator; focus on lung mechanics and not on blood gases. In the most severe cases, consider ECMO as a way to gain time and keep the patients alive to recover from respiratory failure. ■

Biography

Dr Marcelo BP Amato received his initial medical degree in 1985 from Faculdade de Medicina da Universidade de Sao Paulo. After his residency in internal medicine and intensive care, Dr Amato specialized for two years in Pneumology and Intensive Care Medicine at the Pulmonary Division of Hospital das Clinicas in Sao Paulo. He obtained his doctoral post-graduation in 1996. Dr Amato presented his thesis and attained the level of Professorship

at the University of Sao Paulo, Pulmonary Department in 2008.

Dr Amato has conducted extensive research over the past two decades, resulting in publication of over 53 original articles in international peer-reviewed journals, and has also obtained several scientific awards. Dr Marcelo Amato is a globally known profile as lecturer in international intensive care meetings.

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Dr Felipe Saddy with COPD patient in the Ventilatory Care Unit of Hospital Copa D'Or

Experience and implementation of NAVA in COPD patients

The Hospital Copa D'Or in Rio de Janeiro, Brazil has maintained a focus on the development of standards and quality, resulting in 2007 by winning the international certification by the Joint Commission International. Excellence in care is the primary goal of the institution, and this progress is monitored by continuous development within all departments of the hospital.

The Hospital Copa D'Or offers comprehensive critical care services with general ICU, Neuro ICU, Cardio ICU and Pediatric ICU departments. To support and maintain quality in ventilatory care, the hospital is one of the very first in Brazil to implement a Ventilatory Care Unit, headed by Dr Felipe Saddy, which also functions as a step-down unit. In turn, the Ventilatory Care Unit was one of the very first in Brazil to implement NAVA – Neurally Adjusted Ventilatory Assist in mid 2008.

What are your primary responsibilities and the average number of staff members in the Ventilatory Care Unit, which is the step-down unit for the 4 intensive care departments at Copa D'Or?

In the Ventilatory Care Unit, which is a step-down unit we have 3 physicians, or 4 in total including myself. The work for the step down unit is to follow the patients closely in the ICUs and to follow the patients in invasive mechanical ventilation. We are also called in cases of chronic long-term patients depending on ventilatory support that are being treated in the hospital for extended periods of time. My colleagues and myself go to the patients in the other acute ICU departments to follow the patients and to collect and analyze the patient data for continuous mechanical ventilation and other parameters such as glycemic control, fluid balances and lab data as well. Data for ventilator parameters and modes are collected twice a day since 2004. We monitor the patients in the other ICUs and we treat the patients that end up here in the step-down unit. When the patient comes to our unit, we already know him, so it is easier. We maintain the same level of care as the ICU in the respiratory care unit. We manage the strategy to wean the patient, which starts with the resolution of the clinical problem, the most important thing to do. Sometimes we have ventilation related problems, where we can use NAVA or other tools to manage the situation.

You have conducted some research in regard to assisted ventilatory modes in mild acute lung injury models as well as interruption in weaning in mechanical ventilation. Are there standard modes of ventilation that are being used in specific patient categories in the ICU, and what is the basis of the choice for these modes?

In terms of global care, we use controlled modes on the most severely critically ill patients, but as soon as possible we change this to spontaneous modes. In 70% or more of the time on mechanical ventilation we use spontaneous modes in the hospital; it may be CPAP plus Pressure Support,



Dr Felipe Saddy conducts research and is active in educational activities in mechanical ventilation

NAVA or APCV (assisted pressure control ventilation). We use Pressure Support and Bivent a lot, as soon as we can, in patients with acute lung injury, to prevent collapse. With this strategy it is very unusual to have to use recruitment maneuvers. We can manage these patients on spontaneous ventilation, pressurized with high level of pressure, around 28-30 maximum, high levels of PEEP as necessary depending on the gas exchange, respiratory system mechanics and radiologic data, but using much less sedation using Pressure Support with Bivent. This was the strategy on my experimental study of Bivent with Pressure Support, APCV and PCV, and the results were better for Bivent in terms of protective elements of the lungs, inflammatory mediators and mechanics. We have a plan to manage a study with Bivent in acute lung injury patients, however it is nowadays becoming very rare to have those kinds of patients; the emergency room has a protocol to resuscitate these patients much earlier than in the past. When the patient with ARDS and ALI

presents, it is related to something going wrong in the operating room or present in a patient coming in from another hospital. However those are the types of patients that are decreasing in the past five years. This view was discussed together with the Mayo clinic and they have experienced the same impression. More protective ventilation strategies and earlier resuscitation is having a positive effect on these patient categories.

You have had experience of NAVA for a period of time. What was the starting point for your experience of NAVA, how many patients have you treated with NAVA and in which patient categories?

The initial protocol we studied was a small protocol of 10 COPD patients, tracheotomized; of which 8 patients were included from our unit and 2 from the medical ICU. All the patients were on the ventilator more than 10 days, and we compared the energy expenditure between Pressure Support



Dr Filipe Saddy and COPD patient

and NAVA, using both modes to result in a $p01 < 2$. This means that the patients were comfortable, which was the most important factor of this work. We wanted to compare the modes in a comfortable scenario in these patients. We analyzed energy expenditure in each mode and could not find any differences in this scenario of comfort. When Pressure Support was set correctly and analysis made of cycle off and other criteria, there was no difference to NAVA. However, I believe that the patients' demands can change during daytime and nighttime, but Pressure Support is constant ventilation. NAVA provides variable ventilation during daytime and nighttime; NAVA is more physiological than Pressure Support in this respect.

Another important observation is synchrony. NAVA is synchronous and provides information directly from the phrenic nerve. In this respect, we break the vicious cycle of asynchrony, since the mode is always stimulated by the phrenic nerve, compared to pneumatic modes. It is easy to understand, but it depends on the neurological input muscle strength of the patient.

The mean NAVA level used was about $1.5 \text{ cm H}_2\text{O}/\mu\text{v}$, the patients were very stable. Before this protocol we made some tests and it was very interesting that we could use the NAVA but the patients were weaned before we could include them. When we use a high NAVA level, the patient demand was

sustained and sufficiently stable, the tidal volumes could vary, but the minute ventilation was sustained independently of the level of NAVA. Sinderby has shown that before and the Stefano Nava group, and in October A Slutsky and Sinderby published an experimental study in Intensive Care Medicine of ALI in rabbits, with the same result. We have to work with the physiology of the patients and respect it. We don't need "stable" ventilation, but we need to sustain a reasonable minute ventilation to reach patient's demands and not just the same tidal volume in every breath. I believe that NAVA and other modes that can respect that the patient's breathing differs from breath to breath and variation is important, to be sure.

With reference to your general experience of conventional mechanical ventilation and standard modes, what are your impressions of mean/peak inspiratory airway pressures in your experience with NAVA this far? Which levels of tidal volumes and respiratory rates are you observing with NAVA, compared to other modes of ventilation?

The conventional modes limit pressure and tidal volume and/or time, so that NAVA gives us pressure as a huge parameter to measure and monitor. I think that the physician that is using NAVA needs to know what parameters result in the inspiratory pressure the patient will receive with NAVA, the principle of equation of motion must be there. However the main parameter which will result in inspiratory pressure and tidal volume will be the gradient between the lower level of Edi and the higher Edi, this maximum and minimum gradient must be reliable, the signal must be very clean. Others parameters that will interfere are PEEP and the NAVA level. In a first place you have to "homogenize" this mode using the NAVA preview tool. If the patient is ventilating on Pressure Support, you may sustain the same level of pressure, and for that you need to set the NAVA level to result in the same level of inspiratory pressure if it is adequate for that patient. Then you can not turn back, you have to stay there in NAVA, to see the power of muscle strength which is related to the gradient of Edi activity. This will be the main parameter to result in a higher or lower respiratory pressure. Look at the Edi and monitor it from the bedside, and the patient will also help you by means of lung mechanoreceptors to sustain its optimum minute ventilation. If you have a hypothetical hyperdistention situation, the closed loop physiological information from lung reflexes will protect the ventilatory system and the stimulus will decrease. The physiology must be completely connected to the ventilator, and the neurological reflexes and the receptors in the lungs are very important to sustain a healthy system. If the patient breathes with a higher NAVA level or a huge gradient of Edi, the patient will receive a higher level of pressure, however in the

next breath he will regulate himself physiologically. It is a self-regulating situation, the patient is informing the ventilator about his diaphragmatic activity, and the ventilator will respond and deliver respiratory pressure related to the diaphragmatic request.

You have done some research in regard to weaning and weaning interruption in mechanically ventilated patients. What is your perception of patient – ventilator synchrony and weaning in regard to NAVA?

I think this is one of the most important factors in relation to NAVA and that is ventilator-patient synchrony. Not only the fact that patients synchronized with the ventilator can reduce the time the patient spends on mechanical ventilation, I believe that it is very usual in the ICU that the physicians are not prepared to recognize or understand that the usual screen on the ventilator does not reveal asynchrony. Asynchrony is extremely difficult to detect in normal pneumatic

ventilatory modes and you really need to know what is going on. I really think NAVA may help, because of the Edi activity. We can recognize the activity of the Edi of the patient and synchronize the mode with that. We have many cases of COPD patients on Pressure Support where we could literally see the asynchrony by means of the Edi parameter. With NAVA, you simply synchronize the COPD patient and monitor him.

Are there any specific patient experiences with NAVA that you would like to share with us?

We have been working with NAVA since June 2008 and have used it mainly on COPD patients and synchronization has been the most important factor to us so far. However, in these patients we also find the variability of the tidal volume and maintenance of minute ventilation to be very interesting. This aspect is even more important on patients with ALI, but I have no experience yet of NAVA in this patient category. In COPD



Dr Felipe Saddy has been working at Hospital Copa D'Or for many years



Dr Felipe Saddy

patients, I believe that synchronization with NAVA is perfect in these patients. My COPD patients have not had any problems in triggering the ventilator with NAVA; in fact it is very easy for them.

You have a profile in education and training, as coordinator of ventilation in your institution as well as giving lectures in mechanical ventilation. What is your opinion regarding the advantage of Edi signals as a completely new parameter in ventilation?

I am continuing to learn myself about these advantages, but first in terms of the concept – it is basic physiology and it was easy to monitor the Edi signal and learn about the diaphragmatic electrical activity, a very impressive parameter in the first place. After initial observation, we understood the potential and what to do and the first

thing to look at is synchronization. The second question is muscle strength – is it strong or weak in any particular patient? We need to recognize this behavior with the Edi signal and there is a learning curve. In terms of educating, it is easy to teach how to place the Edi catheter and recognize the Edi signals, the basis is just the ECG and the machine can manage the ideal placement by means of the markers. You need to monitor the amplitude of the ECG signal, and look in terms of your placement, if you need to reposition or not. But it is not difficult; I think it is easy for people to learn very quickly.

All of the physicians and respiratory therapists in Ventilatory Care Unit here at Copa D'Or are completely educated in NAVA and familiar with the protocols for NAVA and Edi monitoring. It has been easy to educate them.

If you would give advice to other intensive care colleagues who are just starting out with NAVA and Edi monitoring, what do you think is important for them to learn about NAVA and the capture and interpretation of Edi signals?

The first thing is know the physiology – that is the most important factor. Synchrony in spontaneous ventilation is the most important factor, and NAVA will help, for sure. The next big question is which categories of patients will be helped the most by NAVA? These categories need to be identified in the next step, and I think we will start to see answers in the next few years. We have two areas right now to work in, spontaneous ventilation and weaning, and monitoring of Edi will help us to synchronize and to understand what is going on with the patient and in some cases to diagnose tachypnea, for example. In terms of weaning and synchronizing, the COPD patients are usually the most challenging, and NAVA is valuable in this group.

Synchronization and variation of volume are important factors to be familiar with and to research in terms of NAVA in ALI patients. We need more studies about NAVA in these patients, and how to manage them and sedation levels in this respect.

This hospital has been one of the first to have implemented NAVA and Edi monitoring in Brazil. With consideration to the rapid advances in development and technology in other sectors that have been taking place in this country, what do you feel about the future of NAVA and Edi monitoring in South America in general, and Brazil specifically?

I think it will be related to the financial circumstances here in Brazil. We are growing rapidly, and developing, but we have a lot of other things to do in the health care system. We do not yet have the full infrastructure in many hospitals in regard to basic elementary care. At my hospital a department dedicated to mechanical ventilation is completely new here in Brazil: a dedicated ventilatory care

unit within the hospital. I think that NAVA and other technologies will grow in Brazil, but we need first to sustain the growing scenario of financial circumstances. I think that will depend on the financial background in terms of insurances and the government – we have two healthcare policies here in Brazil – the private insurance and the governmental sector. They unfortunately are not at the same level. Brazil may become positioned in the world to allow for more technology in future, even producing technology ourselves, but for sure we need to offer the patients the best care. If the best thing for that patient is a certain type of technology, we need to have the access to this by means of the insurance systems and the national health policies.

Non-invasive NAVA is coming; do you see any opportunities with that new development in the future?

Yes, I think that non-invasive ventilation and asynchrony are complex issues that occur in patients like the COPD patients, since leakage is such a problem. When you have an interface, like the helmet, to help manage the leakage aspect, or in the case of NAVA when it is independent of leaks to trigger the ventilator, it is very interesting at many levels. I think this is something for sure I would like to use in future, in COPD patients and other patient categories.

We have discussed your clinical research in mechanical ventilation earlier in this interview. Which other research opportunities do you see with the clinical application of NAVA in the coming years? Are there any particular patient categories that you are interested in gaining experience with NAVA in the future?

In the experimental scenario, we are currently studying comparing NAVA and Pressure Support in acute lung injury. It is the first area of interest. In terms of a clinical scenario, I really would like to use NAVA early in invasive ventilation and compare the time of using NAVA and other modes, it would be interesting to study this in terms of an international multicenter study on mechanical

ventilation of more than 24 hours and compare these patients to using Pressure Support and other conventional modes. I am very satisfied with NAVA in terms of synchronization and functionality

in COPD patients, and I feel very secure with it. But I still don't know which the best patient category is for NAVA, and for this we need patient numbers.

Biography

Dr Felipe Saddy received his medical degree from the University of Rio de Janeiro, Uni-Rio, Faculty of Medicine. He obtained his specialization as Adult Intensivist – from the Brazilian Intensive Medicine Association, AMIB. Dr Saddy became a Fellow of Master Sciences, Internal Medicine, Sector Pneumology, Federal University of Rio de Janeiro, UFRJ. He is also invited researcher

of Pulmonary Investigation Laboratory, Carlos Chagas Filho Biophysics Institute, Federal University of Rio de Janeiro, UFRJ.

Dr Felipe Saddy is currently working as Intensivist of the Intensive Care Unit of Hospital Pro Cardiac and is Head of Ventilatory Care Unit, Hospital Copa D'Or.

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A 600 gram infant patient being ventilated with NIV NAVA

First impressions of NIV NAVA in neonatal patients

The staff members of the Neonatal Intensive Care Unit of Turku University Hospital in Turku, Finland treat over 600 newborns on an annual basis, with a total of over 6,000 care days per year. With the objective of reducing days to extubation by means of earlier extubation, the NICU implemented an active weaning policy in 2001, resulting in a dramatic reduction of days to extubation from median of 31 in 2001 to only 2 in 2007 in extremely low birth weight infants, by means of allowing the babies to regulate their breathing with CPAP.

With this culture of allowing the babies to regulate their own breathing, the implementation of invasive NAVA was introduced in the NICU in the past few months, and most recently, non-invasive NAVA was clinically evaluated in a series of pre-term and very low birth weight infants. Critical Care News spoke with Dr Liisa Lehtonen, Director of the NICU, about her observations and experiences with NIV NAVA.

Can you describe the size of your NICU and PICU department at the hospital, average number of patients on a daily/annual basis and amount of staff?

Our NICU has 18 patient beds in total, and our average capacity is filled to 100% most of the time; in fact much of the time we are overbooked. Our uptake area includes the southwest region of Finland, which means that we have 5,000 deliveries within our region, as well as challenging neonatal cases we receive from neighbouring regions brings the total to 7,000 deliveries per year. In Finland, we are effectively centralized regarding neonatal intensive care; with 5 university hospitals in 5 regions of the country. About 90% of very preterm infants are born in university hospitals; we prefer in-utero transport to postnatal transfer. When the baby is stable we transfer them back to home hospital again. We have 600 babies in our unit on an annual basis, and 6,000 care days. In terms of staffing, we have 4 neonatologists, among the NICU, newborn nursery and follow-up clinic. We have 1 resident and 45 nurses on staff as well.

Which are the most frequent types of patient situations that you encounter?

Most of our babies are full-term infants, who come for suspicion of infection, hypoglycaemia, and some long term cases, such as withdrawal symptoms for maternal drug abuse. We do get cases with congenital defects, but we do not perform open heart surgery at this university hospital, so these cases are usually transferred. We do not provide ECMO in this hospital; since we only have maybe one case per year.

About one-third of our infants are preterm infants. Of all preterm patients, we have about 50-60 very low birth weight infants per year on average, which are below 1500 grams, and below 32 gestational weeks at birth. These very low birth weight infants represent about 10% of the patient number. The length-of-stay statistics in Finland show that these infants generally stay for 2 months in the NICU, but naturally there is a wide variability depending on if it is a



Dr Liisa Lehtonen is Director of the Neonatal Intensive Care Unit of Turku University Hospital

23 week neonate or a 32 week neonate in terms of length-of-stay. Half of our care days are from pre-term infants.

For pre-term infants, care routines change at 28 weeks; below that we give prophylactic surfactant and intubate them, and they will be on a ventilator for a period of time. For babies born at 28 weeks or later, we primarily start with CPAP, and intubate only if needed. This differs in different hospitals in Finland, but those are our guidelines here in Turku. We try to avoid delivery room intubations whenever possible. We start nasal CPAP at delivery when the baby is spontaneously breathing usually at

2 minutes of life. We start CPAP very early to avoid atelectasis of the lungs and we bring the baby to the NICU on early nasal CPAP. If the baby is below 28 weeks, we electively intubate the baby and give the baby surfactant in the NICU within 30 minutes of life, early enough to be prophylactic. We wean the baby off the ventilator as soon as the baby can tolerate it. If the preterm baby is older than 28 weeks, we continue with nasal CPAP in the unit as long as needed, if there are signs of IRDS, we intubate the baby accordingly. Early extubation is always our objective.

We have dramatically reduced the



Mari Kaukonen, NICU nurse and Dr Liisa Lehtonen with their 600 gram patient

time to extubation during the past decade. In babies less than 1 kilogram, we have come down from median 30 days time to extubation in 2001 to median 2 days in 2007. However, in order to support this policy in babies of less than 1 kilo we always extubate these infants early to CPAP.

What is your general background experience in regard to non-invasive ventilation?

Of our total patient material, in all newborn patients that have been ventilated, we have come down in ventilator days per year by 40% since 2001. This is a significant change, come by means of active use of early CPAP and active use of early extubation. This means that not only the ventilator days have decreased, but this means that the babies can go home earlier too.

We try very firmly to reduce the need for mechanical ventilation in our infants, which I think is a universal trend as well. We realise that there are dangers in mechanical ventilation.

In terms of additional therapies, we had 20 patients on HFO last year, we do not use it primarily but we use it as rescue if the baby is not ventilating well enough with relatively high settings in conventional ventilation, then we start HFO. On the other hand we don't use it primarily, but we do see benefits in some cases of rescue situations. In many ways it intensifies the treatment. You have to take more blood gases, and x-rays, which may be disturbing to the baby, and the intensity of treatment increases, which is the cost of HFO.

How many years has non-invasive ventilatory support been used in your department, and for which patient categories?

CPAP has been used here as non-invasive support for longer than 20 years, long before I came here. But the increasing use and advances in technology means that we have intensified our use of it in recent years, and CPAP has succeeded better and become more acceptable for us. In weaning, we wean the baby off of CPAP in steps; the nurses will observe

the baby during a break from CPAP, if that interval goes well; they lengthen the times of intervals. That brings us to when the baby has feeding intervals with CPAP and without CPAP, they increase the number of intervals. Traditionally we have used 4 cm H₂O of pressure to wean, as we have not had a smart way to monitor the exact need of pressure in the past but now with the Edi signal we can get feedback to adjust the pressure. If no intervals from CPAP are given for the baby, there is a higher risk for nasal problems from the nose pieces.

Why are you and your department interested in NAVA, and participating in the evaluation of NIV NAVA?

I was in Dublin at the Our Lady's Children's Hospital to observe and learn about NAVA for the first time about one year ago. I saw two patients that were treated with NAVA, and I was very impressed by those two cases. I knew that this was a new option that was coming, and I had heard about NAVA in some sessions in congresses in recent years as well. All the information

supported the idea to implement invasive NAVA last autumn, and to evaluate NIV NAVA at the present time.

What is your general background experience in regard to invasive NAVA?

We implemented invasive NAVA in the NICU and have been using it since last autumn. We have used Edi signals to monitor central apnea in some cases. On our babies in whom we did use NAVA we used Edi monitoring as a factor to help determine when to extubate, and we monitored Edi signals for a time after extubation in these patients. It was helpful to observe the babies' respiratory drive with Edi monitoring, as it helped to titrate medication for surgical patients. We have patients that undergo surgery for gastroschisis or for diaphragmatic hernias, and in the post-operative phase we titrate the medication so that the baby gets enough painkilling, but not too much to suppress breathing. We have had very good recoveries of some of these babies from surgeries, and we can see where we could reduce the analgesic medication when the babies were on NAVA as they were comfortable on NAVA ventilation. The analgesics we use for post-operative pain are opioids and acetaminophen. We use Midazolam as sedation as needed but we try to avoid it due to side effects. NAVA and Edi monitoring gave us the possibility to monitor the sedation levels and spontaneous breathing post-operatively in these surgical infants.

Was NAVA easy or difficult to implement in your department?

It was surprisingly easy; it was one of these things where you immediately see the benefits, which makes it easier to accept as new method or tool. Nurses and parents see the babies sleeping more comfortably and for all of us seeing how some of our babies need less medication makes us feel that this is the right thing to do. The nurses all understand the concept and application of NAVA. We also have many physicians on call who have learned quickly the NAVA concept, and NAVA has succeeded very well also during on-call hours.



SERVO-i delivering NIV NAVA to neonatal patient

Naturally, irrespective of NAVA, we always get some cases where the baby is not breathing, such as cases where the baby may have received a higher dose of medication or due to disease. NAVA switches to back-up settings in these, and if this situation is prolonged, it is a clinical indication that the baby is not ready for spontaneous breathing just yet.

The NAVA philosophy makes perfect sense – let the baby regulate their ventilation just as they do in CPAP. We were already accustomed to treating very small babies who regulate their breathing with CPAP very early in our unit; relating historically back to our goal to reduce extubation days in 2001 with the active weaning policy we introduced at that time. We documented significant decreases from 31 days in 2001 to 2 days in 2007, with 50% decrease in the first year of the policy. The long process of teaching staff members to believe in the baby's own capacity to breathe started back in 2001. It is a cultural shift, and it takes a few years to change a treatment culture.

Can you tell about your current observations or experiences with NIV NAVA in neonates?

We started using non-invasive NAVA in mid-January, and we have experienced it on 7 patients during the course of the evaluation. One infant who had non-invasive NAVA was in the incubator, and the next day in kangaroo care. NIV NAVA worked well in both situations, as well as in a pre-term twin with respiratory difficulty and a very small 600 gram preterm baby that we are currently treating with NIV NAVA.

The small 600 gram preterm baby is an interesting case. We did not think this infant initially would be easy to treat – she is so very small and any nosepiece felt quite large for her. We thought we could not use NIV NAVA for very long, there was also a problem with the humidifier, but we tried another nosepiece and adjusted the humidifier, and she settled in nicely. After that everything worked

beautifully. We have had a very high leak with this 600 gram patient on NIV NAVA, with leakage close to 90%. The baby is ventilating well without any difficulties despite the high leakage.

The preterm twin that was born was at

34 weeks gestation and weighed 2.3 kilograms. She had enough breathing problems to get CPAP at birth at 5 o'clock in the morning. We switched her to NIV NAVA around 10:00 that morning. The PCO_2 level was a little high due to her initial lung problem, but the baby was

started on NIV NAVA at a level of 0.2 cm $\text{H}_2\text{O}/\mu\text{v}$, where she stayed comfortably for the rest of the day. There was also a response seen in the Edi signal level which was reduced on NIV NAVA compared to Pressure Support-CPAP, and it stayed down, so we knew that the treatment with NIV NAVA made a difference. We continued until about 5:00 in the evening, when we switched her back to regular CPAP and we continued to monitor her Edi signal to determine the level of conventional CPAP she should receive. The Edi signal stayed low using CPAP level of 4 cm H_2O , and at 8 in the evening the CPAP was discontinued. The Edi signal was monitored for the rest of the night and stayed at a low level so we knew she was doing well without any support.

Which types of patient interfaces are you using with NIV NAVA on your infant patients?

We are evaluating the Medin interfaces in the process of the NIV NAVA evaluation. They seem to work and are comparable to what we were using traditionally, which are the interfaces by Fischer Paykell. Certainly you need to find the right size and make adjustments for the products from each of these manufacturers.

What are the advantages of being able to provide therapies such as conventional non-invasive ventilation, NAVA and NIV NAVA with the same ventilator?

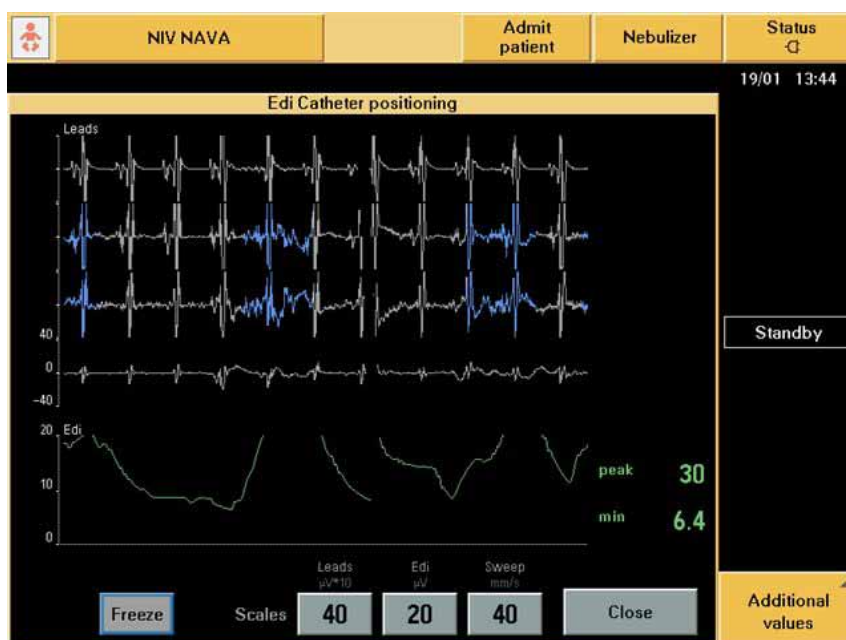
I see a clear benefit, in our cases where we follow our system of one or two days in invasive ventilator care, when giving invasive NAVA. The Edi catheter is already in place and it is easy to switch to non-invasive NAVA after extubation, and to continue Edi monitoring on non-invasive NAVA and thereafter until the nasogastric tube is removed.

Is the Edi catheter placed in the nose as well as the prongs for non-invasive NAVA?

We are used to placing nasogastric



Premature 600 gr NIV NAVA patient



Edi catheter positioning in premature 600 gr infant prior to treatment with NIV NAVA



Dr Lehtonen with neonatologist colleagues Vilhelmiina Parikka, resident and Samuli Rautava

tubes for feeding in the other nostril during CPAP treatment, and it has always worked well for us. We never use oral intubations or oral tubing; we believe that this disturbs the sensory input and process of the child to enjoy feeding.

We did use one of the new Medin nosepieces for NIV NAVA with a curve to allow for a bottle to be used. One baby was bottle-feeding without any problem while on NIV NAVA.

Have you observed if the Edi catheter signals are stable in NIV NAVA?

We have had 2 babies on NIV NAVA on kangaroo care, and the fathers are patting the babies and keeping them close without any problems with signal disturbance at all.

Which NAVA levels have been used in the NIV NAVA evaluation?

We went up to a level of 0.2 cm H₂O/μv but we really did not have any patients with bad lungs, so we have not had a chance to test higher levels. We had 0.5 cm H₂O/μv in one patient, but he had a tendency for burping, even without NIV NAVA. We were worried that 0.5 cm H₂O/μv would be pushing too much air in his stomach and would

disturb his feeding, and therefore we reduced the level from there. The babies we have had so far seem to be doing fine on a NIV NAVA level of 0.2 cm H₂O/μv.

In summary, what are your initial impressions about NIV NAVA from this evaluation?

I think that this proof of ventilation with NIV NAVA is apparent to me, even after only a few patient experiences. I think we can also say that we have had two cases where kangaroo care seems to be completely compatible with NIV NAVA, without any disturbance to the Edi catheter or Edi signals. We have had a few minor technical problems during this evaluation, but on the other hand we have had good education and training. Our strategy continues to focus on gentle, as non-invasive treatment as possible, and invasive NAVA and NIV NAVA work well within this strategy.

We have always used CPAP as a standard of care, and I have not been interested in other means of non-invasive ventilation without synchronization, which has made no sense to me in the past. However I can say that non-invasive NAVA is completely synchronized to the patient in a reliable manner. How much this aspect helps the baby remains to be seen. ■



Dr Liisa Lehtonen shows statistics of the reduction of days to extubation from 2001 to 2008

Biography

Dr Liisa Lehtonen received her initial medical degree at Oulu University in Finland in 1986. She joined the Turku University Hospital as board certified pediatrician in 1993, and received her PhD from the same institution in 1994. She obtained her board certification as neonatologist in 1996, and received her ECFMG certificate in the United States in 1997.

Dr Lehtonen was Research Fellow at the McGill University-Montreal Children's Hospital Research Institute from 1996-1997, and was Fellow in Neonatology at Rainbow Babies and Childrens Hospital, Case Western Reserve University in Cleveland, Ohio from 1997-2000.

Liisa Lehtonen was named Docent in Neonatology at Turku University in 2002. She is member of several Nordic Societies in Pediatrics and Neonatology. Dr Lehtonen has supervised a number of PhD students as well as acted as reviewer of PhD theses. She has published numerous clinical studies on pre-term and very low birth weight infants in a wide number of peer-reviewed journals.

Dr Liisa Lehtonen has worked as the Director of the Neonatal Intensive Care Unit of Turku University Hospital since 2000, a position she currently holds.



Dr Peter Nordlund with COPD patient after treatment with non-invasive NAVA. The Edi catheter remained for Edi monitoring

First impressions of NIV NAVA in a general ICU environment

The Ryhov Regional Hospital in Jönköping, Sweden has an uptake area of about 150,000 inhabitants. The seven bed intensive care unit, which is directed by Dr Peter Nordlund, treats a wide variety of surgical, medical, sepsis and pediatric patients.

About 65% of the patients in the ICU are treated with mechanical ventilation. In the past year, Peter Nordlund and ICU colleagues have been gaining experience with invasive NAVA in over 80 patients, or about 30% of the annual total of mechanically ventilated patients. This extensive recent experience with invasive NAVA and several decades of experience with conventional non-invasive ventilation placed the Ryhov Hospital ICU department in a position to evaluate NIV NAVA: a totally new solution for delivery of non-invasive ventilation, providing synchrony independent of leakage or patient interface. Critical Care News spoke with Dr Peter Nordlund to hear about the recent experiences with this new solution in non-invasive ventilation.



Dr Peter Nordlund is Head of the ICU at Ryhov Hospital in Jönköping, Sweden

Can you give a general description of your ICU; average number and types of patients and number of staff members?

Our province has 300,000 inhabitants, and the uptake area is about 150,000 inhabitants. We have a few patients from other parts of the country that come for specific neuro-orthopedic procedures, so neuro-orthopedic trauma patients may therefore be treated in the ICU. This hospital has about 500 beds, of which 7 beds in the general intensive care unit. There is also a dedicated NICU, but all children and infants from the age of one month and up are treated here in the general ICU, where our main patient mix is comprised of infection, medical and surgical intensive care patients, as well as for pediatric intensive care. We average about 80% of capacity in the ICU, and 65% of our patients undergo mechanical ventilation, of which 25% receive non-invasive ventilation during some part of their treatment process. The trend for treating with non-invasive ventilation has been increasing, and we have been using it increasingly in post-extubation as well. We have two senior intensivists that are accredited with European Diploma of

Intensive Care, as well as two intensive care physician specialists, and we have residents with different competencies. In terms of nursing, we have 60% with ICU specialist level training and our nursing coverage is 1.24 per patient bed 24 hours a day. We have a good level of nursing competency and nursing capacity here, with opportunities for continued development in nursing.

Which are the most frequent types of patient situations that you encounter?

Our mix of patients has varied throughout the years, but in recent years the mix has been 30% surgery, 30% medical and 30% sepsis with 10% pediatric patients. We see all sorts of patients. The most common type of sepsis patients may be peritonitis-related sepsis, pneumonia-related sepsis or renal-related sepsis. Respiratory insufficiency and COPD patients are another common group we treat; the respiratory insufficiency cases we see may be related to many factors: pneumonias, sepsis, and neuromuscular disease. We also treat a great deal of coronary failure, or other coronary related conditions

as well as gastrointestinal patients, patients with secondary bleedings, pancreatitis, and epilepsy and so on.

Please describe how and when you started utilizing conventional non-invasive ventilation therapy?

Depending if you include CPAP in the non-invasive therapies, we started using CPAP in the 1980s. After that we started using other non-invasive ventilation including a SERVO 900C with a mask in 1996 – it was not designed for that purpose but it worked with some limitations. Then we had the SERVO-i with non-invasive modes which became easier and more dedicated for use.

Which patient interfaces do you frequently use for non-invasive therapy, nasal prongs, face masks or helmets?

We use a combination of nasal masks, facial masks and helmets. There are some patients that like the helmets, and they have worked extremely well in these cases, but there are also other patients that feel constricted or uncomfortable or anatomically might present difficulties with the helmet, so we use the helmet more seldom. We use a full facial mask most frequently, but the patient interface may vary from patient to patient in connection with non-invasive ventilation.

How do you make a determination when non-invasive ventilation is indicated?

We follow a protocol where we have certain indications for non-invasive ventilation. Back in the beginning of the 1990s, we were doing non-invasive on almost every patient for a while, but we discovered in time that this was contra-productive in many ways. This led to a protocol where we consider non-invasive ventilation in patients with respiratory insufficiency and NIV is also used primarily for COPD patients that are not too acidic; we use non-invasive ventilation on these patients and measure certain parameters to see how they respond to treatment. If they respond positively we continue NIV, if



Dr Peter Nordlund with intensive care nurses Karin Johansson and Mikael Jardenius

the situation worsens we prepare for intubation and invasive ventilation. Heart failure patients are treated according to the same procedure, and post-extubated patients after major surgeries that have risk factors are also treated with non-invasive ventilation according to this procedure. Currently, there are a number of patients that we defined for indication of NIV, and this protocol has been in use since the beginning of 2000.

How do you wean from non-invasive ventilation?

We do not follow any set protocol; we have a physician led process in initiating weaning in these patients. We follow conventional weaning standards, so when the patient has obtained certain pressure levels and PEEP conditions, we look at oxygenation of 35-50%, and if they fulfil these criteria and if the patients are awake and capable of following the instructions and collaborating in the weaning process. If they can spontaneously breathe for 20-30 minutes with an unchanged status, we stop non-invasive ventilation. The nurses help us to monitor the patients, especially those who are intubated and sedated, to look for signs to help weaning.

When did you implement NAVA in the ICU?

We began in October 2008 with education and training, and started to use invasive NAVA in late autumn 2008 about 1 year ago. We have now used invasive NAVA in over 80 patient cases. If 65% or 300 patients are mechanically ventilated in our unit, this means that 80 patients with NAVA is a high proportion of the total. To get experience with NAVA and become familiar with it, we chose a strategy to use it in a wide number of patients during the past year. We monitored their ventilation when they were switched to NAVA, and we also monitored the Edi signal, and how it presented itself in patients over time. It was an interesting and educational period, and we studied asynchrony in all patients, who were all asynchronous according to the Edi signal no matter which type of conventional mode they were receiving, which for the most part was Pressure Support, before being switched over to NAVA. There were no patients that had asynchrony during that period with NAVA. These 80 patients with invasive NAVA corresponded generally to the patient mix we have here in the ICU: 30% surgical, 30% medical, 30% sepsis and 10% pediatric cases.

Was NAVA easy or difficult to implement in your department?

To teach NAVA and gain understanding was not difficult, but it was a process to adapt to tidal volume variations with NAVA. We are used to a continual value of 6ml/kg bodyweight in conventional mechanical ventilation in all patients, and this will be variable with NAVA, depending on the individual patient and their variability of breaths. This could be stressful to some of the staff members originally, and we went over to traditional Pressure Support in the beginning. In teaching the concept of NAVA and practical application with placing the Edi catheter, etc, there were no difficulties. It is a learning process to understand the Edi signal. NAVA level has been used in different ways, there was a default level to begin with of 2.0 cm H₂O/μv, which we felt was a little high, and we started at lower NAVA levels and increase if necessary by means of the NAVA preview screen. We use the tool to coordinate values with PS and set the NAVA level accordingly.

Have you had any specific patient experiences with NAVA that you would like to share?

In addition to the cases described by my colleague Dr Armela Khorassani at the NAVA Summit meeting last year (Editors note: CCN 19), we were monitoring the Edi signal in a middle aged man with a neuromuscular disease, seeing that he could be switched to NAVA and it worked very well. He was sedated with Propofol and as we woke him, he was a bit stressed in transferring over to oral sedation, but did not trigger strongly, and suddenly the entire signal disappeared, and we had to go over to Pressure Support with flow trigger which worked fine. The Edi signal reappeared after about 8 hours, he was awake but he got a low dose of oral lorazepam again, but his Edi signal disappeared again. It was totally substance-related, and his respiratory muscles under sedation were not strong enough to trigger an Edi signal. We did not see this effect with opioids or Propofol; it was only oral lorazepam. We diagnosed perhaps the reason why he ended up with us in the ICU: he had received Stesolid® with



Dr Peter Nordlund

subsequent secretions which induced breathing difficulties and pneumonia. This means that his primary physicians could be warned against prescribing this substance to him – information would not have been available for diagnosis without the help of his Edi signals.

What is your general opinion of NAVA?

I am positive – there are benefits to NAVA and Edi monitoring. Some of my colleagues have differing opinions and want more evidence and hard facts and multicenter studies compared to

conventional mechanical ventilation. I think it is very individual when it comes to which patients that have more benefit. I hope that we can change our sedation regimes; sedation is needed but is not always optimal, and in fact can cause troubles. Some sedation substances may lead to a hemodynamic instability. NAVA can contribute to synchrony that means that we may minimize sedation or hemodynamic instability – I see advantages here. Some of the most severely ill patients may benefit from implementing NAVA early, by using their diaphragmatic muscles for regulating their own ventilation and minimizing atrophy.

It is a generational challenge to change a treatment culture – we see the changes from volume to pressure, and volume is still more commonly used in some places in the United States for example. To go from Pressure Support and other supported modes to signals that are generated by the patient himself is a generational cultural shift – a process that will take time.

Why are you and your department interested in participating in the evaluation of NIV NAVA?

It was easy since we have so much experience with conventional NIV, and in the past year with invasive NAVA in so many patients, it seems a natural step to utilize NIV NAVA in patients who would receive NIV ventilation. The problem with these patients is that they always have respiratory distress in some way with non-invasive ventilation, due to asynchrony, which Brochard has outlined in his study. Leakage is always a problem. We want to see non-invasive NAVA in these patients, for better synchronization, and to minimize the difficulties that leakage presents in conventional non-invasive ventilation. It was not so hard to see the advantages of evaluating this opportunity.

What are your first impressions of treating patients with NIV NAVA so far?

We have run a limited amount of patients so far, including respiratory insufficiency with COPD, post-op after peritoneal sepsis and intoxication cases.

It has been very simple – we had leakages of up to 80% in patients due to patient interfaces, but it did not affect the patient ventilation in any way at all and there were no alarms. I have never seen a patient with such an extensive leakage, where the non-invasive ventilation was no problem at all. We used the new interfaces and they seem to work just fine. It was what you could expect with NIV NAVA, good patient ventilation values even in the presence of a large leakage – but it was still surprising to

see the first time that NIV NAVA works as it is intended to. None of the patients have had any discomfort in relation to their Edi catheter, we started directly with non-invasive in Pressure Support and went over to NIV NAVA, and there does not seem to be any problem. We

ran NIV NAVA continually, with shorter pauses to moisten the lips and mouth and brush teeth. Most of the patients have been able to leave non-invasive NAVA within a few hours of ventilation, faster than with conventional non-invasive ventilation. The COPD patient

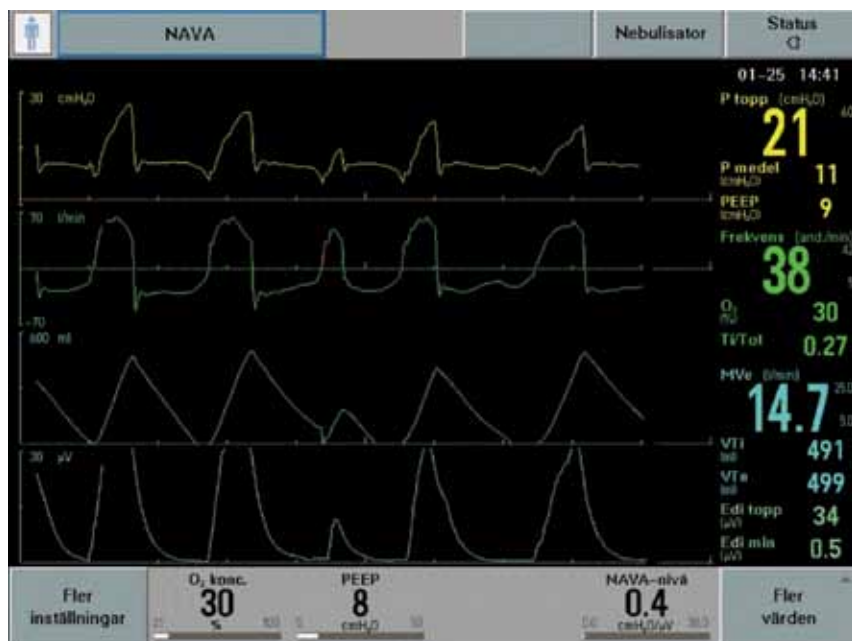
improved quickly too and could leave NIV NAVA after 6 hours. It is too early to say if this result will be maintained in larger groups of patients, but for the few patients where we have tested NIV NAVA so far, it has been simple – just like regular invasive NAVA, NIV NAVA gives the patients what they want and need. We have seen lower Edi levels in NIV NAVA than we have in invasive NAVA. It has looked very comfortable in each patient. The COPD patient was very affected when he presented to the ICU, he was a borderline case for invasive or non-invasive therapy, very acidic, high PCO_2 , but he had a strong Edi signal so we started NIV NAVA. He quickly showed signs of improvement, within one hour his ventilation status had improved significantly.

Is the Edi catheter stable in placement in NIV NAVA?

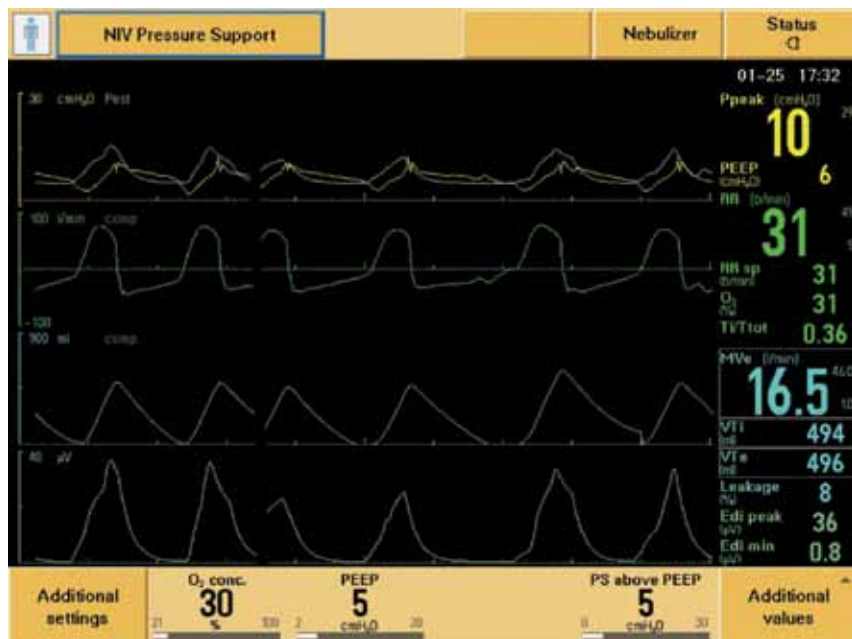
Yes, we have been using the 8 French Edi catheters and we have been able to place this without any difficulties and they have remained stable. NAVA levels in NIV NAVA have been around 0.3 or 0.4 $\text{cm H}_2\text{O}/\mu\text{V}$; we thought it would be higher. We started from 0 when we initiated therapy but then we have observed the Edi signal as the NAVA level was increased and obtained good ventilation in range of 0.3-0.4 $\text{cm H}_2\text{O}/\mu\text{V}$, and reduced if needed but no problem thereafter. We have had no problems with air in stomach using NIV NAVA. Air in stomach can always be problematic in non-invasive ventilation; it could be due to that in conventional non-invasive ventilation asynchrony is present.

Is there any patient category where you are especially curious in evaluating non-invasive NAVA?

Yes, I am definitely curious about testing NIV NAVA in pediatric patients. We have used conventional non-invasive ventilation in pediatric patients, but some of them can be difficult to treat, depending on their age and so on. I am interested in using non-invasive NAVA rather than conventional non-invasive ventilation in pediatric patients, or in children that have been sicker and on invasive ventilation, such as septic children. With invasive NAVA



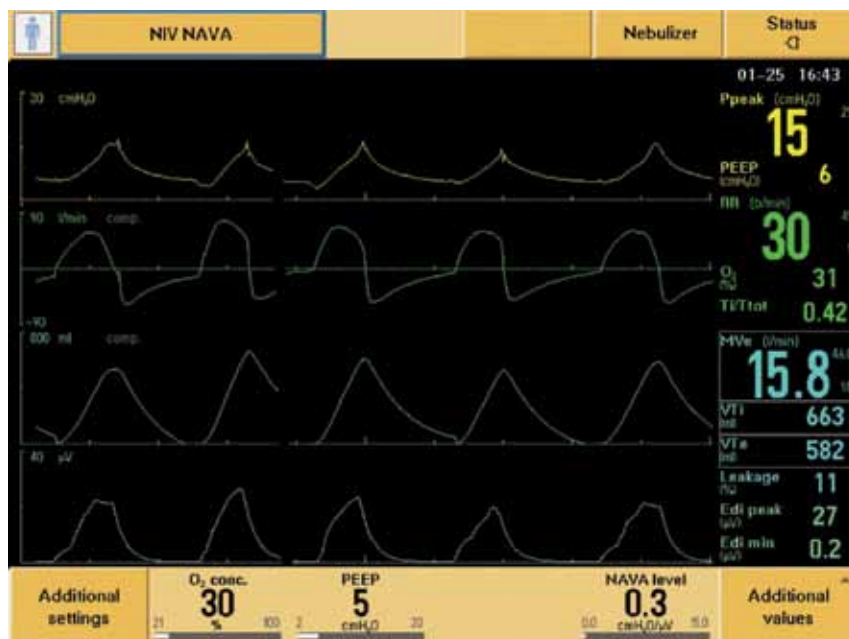
In NAVA invasive mode, prior to extubation and treatment with NIV NAVA. The patient has a variability of small and large breaths



Patient was extubated and switched directly to NIV Pressure Support with NAVA Preview activated. The gray curve shows the diaphragm activity overlapping the pressure given

we have found that we could extubate these types of children 24 hours earlier than with conventional ventilation, and reduce sedation. It would be good to see NIV NAVA on these small children, who are problematic to communicate with and may have large leaks with ordinary non-invasive ventilation. I would like to continue to

use it on COPD patients, who are acidic to begin with. With non-invasive NAVA, they can steer their ventilation in a totally different manner and get a longer expiration time as they may want to have, without influencing their ventilation values, to provide better synchrony and minimize the side effects of leakage. ■



NIV NAVA. The patient was comfortable in NIV NAVA and the breathing looks natural and synchronized



Peak trends in NIV NAVA, identifying that the patient wanted to have different levels of support

Biography

Dr Peter Nordlund received his initial medical degree in 1988 at the University of Lund, Sweden.

During the years of 1988 - 1997 he worked at the University Hospital of Lund, Malmö and Kristianstad in southern Sweden. He obtained his specialist degree in anesthesia and intensive care in 1994.

Dr Peter Nordlund became Chief of the Intensive Care Unit at Ryhov Hospital in Jönköping in 1997, and currently holds this position. He has been active in research and collaboration in the publication of various outcome studies in intensive care.

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Dr Robert H. Pinsker in his office at El Camino Hospital, Palo Alto

Obese and morbidly-obese patients — addressing the challenges of perioperative ventilation

Since the last issue in which a Spanish anesthesiologist was interviewed, Critical Care News has been focusing on certain high-risk patient groups and decided to meet with three clinicians specialized in anesthesia for the obese and morbidly obese patient, to hear what they had to say about the challenges they face in terms of peri-operative ventilation for this patient group.

Critical Care News first met with Dr Jan Paul J. Mulier, MD, PhD during a congress in Austria. Dr Mulier is Founder of the ESPCOP (European Society for peri-operative care of the obese patient) and works at Sint Jan Hospital in Brugge, Belgium.

It was also interesting to travel to the United States and to meet with two anesthesiologists specialized in Bariatrics to hear what they had to say. Dr Jeremy Collins, Chief Assistant Professor of Anesthesia at Stanford University Hospital and Dr Robert H. Pinsker, Medical Director of Anesthesiology at El Camino Hospital, both in Silicon Valley's Palo Alto in California, related their experiences in this field.

Dr Robert H Pinsker, MD, JD

Are you seeing more obese patients presenting for surgery? How does this affect their care as a patient group?

Dr Robert H Pinsker: At our hospital, we are definitely seeing an increased number of morbidly-obese patients, partly because we are an accredited bariatric centre of excellence. Bariatric patients are thus directed here for quality as well as insurance reasons. However, the generic literature, but not necessarily the medical, suggests that obesity may not be growing among adults, and yet we seem to be seeing an increased number of obese patients in our practice; it definitely appears to be on the increase in children. These patterns entail difficult airway management and ventilatory issues. An extensive number of spinal patients, for example, are often obese and as many as half will require surgery in the prone position, which can lead to very complex ventilation issues. But it's not just this area that is problematic. Obese patients can be found scattered throughout all specialties, not only in bariatric surgery.

How different are these patients and how do these differences affect the anesthetic process?

Obese and morbidly-obese patients can be anatomically and physiologically challenging. Studies suggest they have a closing capacity that is significantly different, for example. They also have atelectasis when awake and standing, which, of course, is aggravated by the anesthetic process.

With general anesthesia, the first major concern is securing the airway either before or after the patient is induced. When an obese patient is under MAC (Monitored Anesthetic Care), i.e. sedation, their higher incidence of Obstructive Sleep Apnea (OSA) presents an issue of less airway control, despite the fact that one is avoiding

general anesthesia. Nevertheless, it's general anesthesia that gives the most cause for concern; absent awake intubation, one must make certain that there can be successful induction followed by successful mask ventilation and, ultimately, intubation.

What are your challenges with intubating these obese patients?

When one suspects a patient might be difficult to intubate once induced, one must also ask whether that patient might also be difficult to mask ventilate. Avoiding the so-called "cannot mask, cannot intubate" situation is critical, but, fortunately, these are fairly small in number.

What considerations would you normally implement to optimize ventilation during the maintenance phase?

The anatomical and physiological profile of an obese patient means that one wants to try to maintain the patient in a modified upright position. Unfortunately, this is not possible in most of the cases we see today, including bariatric surgery. In fact, one is expected to be able to place the patient in a fairly steep Trendelenburg, or head down, position. What's more, many procedures are done laparoscopically, during which the increased intra-abdominal pressure compromises the functional residual capacity of the lungs. However, one can usually accommodate for this. In most patients without additional underlying lung disease, positive pressure ventilation, usually including end expiratory pressure, often solves the problem.

Can you give a specific example that illustrates the ventilatory challenges you face for these patients?

As a cardiothoracic anesthesia specialist, I can say that an obese

patient necessitating a pulmonary lobectomy would pose special challenges because we have to be able to provide one-lung ventilation.

One would typically start by obtaining baseline pulmonary function testing. However, this is not always reliable because it doesn't fully anticipate ventilation perfusion mis-match once a lung is collapsed. In addition, once an obese patient is in the lateral position, even before a lung is collapsed, his or her physiology can change dramatically, and this can lead to having, at times, to abort the procedure. Obviously, that is something nobody prefers to see occur. These are all challenges that we need to handle and we have a number of options available. We can apply different degrees of pressure to one or both of the lower and the upper lungs, for example, although with the collapse of the operative lung, we generally prefer not to see peak pressures higher than 10 cm of water. Some, however, can tolerate more than that.

Adjusting the gas flow rates or altering the inspiratory ratios are additional alternatives. Note, however, that applying end expiratory pressure often makes things worse, not better. We've also tried different maneuvers with bronchial blockers (instead of a so-called double-lumen tube), including application of pressure via the blocker. Each patient can present very much a "work in progress", so to speak. Each patient responds differently, so there's no standard formula that works every time. That's a challenge in itself.

Many obese patients suffer from atelectasis even when upright and awake. Do you systematically perform recruitment maneuvers in these patients using a standardized protocol?

That's an interesting question. The whole concept of employing recruitment maneuvers is fairly new to



El Camino Hospital, "The Hospital of Silicon Valley"

anesthesiologists, at least in the United States. But I feel that many of us have been doing these maneuvers for years without really knowing what to call them and assigning them a specific name.

Please tell us about your recruitment protocols. What difficulties, if any, do you experience?

In the case of a patient who is not undergoing pulmonary surgery, there is "no surgeon in the chest," so to speak, and one has the option of intermittently taking the patient off the ventilator in order to manually attempt one or more recruitment maneuvers. One such method involves maintaining high pressure for 5 to 10 seconds, while keeping a close eye on the hemodynamics, which in obese patients can be negatively impacted very rapidly.

Where thoracic surgery is underway, one must communicate with the surgeon at all times in order to make certain that whatever maneuver is attempted, it does not impact the surgery negatively. In a severely ill patient experiencing difficulties with oxygenation or otherwise poorly tolerating one-lung ventilation, one may need to request that the surgeon stop at least momentarily in order to permit reinflation of a collapsed lung.

What can lead to post-operative ventilatory complications in the recovery room and how can the risks be diminished?

Total airway obstruction is the main risk. One wants to avoid transporting morbidly obese patients to the recovery room who are still moderately sedated and/or asleep. It is occasionally

necessary nevertheless, however, and extubating anesthetized patients is what we call deep extubation. In these cases, it is particularly important that the patients be assisted with oral airway devices that stent or maintain open their upper airways.

Additional, more specific problems encountered with obese, neurosurgical patients include high intra-cranial pressures, so one may not want increases in blood pressures of these patients. Nor does one want such a patient to be coughing or bucking on the intra-tracheal tube as they emerge from anesthesia.

While one can't guarantee a smooth emergence from anesthesia in obese patients, one way to help affect it is with opiate administration. Titrating in doses of a short-acting opiate can get



The Golden Gate in San Francisco, CA

the patient to the point where all the other anesthetics can be discontinued, including the gas anesthetics. If there's no other medication on board, one can actually wake most patients up with the endotracheal tube in place and absent coughing or bucking.

The problem is that, because opiates remain in a patient's system, obese patients who have received these drugs and transferred to the ICU or ward can become re-sedated, or what we label re-narcotized. Moreover, a lot of these patients are not prone to voluntarily breathing deeply. In other words, sedation makes it difficult to "recruit" or re-open collapsed alveoli. Therefore, increased atelectasis in addition to an already low functional residual capacity can become disastrous.

One must encourage patients to perform their own recruitment maneuvers, in other words, to work every hour or so against a certain positive pressure. There's nothing fancy about this technique; patients can do it on their own, without a machine – one such maneuver involves simply taking a big breath and holding it.

What mode of ventilation do you find most effective for obese patients?

The Pressure Support mode. We use this for non-intubated patients who have an LMA in place, but also for the intubated and obese who are undergoing short procedures. We're able to keep them spontaneously breathing so they'll be easier to wake up without having to administer muscle relaxation. Without Pressure Support, you often can't maintain proper oxygenation.

We're convinced that Pressure Support needs to be almost universally used in such cases. We have it at the hospital and would also like it at our out-patients surgery center, to where most of these patients come.

What do you view as the limitations of existing studies addressing perioperative ventilator challenges for the obese and morbidly-obese? Are enough patients being included?

Here I have to give you a somewhat empirical answer. I focus on reading anesthesia literature, which, in the U.S.,

largely consists of two main journals. We also reference current textbooks and exchange the occasional letter on the subject, but we don't read a great deal of international literature. I'm not an expert on judging the validity of studies either.

Having said this, I don't think there's a scarceness of literature addressing perioperative ventilatory issues in obese patients. On the contrary, I think everybody in the States acknowledges that these are important issues, particularly regarding the need to address the relevant problem of OSA. ■

Biography

Dr Robert H Pinsker, MD, JD, Robert Pinsker, MD, JD is a double board certified physician as well as attorney who currently specializes in anesthesiology and anesthesiology program management.

In addition to being trained in and having practiced for many years the sub-specialty of cardiothoracic anesthesiology and critical care medicine, from 1995 to early 2004 Dr Pinsker practiced intellectual property law with the Palo Alto-San Francisco law firm of Flehr, Hohbach, Test, Albritton & Herbert, LLP. In this capacity, he secured intellectual property portfolios for a number of medical device start up companies and served on numerous Scientific Advisory Boards.

Subsequently, Dr Pinsker became a consultant in medico-legal administrative and medical program management. Presently, Dr Pinsker serves as the Medical Director of Anesthesiology at El Camino Hospital and Kindred Hospital, S.F. Bay Area, in Hayward, as well as the Medical Director of the El Camino Surgery Center.

Dr Pinsker is the founder of multiple companies, including Fidere Anesthesia Consultants, Inc., Pacific Physicians Medical, Inc., Doctors Billing Service, Inc. and Fidere Capital Investments, LLP.

Dr Collins, Stanford University Hospital



Dr Jeremy Collins in his office at Stanford University Hospital, Department of Anesthesiology

Please give us your views on obesity demographics. What changes have you seen over the last 15 years?

Dr Collins: I have worked in Europe and the US and I can say that the situation is the same in both. The idea that obese and morbidly obese patients are only found in America is just not true.

However, I believe that the US is more likely to see the emergence of a small, super morbidly-obese population. We are now also seeing more numerous younger patients presenting with obesity, as well as more adolescents needing bariatric surgery. Interestingly, the concerns that bariatric surgery in the young leads to malabsorption issues that affect their subsequent development appear to not be the case. The fact that this intervention may help prevent diabetes and irreversible cardiac defects in patients at risk means that it is now

viewed as being worthwhile. In terms of a national health issue, the long-term health savings can be significant. Another interesting fact is the preponderance of female patients presenting early, perhaps due to aesthetic reasons. Males tend to present at an older age with problems related to the co-morbidities associated with their obesity.

What about the different measurement tools used in diagnosing obesity? Which one, other than BMI, is used and do they help the practitioner in assessing the patient's ventilatory parameters?

I think that a lot of the co-morbidity associated with obesity is related to truncal obesity. As hip/waist ratio is a better reflection of truncal obesity, I think we will find that it offers a closer correlation to poor ventilation and sleep apnoea than BMI, for example.

I've seen some correlations where ventilatory parameters improved as patient hip/ratios went down.

We also know that women have a higher BMI partly due to the fact that they've got larger lower bodies. For an anesthesiologist, weight centered around the lower half of the body is not really a major concern.

Do you find that the obese patient in anesthesia is a good model for other high-risk groups?

Yes, that's certainly the case. Firstly, the know-how with the obese helps in dealing with "normal" patients as well. If you are confident in managing obese or morbidly-obese patients with exaggerated pathophysiologies, you will find it much easier to deal with lean patients.

Secondly, when you encounter a high-risk patient in another speciality, you won't have to re-think everything in terms of managing their airway, the equipment, the ventilator, the operating table, etc. You will be used to a more complex situation and the high performance equipment that will help you handle it.

But it seems like even those of us who are not dealing with obese patients on a regular basis will soon have to do so. I believe that a study made in Pennsylvania in 2007 suggested that 1 in 12 patients had a BMI of over 40. And in a cohort of 20,000 patients, something like 365 had a BMI of over 50, that is one per day in the operating room having non-bariatric surgery.

What measures would you consider implementing to optimize ventilation, bearing in mind the anatomical and physiological profile of obese patients?

Their reduced functional residual capacity means that their tendency to desaturate is much greater than in the "normal" patient. Mass loading of the chest and abdomen can be partially offset by positioning in a more upright manner. Early control of ventilation with adequate paralysis prevents the poor tidal ventilation and subsequent desaturation that occurs with bucking on the endotracheal tube. This can be associated with extremely high airway pressures and is not well tolerated by these patients.

In the super morbidly-obese patient (BMI 50-70), many of these problems are exacerbated. Moreover, most bariatric cases are done laparoscopically and the increased intra-abdominal pressure compounds those difficulties that I just mentioned.

However, we sometimes have a mechanical advantage in the fact that a lot of the surgery is done in the reverse Trendelenburg position. This off-loads some of that muscle and fat from the abdominal wall and makes ventilation a little easier. But in many gynecological procedures, the opposite applies because of the need to place the patient head down. If you have a morbidly-obese patient having surgery

in the Trendelenburg position, it may be impossible to ventilate them effectively. We may have to tell the surgeon "The patient won't tolerate this degree of tilt. We maybe have to think about doing an open procedure." This is far from ideal, however, as it is going to mean that the patient's post-operative course is going to be that much more difficult.

What cases do you consider to be most challenging when caring for the obese?

The non-elective, trauma situation. From an anesthesia point of view, this is a big contrast to bariatric surgical procedures, where we have the situation under quite good control. An obese to morbidly-obese person involved in a car accident is definitely more challenging in terms of airway management, respiratory function and vascular access. With a trauma patient having suffered fractured ribs and perforation of the lungs, leading to pneumo and hemothorax, for example, their airway pressure is likely to be significantly higher than in the elective situation. It may then be that you have to generate quite high pressures in order to expand the lungs effectively and maintain them open.

What challenges arise when patients are put to sleep and given muscle relaxation?

Lean patients get some degree of atelectasis, particularly when you give them 100% oxygen, but this is often even more dramatic in the morbidly obese, where up to 20% atelectasis is more common. Although the 100% oxygen used to pre-oxygenate will contribute to atelectasis, the priority in morbidly-obese patients is to maximize the efficacy of pre-oxygenation - this will lengthen the period of time following anesthetic induction before hypoxia develops. The literature suggests two simple approaches.

One is to use some degree of head elevation, for example reverse Trendelenburg or beach chair position. The other is to use CPAP in the pre-oxygenation phase. Pre-oxygenation with 100% oxygen in the head-up position

combined with a period of CPAP has been proposed as a means of prolonging the time to desaturation even more.

What ventilating mode would you use in order to minimize eventual post-operative ventilatory complications?

In the future, it might be worthwhile investigating whether we could minimize atelectasis by using 80% oxygen and maximize the time to desaturation by using CPAP. Obese patients also have around 10-fold more likelihood of OSA, so many of them are prescribed CPAP anyway. However, compliance rates are only about 50%, because patients often consider CPAP uncomfortable, noisy or claustrophobic. Nevertheless, I think we would see a benefit in terms of reduced atelectasis with just 5 or 10 minutes of preoperative CPAP in the upright position, either in the preoperative area or in the OR before we put them to sleep.

I believe that we are seeing increased awareness that CPAP is also safe to use in the immediate postoperative period, and that can be as soon as the tube comes out.

However, the logistics of giving CPAP in the post-operative unit are difficult. In the future, what we may see is a cohort of the severely obese population – BMIs of 70 and above – having some kind of nasal non-invasive ventilation, both in the preoperative and the postoperative areas.

Naturally, we don't want to put patients at increased risk of aspiration by giving so much gas into the upper airway and the esophagus that they then get gastric dilation and aspiration. But if we do it in a controlled way with comfortable nasal strapping or an oro-nasal mask, and we can see the pressures on the ventilator, we could avoid this worry.

How important is ventilator performance in overcoming the special physiological challenges you meet?

Ventilator performance is important -being able to generate higher peak pressures to control poor lung compliance or high intra-abdominal pressures is a good example of specific



Dr Collins in the departments staff room

requirements that are necessary with this patient population.

I try to set the tidal volume to a multiple of ideal body weight based on height rather than actual body weight as the latter may produce tidal volumes that are too big and cause more barotrauma. Even then it may be necessary to accept higher ventilatory pressures to achieve these volumes. I think that it is safe to go to higher pressures as long as the tidal volume is not too great. Experience from the ICU that large changes in volumes cause more morbidity than higher pressures alone.

Assuming that the patient was cardiovascularly stable, I would also attempt to increase oxygenation by using PEEP. This may also assist in minimizing post operative atelectasis. This may result in having to accept higher ventilatory pressures—for example going up to 50 centimeters of water is not uncommon. In a morbidly-obese population, you sometimes have to go

this high to make sure oxygenation is adequate. Pressure Control rather than Volume Control may result in greater tidal ventilation for a given pressure. I've found with a lot of standard ventilators that I've used, when high inspiratory pressures are needed quickly, they are just not powerful enough. In the past, I would sometimes request that an ICU ventilator be brought to the OR so that I could use a more powerful pressure generator. Hopefully, that's not going to be necessary in the future.

**What about the situation today?
In which cases do you bring an
ICU ventilator in to the O.R.?**

I do not do that routinely, largely because we don't have that many extremely obese patients. However, if this situation changes, it would be certainly worth considering, especially when the patients have more complex co-morbidities such as pulmonary hypertension, COPD and pulmonary edema.

With a very obese patient, weighing 900 pounds, for example, who is on high ventilation settings and a lot of PEEP, it is highly desirable that the quality of ventilation is not interrupted during transport between the OR and ICU. Having an inferior ventilator in the OR can lead to sudden hypoxia, a reduction in tidal volumes and an increase in atelectasis.

**Could you tell us something about
the recruitment maneuvers you
recommend. What is your current
clinical practice in this field?**

PEEP of around 10 is one aspect of my current practice. But if you have good respiratory monitoring from your ventilator in the OR, you may be able to find a more optimal PEEP setting. I recall a study looking at recruitment maneuvers that I believe showed going up incrementally from 10 PEEP to 15 then to 20. This improved PO_2 and compliance as well.

Regular recruitment maneuvers using PEEP thus seem important if you want to minimize atelectasis.

In addition, there may be a subset of patients, e.g. those with very heavy chest walls, that might need PEEP pressures very much higher than the levels regarded as “conventional” by many physicians. Levels perhaps even higher than the 50 centimeters of water that I mentioned earlier may be required to expand the lungs effectively and keep them open.

I also feel that the benefits of such recruitment maneuvers may sometimes be lost at the end of surgery. We should be better at maintaining a certain degree of recruitment post-operatively in the first 24 hours, the period when these patients are at high risk of episodic desaturation. Receiving more direct input from critical care staff or respiratory therapists would be beneficial in terms of addressing such post-operative issues.

What ventilator modes do you find to be useful in other phases of the procedure?

I find Pressure Support most useful towards the end of the surgery, as I’m trying to get the patient to return to spontaneous respiration, rather like an extubation maneuver. In the morbidly-obese patient, who may be a difficult intubation and have OSA, it is important to make sure that they are adequately awake before you extubate to avoid early airway obstruction and avoid a need to use positive pressure mask ventilation, which may put the new anastomosis under strain.

How important is patient positioning in helping to optimize peri-operative ventilation?

I spend up to 10 minutes making sure the patient is in a very good position for intubation. But we then take away

that positional support after intubation and therefore face problems lifting them back into that same position later because they are so heavy. As we cannot achieve the same ideal position for extubation that we can for intubation, the conditions are non-ideal at the end of the case. We thus need to be absolutely sure that the patient is adequately awake before we extubate. That relies on good anesthesia so that patients can tolerate the endotracheal tube without coughing and bucking and pulling it out. Whatever ventilation mode you are using, it is important that patients can breathe comfortably on the ventilator to guarantee their airway, and so that they won’t panic.

If we come back to the issue of ventilatory modes for these patients, is there anything you would like to add regarding the end of the procedure?

A good ventilator and good ventilation modes are important. There’s nothing worse than losing good intra-operative tidal volumes with good PEEP at the end because the patient is fighting the ventilator or because you are trying to return to spontaneous ventilation in the supine position, which is not a good position for obese patients. A good spontaneous mode of ventilation that is assisted is very useful at the end of the act when you want to maximize tidal volumes and minimize the occurrence of sudden atelectasis.



Main entrance of Stanford University Hospital, Palo Alto

Biography

Dr Jeremy Collins, MD, Chief Assistant Professor of Anesthesia, is originally from the United Kingdom, but has been established in California for the past ten years. He is affiliated to both Stanford University Hospital and Lucile S. Packard Children’s Hospital, both in Palo Alto, CA. He works closely with Dr Jay Brodsky, Professor of Anesthesiology at Stanford University Hospital, and is the author of numerous publications in the field of airway and anesthesia management of the obese patient.

Dr Jan Mulier, MD, PhD

Which special ventilation aspects do you consider with respect to anesthesia of the obese patient?

When ventilating obese patients, you should not only look at the thoracic compliance but also at the abdominal compliance. By solving the abdominal problems, you also solve the ventilation problems. That is the approach I have been applying in the last two years instead of adapting the ventilator settings only. Traditionally, the laparoscopic surgeon does not care about ventilation, and we, anesthesiologists do not care about surgical workspace. Therefore the abdominal compliance issues were believed to be the realm of the surgeon only. In my view the diaphragm should no longer divide the body between abdominal surgeons and anesthesiologists. My aim today is to see if I can change the abdominal compliance to improve the surgical workspace and the ventilation at the same time. Helping the surgeon with his problems is the reason for our existence as anesthesiologists in the past. We developed our own activities and responsibilities to the patient and forgot the surgical problems. We as anesthesiologists have to improve not only the anesthetic outcome that is already very good but also the surgical outcome by using our knowledge as an applied physiologist. This new way of thinking I call the trans-disciplinary approach that goes one step further than team work.

What methods do you apply when ventilating an obese patient who might be difficult to ventilate?

When I have an obese patient who is difficult to ventilate with high airway pressures, I have several strategies that I can apply: The first one is to give them continuous sufficient muscle relaxant allowing the abdomen to relax maximally and

lower the intra abdominal pressure (IAP) which improves ventilation. Another aspect is positioning of the patient in the beach chair position. By flexing the legs and giving anti-Trendelenburg inclination, we improve the abdominal compliance and lower the IAP. This creates more space for the lungs and lowers the airway pressures again. Beach chair position also prevents also venous stasis. A patient with a BMI of 60 or more has to lose 20 kg or more before the operation to make it easier to insufflate the abdomen and to ventilate the lungs. Inflating the pneumoperitoneum to a minimum surgical workspace instead of a fixed certain pressure means frequently a lower intra abdominal pressure and hence an easier ventilation. In a last aspect we accept higher end-tidal CO₂ as this stimulates the cardiac output and the wound perfusion and requires a lower ventilatory minute volume.

What does high ventilation performance in anesthesia mean for you?

We can start by looking at the different ventilation modes that come to us from the ICU. For example, Pressure Support was developed to facilitate weaning and to improve synchrony between the patient's breathing and the ventilator. In anesthesia, we didn't have this problem of synchrony, For a long time we therefore didn't look at these modes. But some of these modes can also improve ventilation, even under muscle relaxation by adapting them to anesthesia. New modes can be further developed like Volume Support or Proportionally Assisted Ventilation. We can look at the speed of changes in gas concentration, needed at induction or at the end of the procedure, something most anesthesiologists are concerned with and where improvements are still possible. Opposite to speed we can look at the efficiency of gases, inhalation vapors and absorbers used all aspects the

hospital is more concerned with. We can look at the measurement capacities beyond pressures and volumes. Lung compliance for example is not linear which makes it difficult to use. Many other parameters can be measured but without clinical meaning they risk being more fancy than useful. Safety aspects in ventilators still need further improvements. Pressure controlled ventilation is dangerous for volutrauma when no volume adaptation exists and the abdomen is suddenly deflated. Pressure support can also be dangerous for volutrauma when the patient regains his strength. Volutrauma is also possible with most anesthesia ventilators when by human error one forgets to switch from manual to controlled mode with a closed APL valve or when the exhalation tubing is blocked. The safety frog we developed as an external device or built inside the ventilator can prevent this.

Why do you think there are some who say that there is no correlation between obesity and peri-operative ventilatory complications, whereas other studies show the contrary?

One reason is that not enough studies have been done on the obese and the morbidly obese patients with respect to this point. The other reason is the fact that BMI itself is not a good predictor for the risk of metabolic syndrome with its associated cardiac and pulmonary complications. The waist to hip (W/H) ratio predicts the existence of this syndrome and the complications of obesity as it better describes the fat distribution. A W/H ratio above 1,5 means that all fat is situated in the abdomen, increasing the intra abdominal pressure and making ventilation very difficult. This android (W/H > 1) fat distribution is more frequent in men than in women who tend to have more frequently a gynoid (W/H < 1) fat distribution.

It is also a fact that keeping the surgical procedure short for the obese patient

has a positive impact on outcome. The longer the procedure where you keep them intubated and mechanically ventilated, the worse the outcome is.

What about the situation of atelectasis in these patients and how do you ventilate these patients during a routine operation?

Obese patients have atelectasis even while awake and standing. They are not able to breathe deeply as the diaphragm is permanently elevated. Lying flat is very bad and anesthesia induction should start again in the beach chair position. CPAP should be available at pre-induction and during induction, followed by ventilation with PEEP. The same is true at the end of the procedure. Most anesthesia ventilators do not allow giving CPAP by mask, something that needs to be incorporated. Techniques do exist for raising tidal volume and performing recruitment maneuvers. However these require manual intervention with interruption of the PEEP level and this can be very bad in preventing atelectasis. The effect is a nice oxygen saturation. However, we are not sure that recruitment does not overstretch and damage the lungs at the same time, and thus compromising the outcome. After induction, a volume controlled or a pressure controlled mode can be used always with a low PEEP. I prefer Volume Control for its safety and will use Pressure Control if airway pressures are very high. At the end of the surgery I always switch to Pressure Support with PEEP even with full muscle relaxation. Besides a better oxygenation and a more physiological breathing, it allows us to titrate the Sufentanil dose to a maximum without impairing the respiratory rate and allowing a patient to wake up pain free.

Is the obese patient population a good model for other high-risk patients presenting for anesthesia?

Yes, of course. Understanding the physiology of the obese to extreme obese patient helps improve care of other high risk patients with comparable organ problems. The patient with acute

abdominal compartment syndrome, the patient with low cardiac output, the patient with right ventricular failure, the patient with low oxygen saturation are just some examples of high risk patients with comparable problems.

Aspects we have learned from morbidly obese patients and that we now use in other cases are the way we ventilate patients with low oxygen saturation or with high airway pressures, the way we improve skin perfusion and diminish wound infections; the way we prevent post operative surgical bleeding by increasing blood pressure and cardiac output are just some examples.

What about the different phases of the anesthesia? Do you encounter any difficulties?

One must differentiate between difficult intubation and difficult mask ventilation. By elevating the head and the thorax of the patient during induction the intubation is not more difficult than in the non-obese patient. On the other hand, mask ventilation will remain difficult even with the beach chair position, the mayo cannula and two hands available to hold the mask. Obese patients are also at higher risk for aspiration, making mask ventilation frequently dangerous, and therefore not performed.

During induction, ideal body weight is used to calculate the agent dose, while during maintenance a higher agent dose than ideal body weight is needed. You can try to calculate drug doses for every patient but will need to adapt them according to the measured effect.

Good muscle relaxation is important in patients with small abdominal compliance; this is most frequent in the android male type or young girls who have not yet been pregnant or who never have had a laparotomy or laparoscopy. Full muscle reversal is very important so that he/she can gain maximum muscle power while being fully awake. This is crucial to have them breathe deeply. Pain control is also very important and should start before the end of the operation. Loco-regional anesthesia is ideal but more difficult to perform in the obese. ■



Dr Jan Mulier at a patient's bedside at St Jan's Hospital, Brugge, Belgium

Biography

Dr Jan Mulier, MD, PhD, anesthesiologist, is founder of the ESPCOP (European Society for peri-operative care of the obese patient) and Chairman of the Department of Anesthesia at Sint Jan hospital in Brugge, Belgium. He is the author of numerous publications concerning aspects of peri-operative ventilation and has done extensive research in this field.

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