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

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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 SERVO-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 SERVO-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 SERVO-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 SERVO-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 CO_2 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

Pat Tiehen, Rachael Dameron, Education Coordinator Lyndsy Wolfe, Patrice Johnson, Equipment Tech Kelly Romeiser, and Clinical Specialist Kristin Smith

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 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 in-servicing 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% FiO_2 or 21%. Now the transition is much smoother from bedside to MR. We can dial in the FiO_2, 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 CO_2 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."