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

Critical Care News discussed these developments and new strategies with Kim Watkins, RRT-NPS, Clinical Coordinator of Respiratory Therapy, the Neonatal Intensive Care Unit of Swedish Medical Center.
When treating pre-term infants with invasive ventilation modes, which modes or methods do you frequently use?

Our primary mode of ventilation is Pressure Regulated Volume Control (PRVC) and we have chosen to use a low-volume strategy. We typically target our volumes around 5 ml per kilo on each baby, so it is very individualized. We use a shorter inspiratory time of 0.3 seconds and a typical set respiratory rate of 30-40 and then we titrate their FiO₂ based on their O₂ saturations.

We started targeting volumes in 2002, so essentially we have been using this strategy for the last 5 years. Prior to that we were using some volume ventilation, but it was not specifically measuring that low volume target. It was more a question of pressure controlled ventilation, which is more traditionally used to ventilate micropreemies.

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

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

Yes, and on occasion we will still use SIMV, as well as Pressure Control and Pressure Support ventilation, typically babies that require SIMV with PC and PS tend to be a lot sicker. We are pretty proud that we don’t get a lot of chronic lung disease. Chronic lung disease still exists but not as we used to define it, meaning ventilator dependent, they are still oxygen dependent but not ventilator dependent. The infants who are managed on SIMV, PC, PS are typically septic and need a lot higher pressure support, but as soon as they start healing and improve, we try to get them back to PRVC as soon as we can. We really like to control those volumes. And as soon as they are stable on PRVC with tidal volumes approximately 4-6 ml/kg, and we establish that they are at a point where they are triggering the ventilator, and their FiO₂ is at a low enough point we assess their readiness for Automode, as part of the weaning process.

Do you utilize rise time to create laminar flow?

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

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

In regards to inspiratory cycle off, that is actually a more important feature that we use when they are in a supported mode of ventilation, Volume Support or Pressure Support. We usually start at a 5% inspiratory cycle off, we basically want them to get their entire tidal volume since we are in a low volume state anyway. When we see signs of asynchrony with the ventilator or if they develop an air leak, as these infants with uncuffed endotracheal tubes often do, we start fine-tuning our inspiratory cycle off, so that you don’t have those long delays. For instance, the baby we were assessing for extubation readiness this morning had a 50% air leak, so I set his inspiratory cycle off at 50% and it did not compromise his ventilatory needs and he was much more in synchrony and more comfortable.
In regard to the 24 hour trends on the ventilator, which parameters do you feel are the most valuable?

For this unit, as far as trending is concerned, we typically only utilize it when they are in Automode and when we are evaluating extubation readiness. We evaluate the respiratory rate parameter on the trending menu. If it is a post op surgical baby, we might only look at the trend from the last hour to 2 hours, just to see if they are triggering the ventilator. For some of our micropreemies we look at monitoring for over a 24 hour period. For example, if we were thinking of putting them on Automode today, I would start looking at the trends for the next three hours, and the next morning, we might look at the window over 12 or 24 hours, to see if they are continuously triggering, or if there have been relapses to PRVC. If you determine there are some time periods of concern when the infant relapsed to PRVC, we need to collaborate with our nursing team and evaluate the time period and if it coincided with sedation or handling. If there was nothing in particular, and a lot of periodic breathing, maybe they are not ready to be extubated.

So you are not monitoring CO₂?

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

How do you address the challenges of leakage?

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

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

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

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

What are your policies in regard to suctioning and oxygenation?

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

In regard to oxygenation, our delivered FiO₂ is determined by oximetry, we have targets and we have limits. The limits are when the oximeter is going to alarm, and the targets are ideally where we want their O₂ saturations. Our oximetry limits and targets have just been adjusted this year based on COMP-ROP. COMP-ROP stands for Comprehensive Oxygen Management for the Prevention of Retinopathy of Prematurity. We rarely have to do surgery on retinopathy of prematurity, but we still do get a few rare cases. Basically all of our infants who are admitted born at 34 weeks or above have limits set at 85% SpO₂ at the low end and 100% SpO₂ at the high end, with a target between 92 and 97% SpO₂. The babies that are born under 34 weeks have a limit set at low end of 80% SpO₂ and the high end of 95% SpO₂ with a target of 85 to 92% SpO₂. That 34th week is a cut off for which scale you are in. Since we have initiated COMP-ROP the majority of our babies are on low oxygen concentrations. It will be interesting to see when they evaluate the data, how we made progress in retinopathy of prematurity, and what has happened with everything else, status of chronic lung disease for example. All of our blenders at the bedside are set at about 10% O₂ above what their baseline FiO₂ delivery is.

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

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

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

We typically wean per blood gases, and by maintaining those low volume strategies, we look for the FiO₂ to be essentially less than 30%, our peak inspiratory pressures that are generated by our low target volume to be less than 17 cm of water pressure. We are usually pretty generous with PEEP and it is usually around 5-6 cm H₂O, which is probably another reason why we are able to keep our FiO₂ so low. We have not had any instability from using PEEP at about 6 cm H₂O. When they have reached those settings, and their ventilation status is stable, i.e. their pH status is between 7.25 and 7.35, and their CO₂ is between 50 and 60 mmHg, we consider their blood gases to be stable. We will then assess them to switch to Automode, and we will watch their trending for 2 to 12 hours, and if they are not apneic, we pull the endotracheal tube. In other cases, we observe the trend for about 24 hours to be certain before extubation. Especially in cases with very low gestational age, we want to be certain that they can maintain spontaneous breathing before we extubate. Our goal for babies less than 28 weeks is to assess within 3 days of intubation, and then our goal is to extubate them by day 7. Most of the low birth weight babies are extubated, and are maintained on nasal CPAP for a long period of time, in most cases for many weeks. For babies over 28 weeks gestational age, we have a goal to get them extubated as soon as possible. It could be a matter of getting them intubated, giving them surfactant, and getting them extubated within hours or it could be longer, depending on the reason why they were intubated in the first place. If intubation was due to Infant Respiratory Distress Syndrome (IRDS), they are probably more rapid to wean; if it was due to sepsis, abdominal defects or for a surgical patient, more ventilation time is involved.

What is your average extubation success rate?

Our extubation success rate on babies over 30 weeks is probably in the high 90% range, in maintaining and not having to reintubate, depending on their disease process. We usually do not use nasal CPAP on these babies, if they are intubated for IRDS they typically don’t need to be supported on nasal CPAP. For babies under 30 weeks, they might need short term support on nasal CPAP, for example a 28 week baby might need nasal CPAP one week post extubation. The younger gestational ages, the higher the risk of extubation failure; statistically at 1-3 days we have a 70% success rate of extubation. At the second or third day, there are many circumstances giving reason for reintubation. Overall, for 28 weeks and below, the extubation success rate is about 48 to 50%. The number one reason for intubation is apnea. Sepsis is also a factor for higher risk of reintubation. They are at risk for so
much, the younger they are. On average, 50% is our success rate for the Early Low Birth Weight Infant. If an extubation criterion is met successfully, and they can be extubated for longer than 7 days, we can typically manage them on nasal CPAP. If they do need reintubation, we go right back to the low volume strategy to keep it as protective as possible.

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

In 2001, we took on a delivery room approach. Our protocol is we take surfactant with us for any delivery of gestation of 30 weeks or under. We estimate the weight, intubate and we administer surfactant to all infants under 28 weeks. We ventilate them with Neopuff at low pressures, 20 peak inspiratory pressure over 5 PEEP, and initiate our FiO<sub>2</sub> in room air, and place on an oximeter. We will only increase our FiO<sub>2</sub> if the saturations are below 80% and add O<sub>2</sub> in 5% increments to get saturation to over 80% and rising. We use the Neopuff during transport in an incubator up to the NICU, and put them on our low volume strategy. For re-dosing, a second dose surfactant can be given if their FiO<sub>2</sub> is greater than 30%. We re-dose every 6 hours for up to 48 hours. For the babies outside that window, from 28 to 30 weeks, if they are showing signs of respiratory distress we will intubate them and assess their need for surfactant.

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

In addition to nasal CPAP, we do have the SERVO-i non-invasive ventilation mode and we have used it on separate occasions, in PC mode. We use it on babies who have failed their extubation, at their second or third attempt. We don’t want to reintubate them, but know they need a little stimulation, so we use it at low pressures, 14-16 cm H<sub>2</sub>O at a PEEP of 4-6 cm H<sub>2</sub>O, respiratory rate of 10 and 0.4 s inspiratory time. In those cases, the babies have done well, and we have used the Fischer Paykel humidifier and application device. We use nasal CPAP very diligently and have great compliance by our staff. But non-invasive utilizes a different technique and in order to use it successfully it requires diligence, skill and regularity.

Are you using high frequency oscillation ventilation?

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

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

Do you utilize nitric oxide therapy?

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

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

The challenges today are still focusing on the goal of extubation as soon as possible. It is certainly easier to keep the babies intubated, but it is not the best for them. That is a cultural challenge, and you have to be dedicated to wanting to get the babies extubated, and staying on your protocol. I think we have done a good job of working with our low volume strategy, and our delivery room management and our FiO<sub>2</sub> criteria; these all work together to prevent ventilator induced lung injury. The challenge is staying focused on extubating these infants, and keeping them extubated. The other challenge is to have an acutely ill baby who might have a lot of complex changes, to find the correct ventilator settings for his acid base balance, without inducing injury. That is a challenge. Our goal is create no harm.

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

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

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

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

Dr Sweeney: Probably half of Seattle was born here at Swedish Hospital. It is an old hospital, and was known as Doctors Hospital quite some time ago. It was consolidated with Swedish, which was founded by a fellow named Nils Löfgren, a Swedish hospital for a group of Swedish physicians. We had a grand opening of our NICU and labor and delivery unit a few years back, and offered the community a chance to send in pictures and stories. This resulted in an 80 year retrospective of all the people born here, and all the hospital corridors were lined with the photographs.

What development within the NICU organisation have you personally experienced?

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

Our NICU at that time would be considered a level 2 nursery by today’s standards. We kept babies on oxygen, who needed extra monitoring and intravenous therapy, but without any ventilator support. We have such a large presence of perinatal specialists here, they needed a more robust neonatal environment, so that is why we started to become a level 3 nursery to support them, and that relationship has continued over the years since they are the primary gateway to the institutions. Most of our babies arrive here in utero to the perinatal program and are delivered here. A very small number, less than 10%, are born outside and transported here. The majority of our babies are born here because of the maternal program.

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

Dr Sweeney: At that time it was rather unusual to have babies do well at 25-26
weeks gestation. A few of the babies were that size even back then, but with the advent of surfactant and certain ventilation modes, we could start to expect some reasonable outcomes at 24-26 weeks, before that it was really case by case.

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

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

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

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

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

Dr Sweeney: We have about 140 nurses for the amount of babies we have. We have around 6 neonatalogists on staff, and another 6 who are on part-time
We have a staff of 7-8 nurse practitioners who work side by side with us, who are doing procedures on babies and covering deliveries and daily care. A few other staff members include dieticians in the two nursery care settings, three social workers dedicated just to our parents and babies, staff of physical and occupational therapists who are specialised in pediatric patients and are on a weekly basis, speech therapists who help with feeding issues, pastoral support, discharge coordinators, so we are a pretty large team when we are all here in full force. We have 2 dedicated pharmacists, right on the floor here, and at least 2 NICU respiratory therapists 24 hours a day. Most of the resources are pretty close at hand.

**What is your nurse to patient ratio?**

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

**How many respiratory therapists do you have on staff?**

Kim Watkins: We have 22 RT’s on staff, who are trained to our NICU. In the NICU we have 2 respiratory therapists on shift 24 hours a day. We go to all deliveries that are moderate to high risk, and this keeps us busy since we are a big perinatal high risk center. We help with rescues in the delivery room.

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

Kim Watkins: On an annual basis we conduct a four hour skills day, for respiratory therapists, about the holistic package in neonatal and pediatrics. In addition, on a monthly basis, I produce a newsletter for my group, with at least one educational component in it. My current issue is focusing on the neonatal group, and the strategy to prevent ventilator induced lung injury. It is so
involved that I need to do it in 2 parts, I usually list frequently asked questions at the end. For any new protocols or procedures we schedule in-services for the staff. There are also lots of other educational opportunities throughout the year, regional seminars and workshops, for example.

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

Can you describe family involvement in the NICU?

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

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

Dr Sweeney: Our unit is a long-time SERVO user. We used Bear Cubs when I first came here, a good old standard ventilator for many nurseries; we transitioned to Infant Stars for early HFO support. As the SERVO became available, we started using those more and more as the Infant Stars phased out. We still use the Sensor Medics HFO for certain babies, but the trend in recent times is more use of SERVO in PRVC, which by far is our widest mode of ventilatory support, with Automode in weaning, as a step down from ventilation to extubation.

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

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

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

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

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

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

Biography

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

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

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