Evaluation of a ventilator solution
in a mobile ICU

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Kristianstad Regional Hospital has been creating solutions and generating experience in transporting ventilated patients in the southern region of Sweden since 1978. In recent years, they have cooperated with partners and authorities to create a customized transport carriage for a mobile ICU to facilitate transport of critical care patients within the region. All inter-hospital patient transports in the mobile ICU were documented on protocol during the year 2006.

Critical Care News met with the project team members representing key functions; project director, anesthesiologist, ICU physicians, ICU nurse and clinical engineering, to discuss their impressive results.
You have a long tradition of transporting ventilated ICU patients in this region of Sweden. Can you tell us a little about the historical background?

Lennart Ohlsson, MD, Department of Anesthesiology and Intensive Care: We started back in 1978 or 1979 when we equipped an ambulance with a SERVO 900A ventilator with gas cylinders and an electrical converter that was quite advanced for the time, with 220 voltage that was approved and validated for the first time in an ambulance. In 1990 we implemented a SERVO 900 C ventilator on an integrated stretcher-trolley, which worked well as a transport solution for 13 years. During these years, we have gained experience and have developed practical solutions during the course of this experience. Our goal has always been to provide continuous ventilation therapy to the patient during transport, while minimizing interruptions as much as possible. But one of the difficulties with the older ventilator models was the need to interrupt ventilation while transferring the patient from the ICU down to the ambulance, and interrupting again when arriving at the receiving hospital.

When the SERVO-i ventilator was launched in 2001, we saw the possibility of developing a mobile ICU with a bedside adaptation to provide uninterrupted ventilation to the patient for the entire transport chain, from ICU bedside, during inter-hospital transport to the ICU bedside at the receiving hospital. The project group received approval during 2002, and started to customize and develop the new solution, based on our previous years of experience.

This new mobile ICU solution has also been used for transport of small neonatal patients between university hospitals in the region.

Many people in different groups have been involved in the various stages of the process, but we are the primary project team that has been involved in the development and implementation of this latest solution, and many of us have been actively involved in the transport experiences of the past. Our project team has had the resources, some luck, but we have also had enough determination to finalize the project, and implement this latest solution. This means that we have found the evaluation results to be especially rewarding to us within the group.

Ronny Knutsson, RN, ICU nurse: Many of us who accompany the patients in the mobile ICU today have had experience of patient transports with the older systems and vehicles. This means that we have experienced details from practical and care giving aspects that were areas for improvement in the past. We took these experiences with us into the development process for the new solution in this most recent project group for the new mobile ICU.

Christer Karlsson, KAMBER, Project Director: The mobile ICU consists of the TRANSMOBIL stretcher-base combination, which is secured to the trolley and allows transfer of the patient without changing position. The transfer trolley houses the SERVO-i ventilator, up to six jet infusion pumps, patient monitor and suction equipment, with fixed connections and couplings as well as locking mechanisms for the equipment and trolley. This means that the trolley is completely self-sufficient with an operational capacity of 3-4 hours for air, oxygen and power.

The specially designed vehicle contains both a 12 V DC and a 230 V AC power supply. Double air and oxygen tanks are available with 5000 liters each of air and oxygen, and switching between them is easy. Strength, durability and stability were key parameters in designing the mobile ICU, which required special customized frames and braces to hold the equipment. These have been developed to twice the strength and durability required, and will function even after a collision.

What practical and clinical aspects led to the development of your current mobile ICU solution? Can you tell us about the project group behind the solution?

Lennart Ohlsson, MD: It is important to point out that this has been a cooperative project between KAMBER, the Regional Health Ambulance provider, and the Regional Hospital here in Kristianstad, where we have team members from key functions within the hospital; physicians and nurses from the Department of Anesthesia and Intensive Care, and our Clinical Engineering Department.

Mattias Svensson, Clinical Engineer: The entire mobile ICU is composed of
We planned and modifying details to avoid each risk. The transport process, and adjustments and regulations to follow when developing as one system. There are a lot of many components, but must be regarded as one system. There are a lot of regulations to follow when developing and customizing components and the entire system. The initial risk analysis process is the key basis for initiating a project of this scale. It is a long thorough process of identifying every possible risk for the system, components and transport process, and adjustments and modifying details to avoid each risk.

Ronny Knutsson, RN: We planned and anticipated anything that could possibly happen with the patient and treatment during the transport process: traffic jams, vehicle breakdown, the need to intubate or reintubate during transport; we considered every possible risk scenario and came up with solutions to how we would handle these.

In regard to your past experience of transports of intensive care patients, what proportion of patients are acute/emergency as opposed to secondary planned ICU transports?

Tomas Åhlund, MD, Anesthesiology and Intensive Care: The mobile ICU is not often used in acute cases – accidents, bleeding, trauma – these cases are most frequently transported in conventional ambulances.

The mobile ICU is mainly used for transporting intensive care patients who need the clinical performance of an ICU ventilator during transport. Historically, we have transported ICU patients back to Kristianstad ICU from the University Hospital of Lund, where the patients have been sent for specialist care, for example thorax, neurological or plasma pheresis treatment. ICU patients who are returning home here to Kristianstad for continuing ICU care. This inter-hospital transfer of ICU patients within the region started to grow during the 1990’s, and is continuing to expand, due to temporary lack of ICU patient bed capacity within hospitals in the region.

Our hospital here in Kristianstad is about an hour away from the big metropolitan areas and larger hospitals, so we have become a “buffer” hospital within the region, when ICU patient capacity is overloaded at the other hospitals. In this respect, we also cooperate with the region of Sjælland in Denmark, primarily with neonatal patients. As the cooperation between hospitals in the region increases, we have seen an increase in our receiving patients from the hospitals in Malmö, Lund and Helsingborg, while maintaining the same amount of patients we have transferred out of Kristianstad for care in those centers. We understand that this increasing trend of transferring ICU patients between hospitals is at an even higher level in other parts of Europe, for example Germany and Great Britain.

During the course of our one year evaluation of the mobile ICU in 2006, we collected data showing the transfer of a total of 84 ICU patients from 12 ICU departments in the different hospitals within the region. A total of 68 of these patients were mechanically ventilated, of which 15 of these were transported due to capacity overload at the transferring intensive care department.
Which types of patient categories are seen most frequently in these planned ICU transports?

Ronny Knutsson, RN: Basically, you could say that the patients transported in the mobile ICU are the same mix of patient categories in the ICU ward: general ICU patients with pneumonia, COPD, sepsis, post-op, you name it. The ICU patients we treat in the department are the same categories transported in the mobile ICU to other hospitals.

Lennart Ohlsson, MD: We can transport patients in the mobile ICU that otherwise would have been regarded as not suitable for transport in the past. Our objective is to give the patients the same level of care in the mobile ICU as they receive in the ICU departments. This means the same level of patient monitoring, the same treatment medications, the same quality of ventilatory care, without interruption. In order to monitor and ensure that the level of care is the same quality, we document everything that happens, prior to transport, during transport, and after transfer to the new ICU, in order to follow the patients as closely as possible.

Lennart Ohlsson, MD: Much has happened in regard to development and experience during the past decades we have been involved in patient transports. Today, we have syringe infusion pumps, which facilitate the process and are easier to place. In general, most of the equipment has become much smaller and lighter, with increased battery time.

Ronny Knutsson, RN: Another big difference is that in the past the nurse was alone with the patient during transport. Now, depending on the status of the patient, an anesthesia nurse and an intensive care nurse may accompany the patient. We also have better communication with mobile phones, and can be in contact with the responsible physician for consultancy during the transport process, if necessary. The quality of care is much improved; in fact, it is as if the entire care team is accompanying the patient, some of us physically and the rest electronically. Nowadays, we also have room for a third staff member in special situations, and we can also accommodate an aortic balloon pump if needed.

In these general ICU patient categories, which type of clinical performance is required from the mobile ICU ventilator that is delivering therapy?

Lennart Ohlsson, MD: In general, the mobile ICU ventilator should provide the same clinical performance that the patient requires of the ventilator bedside in the ICU. This is a great benefit to the patient, to be able to use the ICU ventilator with the same settings bedside, and continue with the same ventilator and settings throughout the entire transport process, bedside to bedside at the receiving ICU. This is without a doubt best for the patient, it is safer and more comfortable than interrupting therapy, and it is also beneficial to the staff since it requires fewer staff members and less time.

Tomas Ählund, MD: I agree that it is important to maintain the same clinical performance in ventilation throughout the entire process. Transporting ICU patients is a risk factor per se, and the idea that the intensive care patient should receive a lower level of care or become more
uncomfortable due to a suboptimal ventilator during the transport process is very negative indeed. The other factor is that we see a continued increasing focus on non-invasive and supported ventilation in recent years. This means that the mobile ICU must have a ventilator to accommodate these modes, just as at bedside, and the other modes as well: for intubated patients with controlled or supported ventilation modes as well as patients with non-invasive ventilation.

When we purchased the SERVO-i in 2002, it was clear to us that it would suit all of these treatment requirements in transport, as well as the battery back-up time and the other practical features.

Ronny Knutsson, RN: It can be of interest to note how we came to the optimal arrangement of the equipment. We knew what supplies we wanted on the trolley, but we were not sure how to fit each item optimally in proportion to each other, so we were continually sketching and drawing up drafts. At the same time, we had construction going on in the Department of Anesthesiology and Intensive Care, and the floor was covered in sheets of protective paper, so we took some of them and cut them to the size and dimension of the lower level of the trolley. We arranged the gas cylinders, ventilator and other equipment on the paper “trolley,” so that everything would be placed compactly and proportionately. We called this starting at “ground level.”

Christer Karlsson, Project Director: Another issue we were struggling with was how to ensure an uninterrupted gas supply to the ventilator. We were looking at all kinds of elaborate vents, and valves, and ended up with a very simple and easy solution in the final version: a valve on every hose that could be opened or closed, to let us run gas from the cylinders, or from the vehicle supply.

Mattias Svensson, Clinical Engineer: Everything had a challenge, especially how to ensure that all procedures were free from interruption during the entire process. It all stemmed from the risk analysis, right down to extra hoses, tubes and suctioning devices.

Lennart Ohlsson, MD: We strived for optimal simplicity, with one connection for the entire trolley that supplied and conveyed everything: electrical power, oxygen and air. At the same time we wanted to make sure that if anything happened when the patient trolley was enroute in the corridors between the ICU and the mobile ICU, we could simply plug into a wall outlet.

Mattias Svensson, Clinical Engineer: The more cords, tubes and hoses you have, the greater the risk of forgetting something, or something becoming damaged.

What are the types of ventilation strategies or modes that are most commonly used during mobile ICU transports, and why? How often do you transfer the identical settings from the patient’s ventilator in the ICU to the SERVO-i in the mobile ICU?

Ronny Knutsson, RN: A total of 84 patients were transported in the mobile ICU during the year of evaluation in 2006. Of these, 68 patients were mechanically ventilated, with 66 receiving invasive ventilation and 2 patients receiving non-invasive ventilation, with CPAP and masks, which worked very well. A variety of ventilation modes have been utilized during the evaluation.

What is the normal range of trigger settings used during transport?

Ronny Knutsson, RN: Of the 68 patients who were mechanically ventilated during the evaluation period, 47 patients had flow triggering and 21 patients had pressure triggering. The trigger function worked optimally in 67 of 68 cases. In one instance, in the very beginning, we experienced auto-triggering, where we believe that the ventilator sensed some vibrations in the tubes. This was solved by switching from flow triggering to pressure triggering instead. Apart from this instance, we had no problems with auto-triggering.

The objective of the project team was for the mobile ICU process to provide uninterrupted delivery of ventilation and care during the transportation process. What results did you record in your evaluation after one year?

Ronny Knutsson, RN: There was no recorded instance of interruption of gas delivery during the transport process, and there were no recorded instances of interruption of power from the ventilator. In one case, there was loss of power from the vehicle to the ventilator when a fuse went out in the mobile ICU, but the ventilator battery provided back-up power supply in this case, with no interruption in ventilation.
What is the average ventilation time for intensive care transport patients that you have documented in your evaluation?

Ronny Knutsson, RN: Overall, the evaluation revealed an average mean time of ventilation to be 72 minutes per patient. The shortest case was ventilated for 45 minutes, and the longest case was a patient who was ventilated for 300 minutes.

Did you document your experience in regard to CO₂ monitoring with ventilated patients in the mobile ICU?

We monitored four patients with end tidal CO₂ during the evaluation period, and had no difficulties at all from a technical or clinical perspective, it worked excellently.

Can you describe the process of preparing a ventilated intensive care patient for planned transport: at the remitting hospital and at the receiving hospital?

Ronny Knutsson, RN: Preparing the patient in the ICU prior to departure is the most important part of the process. We fasten the tubes and cords, and make sure that everything is stable and in good order, before leaving the ward. If you miss a step here, you will most likely encounter difficulties of some nature later on during the transport period. In the mobile ICU, we are seated to the left of the patient, so if all of the tubing is fastened on the opposite side of the patient, this makes access extremely difficult, for example if you need to administer pharmaceuticals or adjust infusion tubing. It is also important that the staff who are preparing the patient for transport at bedside are the ones who accompany patients in the mobile ICU, which provides experience and continuity in the process. Preparing the patient prior to transport is key to the success of the entire procedure.

Lennart Ohlsson, MD: There are many challenges with these procedures, but now we are at a point where the equipment is so optimal and advanced,
Ronny Knutsson, RN: A part of the preparation process includes having the appropriate pharmaceuticals with us. We have standard drugs in a case for all transports, and each individual patient, depending on his condition, will require specific pharmaceuticals, that we bring with us from the ICU prior to departure.

Tomas Åhlund, MD: We have to state that we have almost never had any serious difficulties. Almost all of the transports have been very successful and without any problems. But the fact that most transports are so uneventful is due to the detailed preparation process prior to departure. The key for each successful patient transport is in the preparation. It is a procedure similar to a pilot prior to take-off, with control of equipment and check-lists for every step of the way in the ICU. The staff involved in each individual case is also part of the preparation, to provide the proper competence to the patient need.

What are the contrasts in ventilation treatment in transport with an intensive care ventilator compared to traditional transport ventilators, such as Oxylog?

Lennart Ohlsson, MD: In the beginning in 1978, there were no reliable transport ventilators, which is why we used the SERVO 900. Some years later when the transport ventilators started to show up on the market, we used these in the ambulance as well, but we noticed that the patients were generally in a much worse condition upon arrival at the hospital. ICU patients many times already have lung complications, which is why an ICU ventilator is to be preferred in a mobile ICU.

How do you handle sedation?
For ICU patients who are not sedated: how do they generally experience the transport process? Do you need to regularly change the sedation level before transporting the patients?

Ronny Knutsson, RN: The relationship between sedated and non-sedated patients in the mobile ICU is generally identical to the relationship to sedated and non-sedated patients in the ICU department. In a few specific cases, we have increased the level of sedation if the patient has required a higher level of
comfort during transport. However, our tradition in the ICU is to avoid sedation if it is not necessary, in order to help the patients wean and recover more quickly.

What do you think are the future trends in regard to transport of intensive care patients? Will there be increasing numbers, requirements or special demands in future?

**Christer Karlsson, Project Director:**
In regard to ambulance care, our current solution is very unique. We did a great deal of research prior to starting the project in 2002, but we could not identify any optimal solutions from our perspective, most of what is being used seems to require equipment that is anchored to the vehicle, which disturbs and complicates the transport process from the ICU to the vehicle. Our concept of securing the customized stretcher-trolley as an integral part of the transport solution means that we now have a bedside-to-bedside solution in transport, from beginning to end.

**Lennart Ohlsson, MD:** Other hospitals in other regions have shown interest in our mobile ICU solution. We are certain that the need to transport ICU patients will continue to increase, as the trend to transfer patients between hospitals grows. And the increasing population density in cities and overcrowded hospitals will influence the need to transfer ICU patients between hospitals.

**Mobile ICU project members, Kristianstad:**

Lennart Ohlsson, MD, has worked as an anesthesiologist since 1972. He has been developing and working with mobile ICU transport since 1976.

Tomas Åhlund, MD, has worked as an anesthesiologist since 1991 and has a special interest in intensive care medicine. He has developed medical routines for the mobile ICU.

Anne Magnusson, RN, has been an anesthesia nurse since 1987 and is a member of the design group for the mobile ICU.

Ronny Knutsson, RN, has been an intensive care nurse since 1984, and is a member of the design group as well as transport coordinator.

Mattias Svensson is a Clinical Engineer at the Department of Clinical Engineering and Physics, and is a member of the design group.

**KAMBER-Skåne, Regional Ambulance Transport Service:**

Christer Karlsson is project director for the mobile ICU and has been working for KAMBER-Skåne since 2002. He became an anesthesia nurse in 1974, and has devoted 25 years to training nurses at the University of Lund, Sweden.