Inter- and Intra-hospital Transport of the Critically Ill

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Summary

Intra- and inter-hospital transport is common due to the need for advanced diagnostics and procedures, and to provide access to specialized care. Risks are inherent during transport, so the anticipated benefits of transport must be weighed against the possible negative outcome during the transport. Adverse events are common in both in and out of hospital transports, the most common being equipment malfunctions. During inter-hospital transport, increased transfer time is associated with worse patient outcomes. The use of specialized teams with the transport of children has been shown to decrease adverse events. Intra-hospital transports often involve critically ill patients, which increases the likelihood of adverse events. Radiographic diagnostics are the most common in-hospital transport destination and the results often change the course of care. It is recommended that portable ventilators be used for transport, because studies show that use of a manual resuscitator alters blood gas values due to inconsistent ventilation. The performance of new generation transport ventilators has improved greatly and now allows for seamless transition from ICU ventilators. Diligent planning for and monitoring during transport may decrease adverse events and reduce risk. *Key words: patient transport; adverse events; monitoring; portable ventilators; transport teams.* [Respir Care 2013;58(6):1008–1021.

Introduction

Intra-hospital and inter-hospital transport of mechanically ventilated patients is a common occurrence when providing modern medical care. Advanced diagnostic procedures often require patients to be transported within areas of the hospital or across town to facilities that house the specialized equipment to perform the testing. Although there are risks associated with patient transport, the benefits of this specialized care may outweigh the risk.[1,2] Additionally, patients must be transported to and from the operating suite and from the emergency department to the ICU. Until several years ago, manual ventilation was the preferred method for patient transport, owing to the poor performance of transport ventilators.[3,4] Manual ventilation presents another set of problems, including the inability to control airway pressure and/or tidal volume (V_T), resulting in hyper- or hypo-ventilation and the possibility of inducing or exacerbating lung injury.[5-7] Additionally, the maintenance of a stable PEEP is problematic, and spontaneous breathing is difficult. The purpose of this paper is to evaluate current practices in patient transport, including the ventilators used, safety, monitoring capabilities, and evidence-based recommendations and guidelines.

Inter-hospital Transport

Systems for transporting patients were born primarily from military needs. The transportation of injured soldiers has been documented as far back as the early 1800s, during the Napoleonic wars. Dominique Jean Larrey is credited for creating the initial concepts of military transport medicine.[8] He recognized the importance of triage of the injured and of providing caregivers with specialized training to use in the field. He also recognized the need to rapidly transport the wounded to a medical facility, and employed a large, horse-drawn carriage with specialized caregivers on board to carry out this task. Civilian transport systems have been refined based on battlefield evacuation techniques and treatments over the last 150 years. The most recent method of transport introduced to civilian medicine from the military experience is the rotary wing air ambulance. This method of evacuation of the wounded war fighter was used extensively in the 1950s and 1960s during the Korean and Vietnam wars.[8]

Pediatric and Infant Transport

The majority of the available literature on the transport of children addresses transport between facilities to acquire specialized care. Civilian neonatologists and trauma surgeons began using military transport techniques for their patients in the 1960s. Pediatric transport evolved from the initial experience with neonatal transport in the 1970s.[8] Several studies describe as much as a 50% improvement in mortality rates in children who were transported to and received care at tertiary centers.[9-13] Not surprisingly, transfers from ICU to ICU had higher mortality and greater resource utilization than emergency department to ICU transfers.[14,15] The need for such specialized care has led to the proliferation of neonatal and pediatric ICUs over the past 2 decades. Safely and efficiently transporting patients in need of specialized care is the goal for transport teams.

Transport Teams

Pediatric and neonatal transport teams are an extension of the ICU. There is no national standard for team composition; it can vary by region and hospital, but often includes nurses, respiratory therapists, physicians, emergency medical technicians, and paramedics. A survey of 229 neonatal transport teams reported that the combination of a registered nurse and a registered respiratory therapist was the most common for specialized teams.[16] Although data indicate that a physician is not required in half of the transports,[17] specially trained team members are the key to safe pediatric transport. Orr et al provide strong evidence that using specialized transport teams results in lower adverse events (AEs) and increased survival: 23% versus 9% (specialized vs non-specialized teams) during inter-hospital transport.[18] Unplanned events were more common with non-specialized teams (61% vs 1.5%). The point of specially trained teams is to take the ICU to the patient in a controlled fashion, not rushing the patient to the ICU. Orr's group showed that transport teams adhering to this model spent nearly twice as long at the scene and took twice as long to get to the hospital, but had better outcomes.

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Table 1. Transport Equipment and Supplies

Type	Examples
Monitoring equipment	Electrocardiograph leads and cables, pulse oximetry probes and cables, thermometer, stethoscope, blood pressure cuff
Suction equipment	Suction catheters, Yankauer, suction tubing
Intravenous/intra-osseous equipment	Angiocatheters, arm boards, intra-osseous needles, tourniquets, tape, tegaderm, gauze
Chest tube/needle drainage equipment	Chest tubes, pleurovacs, syringes, stopcocks
Nasogastric/urinary equipment	Feeding tubes, nasogastric tubes, Foley catheters, syringes
Sterile field supplies	Betadine, chlorhexidine, alcohol wipes, sterile gloves, sterile drapes
Communication equipment	Cell phones, 2-way radios
Intubation equipment	Endotracheal tubes, nasal and oral airways, CO_2 detectors, stylets, laryngeal mask airways, tape, Magill forceps, commercial tube holders, tracheostomy tubes
Laryngoscopy equipment	Laryngoscope blades and handles, batteries, bulbs
Oxygen-related equipment	Nasal cannulas, oxygen tubing, flow meters, head hood, self-inflating bags, resuscitation masks, simple masks, venturi masks, non-rebreather masks
Aerosol equipment	Aerosol mask, tracheostomy mask, aerosol tubing, sterile water, nebulizers
Miscellaneous	Defibrillator pads, tape, needles, cervical collars, butterfly catheters, syringes, blankets

(Data from reference 19.)

Table 2. Transport Medications

Type	Examples
Narcotic analgesics	Fentanyl, morphine, hydromorphone
Resuscitation medications	Atropine, epinephrine, calcium, sodium bicarbonate
Sedatives	Ketamine, midazolam
Anti-arrythmics	Amiodarone, adenosine, lidocaine
Anti-hypertensives	Labetalol, metoprolol, atenolol
Neuromuscular blockers	Succinylcholine, rocuronium, vecuronium
Reversal agents	Naloxone
Bronchodilators	Albuterol, ipratropium, methylprednisolone
Anti-microbials	Ampicillin, vancomycin, gentamicin, ceftriaxone
Anti-epileptics	Fosphenytoin, lorazepam, phenobarbital, diazepam
Intravenous fluids	Normal saline, lactated ringers, 10% dextrose, 5% dextrose, albumin
Intravenous medications	Dopamine, dobutamine, epinephrine, lidocaine, insulin
Anaphylaxis agents	Racemic epinephrine, cimetidine, diphenhydramine
Miscellaneous	Acetaminophen, activated charcoal, furosemide, heparin, mannitol, 3% saline, calcium gluconate, dextrose

(Data from reference 19.)

Patient Monitoring

Patient monitoring during transport is an important safety issue. Since the evidence shows that bringing the ICU to the patient is important to completing a successful transport, having the monitoring capabilities of the ICU as well as an array of equipment and supplies available on transport would enhance transport safety. Horowitz and Rosenfeld[19] provide the recommended equipment and supplies needed for the transport of children (Tables 1 and 2). It is intuitive that the more information the transport team can obtain about the patient's status before transport, the less likely are unexpected events. In a randomized controlled trial conducted by Stroud et al, continuous noninvasive monitoring of blood pressure was compared to intermittent blood pressure monitoring by cuff during transport of 94 pediatric patients.[20] The hypothesis of the study was that continuous blood pressure monitoring would facilitate more timely interventions and improve outcome. In the continuous measurement group, systolic, diastolic, and mean arterial pressure were lower. This group also received more resuscitation interventions, received more intravenous fluids, and had a significantly shorter hospital stay. However, ICU stay was not different between groups. Although the sample size was relatively small, this study shows that more frequent monitoring may lead to timely interventions and improve outcome during the transport of children.

Adverse Events

Avoiding AEs during inter-hospital transport is the primary goal in providing a safe transport. While many transports are uneventful, sometimes the patient's condition deteriorates as a consequence of disease progression. Patient monitoring is difficult during transport, due to noise, limited space for the caregivers, and low light. In a study from the United Kingdom, 56 children were prospectively monitored for AEs during inter-hospital transport. Seventy-five percent of the patients experienced important complications, with 20% of those being life-threatening. The most common AEs were hypothermia, drug errors, tachycardia, procedure errors, loss of intravenous access, and cyanosis. Life-threatening events included cardiac arrest, bradycardia, hypotension, and inadequate respiratory support as a result of failed oxygen systems and ventilator malfunctions. Although not categorized in this study, the most frequent equipment failure was battery failure.[21] In a much larger study by Orr et al, 1,085 children were prospectively monitored during inter-hospital transport, and unplanned events and 28 day mortality were recorded.[18] Fifty-five of the patients (5%) experienced unplanned events, which included airway events, cardiopulmonary arrest, equipment failure, hypertension, hypotension, loss of intravenous access, and medication error. Ten percent of the patients died during the 28 day assessment period. It should be noted that in both studies, specialized and non-specialized transport teams were utilized, with the majority of the patients experiencing adverse/unplanned events while being transported by the non-specialized teams. One possible reason for the greater number of AEs with the non-specialized groups is that they tend to focus on getting the patient to definitive care quickly, rather than focusing on stabilization before and during transport.

Minimizing Risk

Currently, there is no mandatory regulatory oversight for transport teams. The Commission on Accreditation of Medical Transport Systems is the only accrediting body, but participation is voluntary and only 20% of transport teams have received accreditation. There are few Joint Commission transport related requirements. It is the responsibility of individual facilities to monitor and train transport teams. The literature offers several suggestions for decreasing the rate of complications during transport. Bringing the ICU to the patient is the first step in this process. Getting the patient to the receiving facility quickly is important, but not at the risk of the patient becoming unstable. Enhancing monitoring capabilities may provide caregivers with vital information to avert AEs by providing earlier interventions. Finally, utilizing specialized transport teams that focus on patient stabilization appears to be the most effective way to avoid potential life threatening events during the transport of children.[22]

Specialized Therapy

Nitric oxide (NO) is often used in the ICU for term and near term infants with severe cardiopulmonary dysfunction. Inter-hospital transport of patients requiring this therapy is performed infrequently, but may be the only way the patient can remain stable when transport is unavoidable. Lutman and Petros describe the use of NO during transport and found that it can be used safely during ground, and fixed wing and rotary wing transport, although the delivery and monitoring system can be cumbersome.[23] They also recommend mandatory NO delivery training for caregivers, and found that few patients respond to doses > 20 ppm. For safety purposes, NO and NO_2 levels must be monitored for the patient as well as for the air inside the ambulance or aircraft. Lowe and Trautwein performed a retrospective review of 88 neonates with persistent pulmonary hypertension or severe hypoxic respiratory failure transported to a tertiary hospital for care.[24] Sixty patients were started on NO before transport, and 28 were started at the receiving facility. Mortality and extracorporeal membrane oxygenation (ECMO) use were no different in either group. For the surviving patients who did not receive ECMO, total hospital stay and stay at the receiving hospital were significantly less in those patients who had NO started at the referring hospital before transport.

ECMO

Many hospitals provide ECMO support for children with refractory hemodynamic instability, but lack the ability to transport these patients. Cabrera et al[25] reviewed the transports of 38 such patients over a 15 year period, to determine effectiveness and safety. None of the patients had major complications or died during transport, although the authors were quick to add that mobile ECMO is extremely risk laden and expensive. The logistics for their system were challenging, as the equipment was large and cumbersome, measuring 183 cm long × 66 cm wide × 102 cm high. They recommend maximizing all available therapies before considering transport of these patients. Recently, a portable ECMO device has been approved for use in the United States (Cardiohelp, Maquet, Wayne, New Jersey). The device measures 30 cm × 25 cm × 43 cm, and weighs 10 kg, which greatly enhances the portability and minimizes the footprint inside the transport vehicle, while providing pulmonary and/or circulatory support for up to 6 hours.

Adult Transport

Inter-hospital transfer of adult patients is common, whether the purpose is to receive specialized treatment or diagnostic procedures, or to receive lower levels of care after acute illness has resolved. Nearly 5% of Medicare patients will be transferred from one hospital's ICU to another.[26] Up to one half of patients suffering a myocardial infarction admitted to a hospital that does not have revascularization capabilities will be transferred to another facility.[27,28] Trauma victims are frequently transferred from non-trauma hospitals to trauma centers to receive specialized care. A retrospective study conducted by Haas et al showed that 30% of injured patients admitted to their trauma center were transferred from another facility.[29]

Table 3. Risks and Benefits of Transfer

Risks	
	In-transport complications
	New care team at receiving hospital
	Back-end discontinuity of care: failure to follow up on new problems
	Anxiety due to lack of familiarity with new facility
	Increased distance from family
Benefits	
	Access to newest treatment/equipment
	Hospital skilled at a specific treatment
	Hospital skilled in other areas of care
	Reevaluating/changing treatment plan
	Comfort in receiving the best possible care

(Data from reference 30.)

Risks and Benefits of Transport

The benefits of transport must be weighed against the risks. The anticipated benefit of improved survival provided by transport must greatly exceed the risk of death by precluding transport. The transfer itself imposes its own risk. Table 3 outlines the risk/benefit possibilities of inter-hospital transfer.[30] Although there is often patient benefit from transfer to another facility, it comes at a cost. Golestanian et al[31] conducted an observational study to identify the outcomes and associated costs when patients were transferred to a tertiary facility. The study showed that transferred patients were sicker, as evidenced by higher Acute Physiology and Chronic Health Evaluation III scores. They had higher ICU and hospital mortality, and longer ICU and hospital stay. On average, transferred patient costs were $9,600 higher per ICU admission than non-transferred patients. Interestingly, the patients associated with the highest costs were those with the lowest predicted mortality.

Patient Monitoring

Similar to the transport of children, critically ill adults should have the same level of physiologic monitoring available in the ICU. At a minimum, continuous electrocardiography, pulse oximetry, blood pressure, heart rate, and breathing frequency monitoring should be used. Depending on the patient, monitoring intracranial pressure, pulmonary artery pressure, continuous arterial pressure, or capnography may be beneficial. For mechanically ventilated patients, the endotracheal tube must be properly secured, its position noted prior to transport and monitored until care is transferred at the receiving hospital. Additionally, V_T and airway pressures should be continuously monitored and alarms set appropriately to notify caregivers of problems.[32]

Adverse Events

Transport personnel attempt to avert any problems during patient transport, but inevitably not all transports go smoothly. Adverse events occur, and the role of the caregiver is to recognize problems early and to provide corrective action as soon as possible. Fried et al performed a retrospective review of 2,396 inter-hospital patient ground transfers to determine the reason for transfer and to quantify AEs.[33] Eighty-nine percent of transports were for special diagnostics or specialist care. Twenty-nine of the 2,396 transports reported AEs. The most common events were monitor failure, infusion pump failure, and unspecified ventilator failure. There was one instance of accidental endotracheal tube dislodgement. No patients died during transport. Of patients requiring mechanical ventilation, equipment failure occurred in 9.8% of transfers that did not use a dedicated transport team, as opposed to $< 1\%$ of those that did.

In a prospective audit of ground transports of ICU patients in the Netherlands, Ligtenberg and associates[34] found that AEs occurred in 34 of 100 transports. Interestingly, in 50% of transports, instructions by the intensivist from the referring hospital were ignored during transport. The authors did not indicate the reason for the deviation from the intensivist instructions.

Respiratory problems were the most common reason for transport, followed by multi-system organ failure and sepsis. Sixty-five percent of the patients were mechanically ventilated. Adverse events ranged from equipment malfunctions to severe physiologic instability. After reviewing records, the authors estimated that 70% of the AEs could have been avoided by better preparation prior to the transport, through better communication between referring and receiving hospitals, and by the use of a checklist and protocols.[34]

Transport of Trauma Patients

Barnes et al recorded pulse oximetry and ventilator data from 22 wounded United States soldiers transported via aeromedical evacuation from Iraq to Germany by Air Force Critical Care Air Transport Teams.[35] The aim of the study was to determine the mechanical ventilatory needs, including oxygen requirements, which is essential to resource planning. F_{IO_2}, V_T, minute ventilation, airway pressure, breathing frequency, heart rate, and oxygen saturation were continuously recorded during 117 total flight hours. Set V_T averaged 8 mL/kg or less in 19 of 22 patients. F_{IO_2} ranged from 0.24 to 1.0, with an average of 0.49, which correlated with an average oxygen saturation of 98%. Calculated oxygen usage averaged 3 L/min or less in 68% of the patients (15 of 22). This finding was important in that some commercially available portable oxygen concentrators have the ability to produce up to 3 L/min continuous flow oxygen. This could allow the use of concentrators to provide oxygen to mechanically ventilated patients for transport during mass casualty events, when oxygen resources are scarce.

Although the environment inherent in rotary-wing transport presents the potential for a greater number of AEs, it appears from these reviews that this has not been substantiated in the literature. The occurrence of AEs is comparable with ground transports. The difficulty with direct comparison is lack of consistency or consensus on the definitions used to describe major and minor AEs.

Evidence suggests that there may be a difference in outcome between trauma patients transferred from other facilities and those directly admitted to trauma centers. A meta-analysis of 36 observational studies found that there was no difference in mortality between the 2 groups, although most of the studies did not include patients who died at outlying hospitals. Total costs for transferred patients were higher, and these patients had longer hospital stay than direct admits.[36]

Many patients who are victims of major trauma are taken to trauma centers via rotary-wing transport. The nature of their injuries and the environment within the aircraft, which is noisy and cramped, may increase the chance of AEs. Seymour et al performed a retrospective review of 191 trauma victims transported via rotary-wing aircraft to the hospital of the University of Pennsylvania.[37] In-flight AEs were the primary outcome of the study. There were no major AEs (death, cardiac arrest, or pneumothorax) recorded during the transports. Twenty-two percent of the patients experienced at least one minor AE, such as oxygen desaturation, in-flight ventilator changes, hypotension, bradycardia, or administration of medications due to physiological disturbances or ventilator asynchrony. In a similar study by Lehman et al, AEs were assessed during 149 rotary-wing transports of ill and injured patients during Operation Iraqi Freedom.[38] Fifty-three percent of the patients were mechanically ventilated. Along with the challenges of caring for patients in a civilian rotary-wing aircraft, as described above, caregivers for these patients often must work under low light conditions, to avoid any unnecessary attention from insurgents. At least one equipment failure occurred in 17% of flights, although the types of equipment failures were not characterized. In-flight clinical deterioration, including hypotension, oxygen desaturation, arrhythmia, and tachycardia or bradycardia, occurred on 30% of the flights. On arrival to the receiving facility, 9% of the patients required emergency intervention. No deaths or important morbidities were recorded. Many of these patients were critically ill, with 20% requiring $\geq$ 10 units of packed red blood cells at some point prior to transport.

The Transport Team

Just as with the transport of children, the inter-hospital transport of adults requires a team of highly skilled members. It is recommended that, in addition to the vehicle operator, a minimum of 2 people should accompany the critically ill patient. The team can be a combination of doctors, nurses, respiratory therapists, and paramedics, with each being skilled in advanced airway management and advanced cardiac life support.[33] McGinn and associates retrospectively examined the transport of 192 multiple trauma and isolated head injury patients by a specialized transport team, as described above.[39] All but 4 were ground transports, with the longest transport being 120 miles. Eighty-three of the multiple trauma patients required mechanical ventilation. The authors did not report the number of isolated head trauma patients requiring this type of intervention. One patient died during transport, from progressive disease, rather than the actions of the transport team. Based on the outcomes and lack of serious AEs with these trauma patients, the authors recommend the creation of a central retrieval team associated with the local trauma center. The expertise and experience of these team members could have a positive impact on the outcome of transported trauma and other critically ill patients, which may outweigh the cost of training and maintaining such a team.

Inter-hospital Mechanical Ventilation During Transport

Much has been written about mechanical ventilation practices in the hospital setting, but mechanical ventilation practices during transport and the possible impact on patient outcomes are not well known. It is widely accepted that if lung-protective ventilation strategies are not applied, it can lead to the development of acute lung injury and ARDS.[40,41] Singh et al performed a retrospective review of 1,735 patients requiring mechanical ventilation who were transported outside the hospital setting.[42] Ventilation practices and critical events were assessed. The authors found that 60% of patients were ventilated using volume control, with a mean V_T of 500 mL (6.7 mL/kg). Predicted body weight was not used, because patient height was not recorded. Instead, they used actual body weight minus 20% to determine the V_T delivered. Mean peak inspiratory pressure was 24 cm H_2O, but plateau pressure was not recorded. Mean PEEP was 5 cm H_2O, but 22% were ventilated with PEEP of $<$ 5 cm H_2O, and zero PEEP was used with 3 patients. Overall, 68% of patients at risk of acute lung injury/ARDS were ventilated with the authors' calculated and observed protective ventilation thresholds.

Critical events, defined as hypotension, vasopressor use, oxygen desaturation, or in-transport fatality, occurred during 17% of transports. The most common AE was hypotension, occurring during 11.8% of all transports, which was frequently associated with administration of sedation. Six of 1,735 (0.3%) patients died during transport. The authors concluded that the ventilator settings were reasonable in relation to peak inspiratory pressures and V_T, although the lack of recorded patient height leaves some doubt as to the accuracy of the predicted body weight calculations.

Intra-hospital Transport

The majority of the available literature concerning intra-hospital transport involves adult patients. Therefore, all information provided in this section pertains to adults unless otherwise noted. Advancements in medical care have given caregivers the ability to prolong patients' lives, which has increased the acuity in the ICU. The safest place for these patients is in the stationary ICU, attached to sophisticated devices and monitors, with close attention by the medical staff. Advancements in medical care have been facilitated by increased diagnostic imaging and procedures, such as computed tomography (CT), magnetic resonance imaging (MRI), nuclear medicine imaging, angiography, and gastrointestinal studies, that require that patients be taken to other areas of the hospital. Hurst et al observed 100 consecutive surgical patients requiring intra-hospital transport, and found that 84% of those transports were for abdominal CT scan, head CT scan, or angiography.[43] Transfers from the emergency department to the ICU and/or operating room, or from the ICU to the operating room, also occur with great frequency. It has been suggested that transports within the hospital occur much more often than those outside the hospital, and the in-hospital patients tend to be sicker than those transferred from other facilities.[44] Undoubtedly, the risk of transport must be weighed against the potential benefit for the patient. Waydhas's review found that diagnostic evaluations of patients changed management in 24–70% of cases.[45]

Adverse Events

The first comprehensive review of the literature concerning AEs and their prevention was published by Waydhas in 1999.[45] Fanara et al published a review of AEs and recommendations for intra-hospital transport in the published literature for the decade prior to 2009.[46] Both reviews found that AEs occur in as many as 71% of in-hospital transports. While this appears to be a substantial number, most of the studies reviewed did not differentiate between major and minor AE. Even terminology differed between studies. The terms AEs, unexpected events, and mishaps were often used in the different studies to describe the same events. Given the lack of clear definitions of AEs (major, minor, life threatening, et cetera), it is impossible to standardize the results of all the studies. Table 4 shows examples of AEs as they are described in the studies, as events occurring during transport, although the list is not all-inclusive.

Table 4. Types of Events Reported as Occurring During Transport

Incorrect identification
Systolic blood pressure > 160 or < 90 mm Hg
Heart rate > 100 or < 50 beats/min
Arrhythmia
Temperature < 35°C
Equipment problems
≥ 20 unit change in heart rate, breathing frequency, blood pressure, intracranial pressure
≥ 5% reduction in S_{pO_2}
Hypoxia
Cardiac arrest
Air embolus
Increased intracranial pressure
Spinal destabilization
Hypertension
Hypotension
Electrocardiographic changes
Altered mental status
Need for restraints
Accidental extubation
Monitor battery failure
Code activation
S_{pO_2} < 90%
Loss of airway
Obstructed airway
Respiratory arrest
Ventilator-associated pneumonia
Pneumothorax
Hemodynamic instability
Bleeding
Ventilator failure
Oxygen failure
Death

(Data from references 45 and 46.)

Waydhas[45] was able to broadly categorize AEs in his review. Cardiorespiratory AEs and respiratory complications occurred in up to 47% and 29% of transports, respectively. Equipment complications occurred in 10–34% of transports of mechanically ventilated patients. It was unclear from the reviews what percentage of these complications were from actual ventilator failure. Fanara[46] found only 2 studies that differentiated AE as minor (physiologic change of > 20%) and serious (puts patient's life at risk), and it was reported that a therapeutic intervention was necessary in 80% of all AEs, whether major or minor. Fanara's review found that, in one study, 22% of AEs involved the transport ventilator, with two thirds of those being untimely alarms and gas or electrical failure. The other major sources of equipment-related AEs were infusion pump and intravenous malfunctions. This review identified the number of infusion pumps, use of catecholamines, level of PEEP, and the emergency nature of the transport as risk factors for AEs. Interestingly, a study published by Papson et al found that most AEs were not related to patient instability and did not adversely affect outcomes.[47]

Bercault et al performed a retrospective matched cohort study to evaluate the effect of intra-hospital transport on the incidence of ventilator-associated pneumonia (VAP).[48] The authors reviewed 236 patients, half of whom were transported. Duration of mechanical ventilation, antibiotic therapy duration, indication for ventilator support, age, probability of death, mortality rate, and surgical procedures were not different between the 2 groups. The VAP rate was 26% and 10% for transported and non-transported patients, respectively. Need for reintubation was also found to be a risk factor for developing VAP. The rates of VAP are in concordance with the results of an earlier study published by Kollef and associates in 1997.[49] The increased VAP rates for transported patients may be the result of the need to place the patient supine for diagnostic procedures (eg, CT scan or MRI) and/or the manipulation of the endotracheal tube and ventilator circuit, which may facilitate aspiration of secretions from above the endotracheal tube cuff.

Adverse Event Prevention/Mitigation

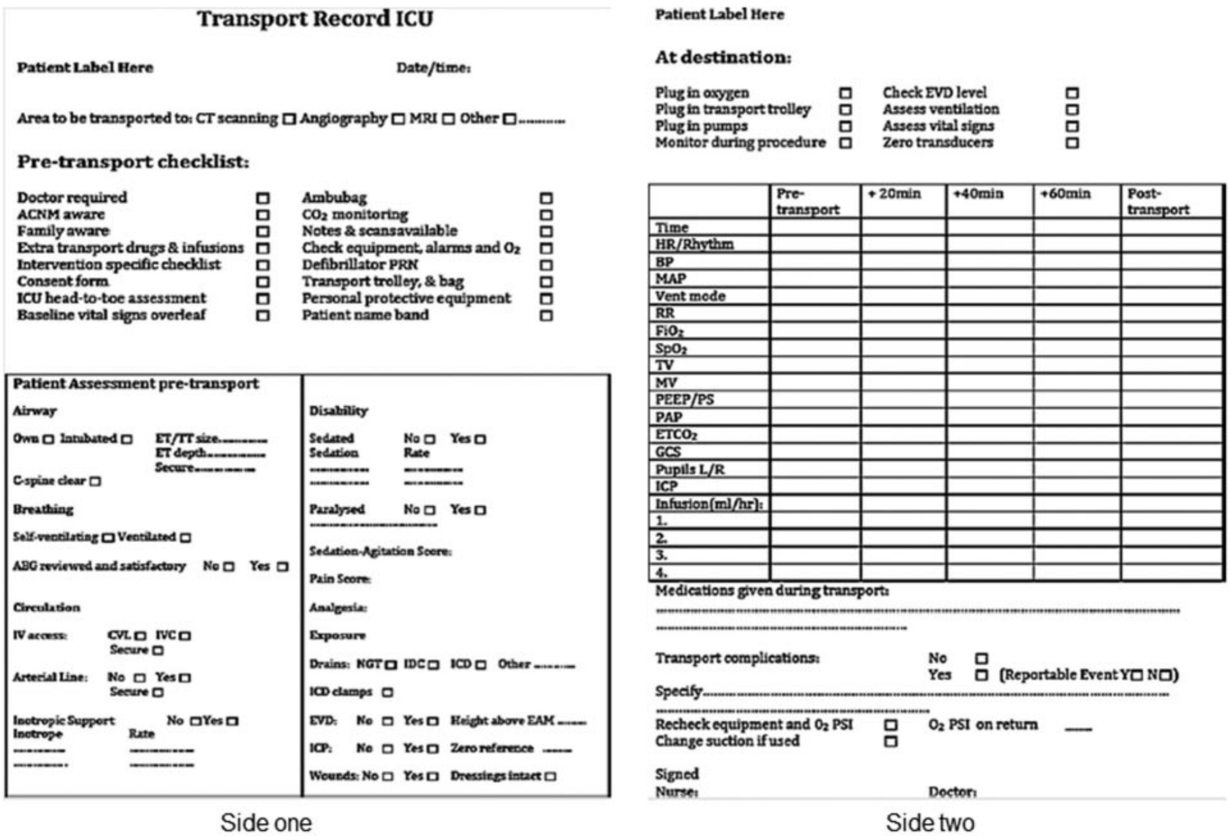
There is no shortage of advice on how to prevent or lessen the impact of transport on patients. There are published guidelines provided by the Society of Critical Care Medicine,[32] American Association for Respiratory Care (AARC),[50] Study Group for Safety in Anesthesia and Intensive Care,[51] Intensive Care Society,[52] and Australasian College for Emergency Medicine,[53] although most of the guidelines are based on small observational or retrospective studies, or expert opinion. It has been suggested that patients should be accompanied by at least 2 caregivers, one of them a critical care nurse and the other either a doctor or a respiratory therapist, with mechanically ventilated patients. Minimum equipment should include a cardiac monitor with defibrillating capability, airway management equipment, manual resuscitator and mask, oxygen supplies, resuscitation drugs, intravenous fluids, battery operated infusion pumps, and a portable ventilator, as required.[45] Preventive factors have also been suggested.[46] Regular patient and equipment checks during transport, careful preparation of the patient, appropriate sedation, use of protocols and check lists, and diagnostic destinations that are easily accessed from the ICU could help limit the number and severity of AEs.

Specialized training has also been recommended for transport of critically ill adult patients.[45-47] Kue et al evaluated AEs during 3,383 intra-hospital transports of patients using a dedicated transport team at Johns Hopkins, which was adopted from their inter-hospital transport team model.[54] The reported AE rate was 1.7%. The most common AEs were hypoxia and hypertension and hypotension. The most common interventions were oxygen and vasopressor manipulations. Even though the low AE rate was impressive, due to the cost of training and maintaining a dedicated transport team it is unlikely this model will be universally adopted unless a clear mortality benefit can be shown through randomized controlled trials.

Pre-transport check lists and in-transport monitoring tools have been suggested as ways to decrease AE during transport.[55-57] Figure 1 shows an example of such a tool.[56] Choi et al reported a decrease in overall AE rate, from 36% to 22%, and a decrease in serious AE rate, from 9% to 5%, with the use of a transport checklist with patients transported from the emergency department to the operating room, MRI, CT, or other interventions, ICU, or general wards.[55]

Capnography

Capnography is widely used in the pre-hospital and emergency department settings and is the standard of care for intubation verification, cardiopulmonary resuscitation effectiveness, neonatal and pediatric transport, military transport, and in the operating room.[58-61] The evidence for when and in which adult transport patients to use capnography is mixed. Walsh et al reviewed published papers concerning capnography use during mechanical ventilation for 1990 to 2010.[62] This review was used as the basis for the AARC clinical practice guideline (CPG) on capnography use. Based on the available evidence, the recommendations from this group are to use capnography/end-tidal CO_2 (P_{ETCO_2}) monitoring for all endotracheal tube confirmations and all transports of patients requiring mechanical ventilation. The CPG also suggests its use for other purposes that are beyond the scope of this paper. Palmon et al conducted a randomized analysis of capnography use to guide ventilation, versus blinded capnography measurements, during 50 patient transports from the operating room to the ICU or the ICU to radiology.[63] Arterial blood gas analyses were done before and after transport, which showed that there was no significant differences in P_{aCO_2} in either group. The recommendation from these results is that capnography is not needed for short transports, although it may be of some benefit to those patients who require tight control of P_{aCO_2} (ie, patients with traumatic brain injury). Two other prospective studies of intubated trauma patients showed that monitoring and guiding ventilation via capnography resulted in a significantly higher



Transport Record ICU

Patient Label Here Date/time:

Area to be transported to: CT scanning ☐ Angiography ☐ MRI ☐ Other ☐..........

Pre-transport checklist:

Doctor required ☐
ACNM aware ☐
Family aware ☐
Extra transport drugs & infusions ☐
Intervention specific checklist ☐
Consent form ☐
ICU head-to-toe assessment ☐
Baseline vital signs overleaf ☐
Ambubag ☐
CO_2 monitoring ☐
Notes & scansavailable ☐
Check equipment, alarms and O_2 ☐
Defibrillator PRN ☐
Transport trolley, & bag ☐
Personal protective equipment ☐
Patient name band ☐

Patient Assessment pre-transport

Airway
Own ☐ Intubated ☐ ET/TT size.......... ET depth.......... Secure..........
C-spine clear ☐

Breathing
Self-ventilating ☐ Ventilated ☐
ABG reviewed and satisfactory No ☐ Yes ☐

Circulation
IV access: CVL ☐ IVC ☐ Secure ☐
Arterial Line: No ☐ Yes ☐ Secure ☐
Inotropic Support No ☐ Yes ☐
Inotrope Rate

Disability
Sedated No ☐ Yes ☐
Sedation Rate
Paralysed No ☐ Yes ☐
Sedation-Agitation Score:
Pain Score:
Analgesia:

Exposure
Drains: NGT ☐ IDC ☐ ICD ☐ Other ....
ICD clamps ☐
EVD: No ☐ Yes ☐ Height above EAM ......
ICP: No ☐ Yes ☐ Zero reference ......
Wounds: No ☐ Yes ☐ Dressings intact ☐

Side one

Patient Label Here

At destination:

Plug in oxygen ☐
Plug in transport trolley ☐
Plug in pumps ☐
Monitor during procedure ☐
Check EVD level ☐
Assess ventilation ☐
Assess vital signs ☐
Zero transducers ☐

	Pre-transport	+ 20min	+40min	+60min	Post-transport
Time					
HR/Rhythm					
BP					
MAP					
Vent mode					
RR					
FiO_2					
SpO_2					
TV					
MV					
PEEP/PS					
PAP					
$ETCO_2$					
GCS					
Pupils L/R					
ICP					
Infusion(ml/hr):					
1.					
2.					
3.					
4.					

Medications given during transport:

Transport complications: No ☐ Yes ☐ (Reportable Event Y☐ N☐)
Specify..........
Recheck equipment and O_2 PSI ☐ O_2 PSI on return ____
Change suction if used ☐

Signed
Nurse: Doctor:

Side two

Fig. 1. Transport checklist and monitoring tool. (From reference 56, with permission.)

incidence of normo-ventilation and a lower incidence of hypo-ventilation during transport.[61,64] Again, the recommendation is for use of capnography with those patients who require close control of P_{aCO_2} (ie, those patients with head injuries).

Ventilators for Transport

Transport ventilators are utilized in prehospital, inter- and intra-hospital transport, military transport, and civilian disaster response. Although important improvements have been made in the performance of transport ventilators, manual resuscitators are still frequently used in the transport of patients to and from the operating room and from the emergency department to the ICU, diagnostics, or the operating room. Although the use of a manual resuscitator is easy and does not require a specialized skill set, alterations in the patient's respiratory status and arterial blood gas values can occur. Gervais et al[65] and Hurst et al[66] observed severe respiratory alkalosis during intra-hospital transport in prospective randomized trials, comparing ventilation with a manual resuscitator to a transport ventilator. Braman and associates also observed the same ventilation and blood gas changes, in addition to hemodynamic changes of hypotension, and arrhythmias that were significantly correlated to blood gas alterations.[67] In a bench model, Hess and Simmons found substantial increases in resistance with some manual resuscitators, which could increase work of breathing in spontaneously breathing patients.[68] Nakamura et al compared ICU physicians ventilating patients during transport with a manual resuscitator to transport with a portable ventilator, and found that the use of a portable ventilator provided more consistent ventilation and that patients were less likely to have a deterioration in oxygenation.[5]

Due to the variability in respiratory parameters and the possible deterioration of blood gases and changes in hemodynamics during manual resuscitator use, portable ventilators have become the preferred method for transporting patients within and outside the hospital. In the prehospital setting the use of a transport ventilator should provide a stable minute ventilation and, more importantly, free up a caregiver to perform other tasks. In the hospital setting a transport ventilator should provide the same settings as on the patient's ICU ventilator. Although there are often more people available to assist with the transport, ICU patients tend to be the most critically ill and are often on more aggressive ventilator settings as a result of their disease process. The AARC CPG provides minimum recommendations for transport ventilators.[50] At a minimum, whether used in or out of the hospital setting, the transport ventilator should provide: battery power sufficient to finish the transport; full ventilatory support; independent control of V_T and breathing frequency; stable V_T with changing lung compliance; a disconnect alarm; airway pressure monitoring; stable PEEP; and F_{IO_2} up to 1.0.[5] Other desirable features for transport ventilators are: rugged, lightweight, and easy to use; low gas consumption; easy to trigger; both volume and pressure modes; adjustable F_{IO_2}; and ability to operate from a 50 psi O_2 source.[69]

Since the late 1990s there have been several papers detailing evaluations of some or all of the performance characteristics of transport ventilators, including triggering, work of breathing, battery life, intrinsic PEEP, and V_T delivery.[70-74] As technology has improved, the performance of many but not all of the devices showed advances with each subsequent model of ventilator introduced. Spurred by the need to transport the sickest of patients for diagnostics and procedures, recent research into the performance of the available transport ventilators has been accomplished.

Chipman and associates evaluated 11 "simple" and 4 "sophisticated" ventilators in a bench and animal model.[75] The sophisticated devices were electrically powered (battery or alternating current), had multiple modes and allowed spontaneous breathing, provided an adjustable range of F_{IO_2} settings, and provided adjustable PEEP. The simple devices lacked one or more of these characteristics. The goals of the study were to determine which ventilators could ventilate both injured and healthy lungs and provide specifically set V_T and breathing frequency settings in both the animal and bench model, and to determine which devices were most appropriate to transport patients in various settings.

The results of the study showed that all the devices were able to ventilate the healthy animals' lungs. Only 4 of the devices were able to ventilate the injured lungs. Breathing frequency settings were the limiting factor in those devices that could not. With the bench evaluation, only 6 devices could achieve the breathing frequency and V_T target settings. In those that could not achieve the targets, it was most often due to variation in V_T, due to increased airway resistance and/or decreased lung compliance. There are important limitations in this study, which include the use of a pediatric sized animal and the use of up to 5 devices on the same animal. Five of the 14 devices were able to operate by battery power alone, but the battery duration differed considerably (75–490 min). The time required to deplete the usable O_2 from an E-size cylinder ranged from 30 to 77 min on F_{IO_2} of 1.0. The investigators determined that, with combined bench and animal testing, only 2 of the 15 transport ventilators met all the targets and would be the most appropriate to use when transporting patients with high ventilatory requirements.

Fig. 2. Portable ventilators used for performance evaluation. EMV+ image courtesy of Impact Instrumentation. LTV 1200 image courtesy of CareFusion. HT70 image courtesy of Newport Medical. T1 image courtesy of Hamilton Medical.

New Generation Transport Ventilators

Over the past few years, several new transport ventilators have been introduced, with claims of increased performance and features over previous models. Our group evaluated 4 of the newest devices available for sale in the United States in a bench study.[76] All devices are considered to be sophisticated, based on the work of Austin et al[6] and Chipman.[75] We evaluated the EMV (Impact Instrumentation, West Caldwell, New Jersey), LTV 1200 (CareFusion, San Diego, California), HT70 (Newport Medical, Costa Mesa, California), and T1 (Hamilton Medical, Reno, Nevada) (Fig. 2) in terms of triggering response, V_T and F_{IO_2} accuracy, gas consumption, and battery duration. Unlike many previous generation transport ventilators, all but one of the devices utilized flow triggering. Historically, flow triggering was superior to pressure triggering due to the slow response time and effort required to open the demand valves. The triggering delay time (Fig. 3), which is a good indicator of the responsiveness to patient effort and work of breathing, was comparable between all 4 devices, including the EMV, which was pressure trig-

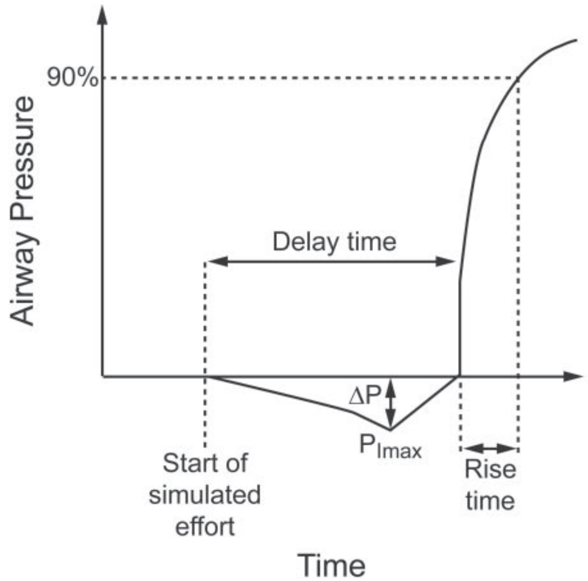


Fig. 3. Triggering evaluation diagram showing delay time, rise time, and maximum negative inspiratory pressure (P_{Imax}).

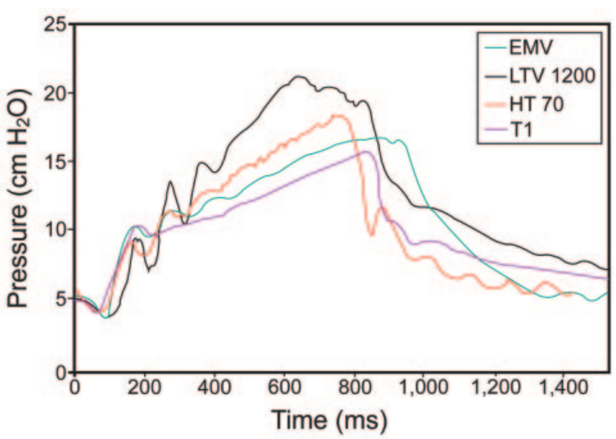


Fig. 4. Representative breaths with each device, using aggressive effort, fast rise time, and pressure support of 10 cm H_2O.

gered. The rise time differed among devices, due to the algorithm used for the rise time profile with each device. Figure 4 shows representative waveforms with each device, using a simulated aggressive inspiratory effort. Interestingly, the ventilators that had the fastest rise time profile overshot the set pressure to a greater degree. V_T accuracy was comparable between ventilators. F_{IO_2} accuracy was comparable among the devices, with the exception of the EMV at $F_{IO_2} < 0.4$ and the LTV 1200 at $F_{IO_2} > 0.6$, which were $> \pm 5\%$ of set F_{IO_2}. Gas consumption and battery duration were the areas that showed the widest differences between devices. Gas consumption differences were due to use of bias flow. Battery duration differences were due to the battery type, operating characteristics, and drive mechanism (continuous or variable speed turbine or compressor). Although there were some differences between the devices tested, unlike previous transport ventilator evaluations, all met or exceeded the minimum requirements outlined in the AARC CPG.

MRI Transport

Arguably the most challenging and potentially dangerous transport in terms of logistics, specialized equipment, and patient safety is the transport for magnetic resonance imaging (MRI). There have been reports of office furniture, hospital beds, oxygen tanks, and medical equipment[77] being pulled into the magnet. Deaths due to objects flying into the magnet, although rare, have also been reported.[78] Caution must be taken when exposing a patient with implantable devices such as pacemakers and defibrillators, as the magnet many render them inoperable. Also the use of other devices, such as reinforced endotracheal tubes and pulmonary artery and central venous catheters that contain metal wires, has the potential to inflict burns on patients due to the wires heating up when in close proximity to the magnet. MRI suites are often far away from patient care areas, and the procedures performed typically are more lengthy than other diagnostic modalities such as CT scans. Therefore, the intravenous pumps, monitors, ventilators, et cetera must be capable of operating on battery power for extended periods if needed. Equipment being considered for use in the MRI suite will fall under one of 3 categories:

- MRI safe: poses no hazards in an MRI environment
- MRI conditional: suitable under certain specified conditions
- MR unsafe: not suitable for use in an MRI environment

MRI safe equipment is the most desirable because it contains no ferrous material and can be used without regard for distance from the magnet or the equipment function being affected. MRI conditional equipment is functional inside the MRI suite but is composed of some ferrous material or has special shielding and must remain a certain distance from the magnet, depending on the device and the magnet strength. MRI conditional equipment tends to be more sophisticated in terms of monitoring, alarms, and operational capability, but some devices must be tethered in place to ensure that they do not drift toward the magnet.[78] In some cases, placing the ventilator outside the MRI suite and using an extremely long circuit may be the only option if the facility does not have the appropriate MRI safe or conditional device. Not being directly near the patient means using a longer ventilator circuit, which may affect V_T due to additional compressible volume lost in the circuit. Patient triggering may also be affected.

MRI is being increasingly used for the diagnosis of disease and injury. Historically, MRI was often delayed due to the patient being considered too sick to transport to the suite and monitor during the test, owing to the poor monitoring capabilities and ventilator performance. During the past decade, monitoring inside the MRI suite has improved and now can include pulse oximetry, electrocardiography, and invasive and noninvasive blood pressure monitoring. Typical MRI safe transport ventilators are powered by pressurized oxygen and have very few, if any, audible and/or visual alarms, making safety a major concern. Gas consumption of these ventilators is very high and can empty a full E-size cylinder in 30 min or less, often necessitating transport with 2 or more cylinders. Advantages of these devices include that most are light and can easily be placed in the patient's bed for transport and placed on the MRI table with the patient during the scan. Triggering and flow capabilities are not conducive to spontaneous breathing with some of these ventilators. Chipman et al evaluated 2 MRI safe ventilators and found that both used 100% oxygen as the power source, and had limited monitoring capability. One had high pressure and disconnect alarms, and the other had no alarms.[75] It was also found that breathing frequency and/or V_T changed in response to changes in airway resistance and lung compliance.

MRI conditional ventilators are suitable to use in the MRI suite, but with some restrictions. Since these ventilators often contain some components that are ferrous based, the main restriction is to have the device positioned a certain distance away from the magnet, and usually tethered to prevent drifting toward the magnet. The advantage of these ventilators is enhanced monitoring and alarm capabilities and better patient/ventilator interaction, due to their being ICU comparable. The disadvantage is the requirement for an extra-long ventilator circuit, due to the required distance away from the magnet. Ventilator triggering may be compromised and work of breathing may be increased with use of the longer circuit.

Given the limitations of transport ventilators suitable for MRI use and the monitoring capabilities during the procedure, the decision must be made as to when the transport can be safely accomplished. Since MRI is typically not a life-saving intervention, ideally only "stable" patients would be transported to MRI, although stability as a criterion is open to considerable interpretation. In our trauma/surgical ICU we have informal criteria, although not in policy form, that we believe describe a patient who is stable enough to endure the transport with the least amount of risk. The patient should have stable vital signs without the use of vasopressors or inotropes, blood pressure that can tolerate sedation, set ventilator breathing frequency ≤ 20 breaths/min, PEEP ≤ 10 cm H_2O, and $F_{IO_2} \leq 0.6$. Even with fairly conservative criteria, the potential remains for the patient's condition to deteriorate, so diligent use of the monitoring available during MRI is warranted.

Summary

Whether outside or within the hospital, patient transport remains a necessary facet of today's healthcare environment. Advanced diagnostics and centers specializing in the care of difficult diseases and conditions require that patients be moved, often when they are not stable. The additional requirement for mechanical ventilation when transporting the sickest patients renders an already potentially unsafe scenario even more so. The performance of transport equipment, including ventilators, is improving, which enables caregivers to get closer to the goal of bringing the ICU to the patient throughout the transport. Careful planning, monitoring, and resource allocation, including personnel appropriate for the transport, are extremely important to ensure patients remain as safe as possible.

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Discussion

Kacmarek: You said the average O_2 flow on military transports is 3 L/min?

Blakeman: Yes, in 68% of the patients.

Kacmarek: OK. An E-size cylinder contains about 660 L: that's 3.5 hours of O_2 per cylinder. Why go through the problem of dealing with a concentrator, which is much more expensive than E cylinders, and potentially less reliable, if you've got 3.5 hours per cylinder? Even flying from Iraq to Germany requires only a few cylinders.

Blakeman: Good point; it's about a 9-hour flight. The reason is that, in the military's eyes, if they didn't *have* to take O_2 tanks, they wouldn't, because of the danger, which is an important issue. If they had 3 patients and they could take 3 E-size cylinders, it would be perfect, but they would prefer not to take any; this comes from the military side. In the hospital or even prehospital setting maybe they don't mind carrying a couple of E cylinders, but not on military transports.

Branson: The idea, Bob, is that in an immature theater or mass casualty situation, you always have electricity before you have compressed O_2. The thought is that, if you have a small concentrator and a ventilator, you could provide a little bit of O_2 for several patients and maintain oxygenation, which can be life-saving. The idea of the concentrator and ventilator together is for before the liquid oxygen systems or cylinders show up. What can you do if you just have electricity? And right now they're not allowed to have cylinders on the aircraft with the patient at the same time. In the bigger aircraft they have liquid oxygen systems, but some of the helicopters and smaller aircraft don't have access to O_2 at all.

Blakeman: When an Israeli army medic picks up a patient in the field, right now they use no O_2. They don't carry any cylinders. If their patient needs O_2, too bad, they don't carry it. They do the best they can with what they have.

MacIntyre: This may be a naïve question to the respiratory therapists in the group, but I remember a case back home a couple years ago where somebody who required O_2 was transported down to radiology, and while they were in the waiting area with nobody around, the O_2 tank ran out and the patient was found dead. Are there gadgets you could put on the cylinders to alert you that you're low on O_2?

Blakeman: Unfortunately, that's part of the problem. Time didn't permit me to talk much about MRI transport ventilators, but we all know they're not good. The one we have doesn't have any audible alarms.

MacIntyre: But how about just the tank?

Blakeman: There's nothing I know of that can alert us. What I want to know is where was the therapist when that incident happened?

MacIntyre: Don't go there.

Blakeman: OK. My point is that in the United States there should always be a therapist with the patient, but I understand. As far as I know there's nothing quite like that. One of the MRI-safe ventilators has a low-pressure alarm. Rich?

Branson: No, I'm not aware of anything either. It's an interesting idea. A long time ago I saw my next-door neighbor collapse in the driveway. I picked her up and put her in her house and called 911, and had started mouth-to-mouth resuscitation and CPR on her and she revived. Then the paramedics showed up and started doing everything else, but I noticed that after they were there for about 10 minutes, their O_2, cylinder was completely empty. I talked with Dr Bird about making some kind of device that would chirp on the regulator when gas pressure was low. Regulators are commodities; nobody wants to make something like that.

Kallet: Did you say that about 70% of the transport problems are related to poor planning?

Blakeman: Yes. That indicates that they aren't using a check sheet that asks, do you have the right drugs, do you have enough O_2, are all your batteries (for the monitors and ventilator) charged, and so forth? That was what I was referring to.

Kallet: How much of that is directly related to respiratory care?

Blakeman: It was not reported. It was just noted as "equipment problems".[1]

Kallet: Your conclusion about the relationship between VAP and transport was that it might not be cause and effect, but just that these patients are sicker and they require transport.

Blakeman: I think it's both cause and effect. We're changing positions on these patients and laying them down flat. If we do that 6 or 8 times during their stay, there's no way, in my opinion, that 90% of them aren't going to get pneumonia.

Kallet: In Taiwan, in a nursing practice study, they did mouth suctioning before transport, just a very quick suctioning of the back of the mouth, and supposedly it decreased their VAP rate.[2]

Blakeman: For transport? I could see where that probably doesn't happen enough. A lot of that comes from when we try to decontaminate the mouth with chlorhexidine, mouth suctioning, et cetera, and if it doesn't get done, whether you transport them or not, they'll get VAP. They did not address that issue in the study: just transporting versus not transporting.[3]

Kallet: My experience as a bedside clinician has always been that, even with monitoring cuff pressure over the course of a 12 hour shift, you usually have to put one or two mL of air in the cuff every 4 hours or so, apparently because of tiny leaks. In that context, transporting a supine patient, schlepping them back and forth on a stretcher, and moving them onto and off of the CT or MRI table, the chances are pretty high that they'll have some type of aspiration.

Blakeman: The protocol at our hospital is that we check cuff pressure every 12 hours. But, like you say, do they check them routinely before and after transport? No. That's a good point.

Kacmarek: If you put an endotracheal tube in a simulated trachea, inflate the cuff appropriately, put fluid above the cuff, and then tug a little on the tube, you'll be amazed at how much fluid moves right past the cuff as soon as you jerk it. Any time you move a patient and there's any kind of torque put on the airway, you immediately allow rapid aspiration of the fluid sitting above the cuff. If you very carefully suctioned prior to transport, you might reduce it, but it's pretty hard to suction all of the secretions that sit above a cuff.

Blakeman: Those subglottic suction tubes have been, in our experience, suboptimal. We just can't get them to work very well consistently.

Kallet: Another point is that, with daily sedation interruptions, particularly with neuro-trauma patients, you wake them up and often they're gasping. Several of our therapists think that causes VAP. You can see this tracheal tugging: they're thrashing around and the tube shifts back and forth.

Blakeman: You're right. Those patients, if you wake them up at all, they tend to be pretty wild.

Gajic: Telemedicine has been increasingly used across hospitals, but I have read nothing about the possibility of providing oversight to transport, especially these critically ill ventilated patients: a visual communication with a specialist who understands.

Blakeman: During the transport?

Gajic: During transport as well, absolutely, or when we accept a patient from the referring hospital. I am thinking that if telemedicine helps remind us what to do with the ventilator bundle, maybe it can also be used during the critical hours of transport.

Blakeman: You're talking about having visual monitoring, correct? I've discussed that with therapists, and their feeling is that big brother will be watching them every minute. They already feel like that now. Having somebody watch me doing the transport could be a bit unnerving.

Gajic: No, just as a readily available decision support when needed.

Blakeman: I understand what you're saying, but I think you'll have the same problem. That would work in the hospital, but I don't know if it would work inter-hospital or prehospital, or in the air. It's possible, and it may come to that. We don't have e-monitoring or anything like that yet at our facility.

Berra: Aspiration is a key factor, but I think that changes in oral flora are the most important feature. In fact, unperceived aspiration is not unusual even in a healthy subject, especially during the night. Indeed, oral care is of the greatest importance to prevent oral colonization from pathogens in intubated and mechanically ventilated patients.

Blakeman: Right, and that's true with any patient, whether they're being transported or not. As Rich Kallet said, there may not be a cause and effect, but there's an association there, and whether it's changing flora or not, there's still association between the two.

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