Chapter 47. Safety During Transport of Critically Ill Patients

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Background

The care of acutely ill patients routinely includes transportation, both within a given hospital to undergo tests and procedures, and between hospitals, as patients may require transfer to other facilities for specialized services. Critically ill patients in particular commonly require such transfers and are at high risk for complications en route.[1-4] Developing practices to reduce or minimize this necessary risk represents a potentially important area of patient safety research. This chapter focuses on transportation of critically ill patients by health professionals (paramedics, nurses, physicians and/or respiratory therapists) between hospitals (to receive higher levels of care) and within the hospital (for diagnostic or therapeutic procedures).

Stabilization before transport, in the field or in the transferring hospital, and the mode of transferring patients from the field to specialized centers also present important research and policy questions.[5] However, we regarded these issues as clinical research topics and quality improvement issues for the fields of pre-hospital and emergency medicine, rather than patient safety in general, and so do not review this literature here.

Practice Description

Intrahospital transport refers to transportation of patients within a hospital for the purpose of undergoing diagnostic or therapeutic procedures or transfer to a specialized unit. In the context of this chapter, this generally involves movement of critically ill patients from intensive care areas of the hospital (including intensive care units, emergency departments, operating theaters and recovery rooms) to areas typically not involved in the delivery of such care (eg, a hospital radiology department). Equipment and staffing used for intrahospital transport varies by hospital, clinical service and patient acuity. Studies of intrahospital transport have mainly focused on the adequacy of patient monitoring and ventilator support. The specific practices evaluated in this chapter include:

- The continued use of mechanical ventilation instead of switching to manual ventilation. Manual ventilation involves a self-inflating bag with or without a volumeter, while mechanical ventilation consists of a portable, time-cycled, volume-constant transport ventilator.
- The use of specialized transfer units during intrahospital transport. The unit is attached to the patient's bed and contains all equipment necessary to meet the patient's needs (ventilation, monitoring and infusion of drugs) in the ICU and during transport. The unit works as a stand-alone unit.

Interhospital transport refers to transportation of patients between hospitals by ground or air ambulance. Interhospital transport teams vary widely in composition, training and experience. The transport team does not always include a physician; even when a physician is present, his or her training may not include skills necessary for this task.[6-8] Nurses and respiratory therapists frequently accompany critically ill patients during interhospital transport. Some paramedics

receive special training in skills necessary for the interhospital transport of critically ill patients.[9] As with physicians, the training of nurses and respiratory therapists assigned responsibility for interhospital transport varies widely. Equipment used during interhospital transport also varies widely,[6,7] but the practices evaluated in the literature mainly relate to the use of *specialized transport teams*.

Specialized transport teams characteristically receive consistent and high levels of training and experience in the transportation of critically ill patients,[10-12] compared with teams assembled *ad hoc*. Further details of the composition of these teams are presented in connection with the specific studies reviewed below (see Table 47.1). Because of the relative paucity of studies of practices for improving the safety of patient transport, we have reviewed the pediatric and adult literature together.

Prevalence and Severity of the Target Safety Problem

Adverse events during transport of critically ill patients fall into two general categories: mishaps related to intensive care (eg, lead disconnections, loss of battery power, loss of intravenous access, accidental extubation, occlusion of the endotracheal tube, or exhaustion of oxygen supply), and physiologic deteriorations related to critical illness (eg, worsening hypotension or hypoxemia). Unfortunately many studies do not distinguish clearly between these 2 categories. Further complicating assessments of patient transport as a safety problem is the confounding effect of patient selection, as patents requiring intra- or interhospital transport likely represent a sicker patient population than unselected critically ill patients. In fact, one case-control study reported no differences in adverse events (equipment-related or physiologic) in critically ill adults during the period of intrahospital transportation as compared to matched subjects in the ICU.[13]

Death during transport is a rare event. The majority of studies reported no mortality during intrahospital transport[13-17] or interhospital transport,[18,19] and some do not mention deaths.21-23,24

For intrahospital transport of critically ill patients, reported rates of adverse events range from 5.9% to 66%.[13,14,16,21,22,25] (We could find no comparable reports of event rates for critically ill children.) Much of this variation undoubtedly reflects definitional differences, but differences in patient populations also contribute to this wide range. For instance, a prospective study of 50 high-risk adult cardiac patients reported arrhythmias in 84% of patients, with 52% of these arrhythmias providing an indication for emergency treatment.[17] These event rates are clearly much higher than would be observed in an unselected population of critically patients. Similarly, Insel et al showed a significantly higher incidence of hemodynamic changes requiring therapeutic intervention when intrahospital transport involved transfers from the operating room to the ICU compared with patients transported from the ICU to diagnostic procedures.[26]

In contrast to the above, the literature on adverse events during interhospital transport has generally involved critically ill children, not adults. Reported rates of adverse events during pediatric interhospital transport range from 0 to 75%.[2,10-12,19,24,27-29] In one of these studies, a prospective cohort design reported a morbidity ratio of 1.85 (95% CI: 1.12-3.06) for pediatric patients transported from another hospital to the pediatric ICU (PICU) as compared with those admitted directly (emergency room and wards). Importantly, this increased morbidity reflected an increased rate of “intensive care events” such as plugged endotracheal tubes and loss of intravenous access, not an increase in physiologic events. Patients experiencing such adverse events tended to have higher morbidity scores (on the PRISM scale) and lower therapy level (TISS) scores prior to transport. Thus, as noted above, confounding of differences in patient

sickness and intensity of therapy could account for much of the observed variation in transport-associated morbidity.[24]

Opportunity for Impact

A survey conducted in 1990 to review voluntary compliance with the American Academy of Pediatrics (AAP) recommendations to include physicians with higher level of training (at least 3rd year residency) reported that only 28% of hospitals with a pediatric critical care transport team met this recommendation. All teams included a nurse with pediatric experience and a varying degree of training, and 50% of teams included a respiratory therapist.[7]

Subchapter 47.1. Interhospital Transport

Study Designs and Outcomes

We identified 3 studies with at least a Level 3 study design and Level 2 outcomes (see Table 47.1). Two of these studies[10,12] involved pediatric patients. One12 reported the prospective comparison of outcomes for high-risk pediatric patients admitted to two different ICU's, one of which employed a specialized transport team, while the other followed the standard practice of using non-specialized teams. The specialized team consisted of a second-year pediatric resident and a pediatric ICU nurse, both trained in pediatric advanced life support, and a respiratory therapist with pediatric experience. Non-specialized teams varied in composition—a physician was not always present and level of training in pediatric care for other personnel was not standardized. The other pediatric study, from England,[10] retrospectively compared outcomes using a specialized team for the transport of intubated newborns from hospitals within 80 miles to a NICU at a referral center to outcomes during a control period in which transport was performed by *ad hoc* doctor/nurse teams. The specialized teams included physicians with more years of experience and dedicated transport nurses with specialized training, as well as slight equipment improvements (humidifier for ventilator and invasive/noninvasive blood pressure monitoring).

The third study (the one involving adults) describes the experience of a London teaching hospital that receives critically ill patients from other facilities by two methods: either accompanied by the receiving hospital's special retrieval team consisting of an ICU physician, nurse, and medical physics technician (a technician to fix and maintain equipment) or standard ambulance transport, with an escorting physician supplied by the referring hospital.

The 2 pediatric studies[10,12] reported adverse events during transportation. We counted adverse events related to intensive care (eg, accidental extubation) as Level 2 and physiologic events (eg, ph < 7.2) as Level 3. (A case could be made for classifying both types of adverse events as Level 3, as neither has a clearly established relationship to adverse events of interest). All studies provided information on case mix in the study and control groups.

Evidence for Effectiveness of the Practice

Although of theoretical and practical concern, the literature to support the scope, frequency and outcome of adverse events during transportation is sparse and methodologically weak. Most studies are small descriptive studies of local practices. Factors that limit comparability between studies include a variety of definitions for transport-related adverse events, unclear descriptions of transport team training and experience, diverse equipment

availability and different scoring systems for severity of illness (APACHE II, APACHE III, Glasgow Coma Scale, PRISM, etc). Many confounders affect the evaluation of transportation of a critically ill patient, among them selection bias, the intervention received at primary hospital, time spent at primary hospital, adequate stabilization before transport and duration of transport.

As shown in Table 47.1, 2 studies involving pediatric populations revealed reductions in intensive care-related adverse events through the use of specialized teams for interhospital transport.[10, 12] In one of the studies, patients transported by the standard (non-specialized) team were older and more likely to have trauma as a diagnosis.12 This difference in patient populations clearly limits the ability to interpret the results, although the direction of bias this might introduce is not clear. The other pediatric study [10] reported no significant differences in basic clinical and demographic factors between the 2 patient populations, but did not report PRISM scores.

The single study in adults did not report intensive care-related adverse events, but did observe significant reductions in surrogate physiologic markers and a non-significant reduction in mortality within 12 hours of arrival at the receiving facility. Although an observational study, there were no differences in the patient populations in terms of demographic factors, basic physiology measurements (FiO_2, PaO_2, $PaCO_2$, PaO_2/FiO_2, MAP, heart rate and temperature) or sophisticated measures of severity of illness (APACHE II, Simplified Acute Physiological Score-SAPS II).

Studies were underpowered to detect significant mortality differences.

Potential for Harm

A delay in the transfer of critically ill patients to referral hospitals because the specialized team is not available in timely fashion could create a potential for harm although one study showed no delay or cancellation due to unavailability of specialist team.[11]

Costs and Implementation

Although no firm recommendation can be made, the costs and implementation requirements may only be feasible for tertiary centers that have enough volume to justify the investment in human and physical resources. Time out of hospital will vary depending on the time required to stabilize the patient—not the focus of our study. (One study reported an increase in stabilization time from 80-105 minutes ($p<0.0001$) after the implementation of a specialized team[10] and another reported no difference in duration of transport between non-specialized and specialized team.[12]) The third study did not mention duration of transport.

Comment

This practice has high face validity, and what little evidence exists does support the practice. No direct potential for harm exists, but adopting this practice without further study might unnecessarily strain scarce health care resources. Moreover, if adopted as a standard of care, lack of timely availability of designated transport personnel may become a factor in delaying inter-facility transfers. For some critically ill patients, the time lost in assembling the transport team may have a greater negative impact than the safety gained by their eventual presence. Further research on this topic is required, fundamentally controlling for confounders and improving outcome measures to include morbidity. Two areas that have evolved enormously over the last 2 decades are training requirements of health personnel and the quality of transport monitoring and ventilation equipment.

Subchapter 47.2. Intrahospital Transport

Study Designs and Outcomes

As shown in Table 47.2, the 3 studies of manual versus mechanical ventilation employed a randomized (or quasi-randomized) controlled design. Randomization procedures were not described in two studies[30, 31] and used the last digit of the patient record in one study.[32] The quasi-randomized study[32] implemented a crossover design using manual ventilation or transport ventilator on one leg of the journey and vice-versa on the other leg.

Two studies reported on Level 2 and 3 outcomes[30, 32] and one on level 3 outcomes,[31] venous pressure, oxygen saturation, $PetCO_2$ and mean airway pressure during transport. All studies report on before-after variation, one study[30] also reported on minute variations during the first 8 minutes of transport (see Table 47.2). Only one study reported scores for severity of illness (PRISM).[30] Case-mix was inadequately reported in one study[31] and not reported in another.[32]

It is worth briefly noting a third practice which involves the use of mobile bed/monitor units versus standard procedure for intrahospital transportation. Studies on this topic are limited to descriptive experiences of local practice with no definition or systematic evaluation of adverse events,[17,33-35] so these practices were not reviewed further.

Evidence for Effectiveness of the Practice

The clinical significance of the hyperventilation observed in manually ventilated patients during intrahospital transportation has yet to be determined. Mechanical ventilation was associated with respiratory alkalosis when precision of ventilatory settings was inaccurate. No adverse effect, (ie, morbidity) was observed as a result of the method of ventilation. Use of a volumeter when manually ventilating a patient reduced the risk of hyperventilation. Studies were underpowered to detect significant mortality differences.

Potential for Harm

Inadequate maintenance and/or precision of transport ventilator may create an opportunity for harm.

Costs and Implementation

Portable mechanical ventilators are much more expensive, require more hours of training to manipulate and frequent use to maintain experience. Costs were not mentioned.

Comment

One randomized controlled trial in pediatric postoperative cardiac patients showed an increase in markers of hyperventilation for patients in the manually-ventilated group. Otherwise, manual ventilation appears to achieve results comparable to portable mechanical ventilation. Use of a volumeter when manually ventilating patients, and the addition of a blender to reduce FiO_2 when manually ventilating neonates,[30] may adequately reduce the risks of hyperventilation, rendering mechanical ventilation during intrahospital transport unnecessary.

Table 47.1. Specialized transport teams versus standard care for interhospital transport

Study Setting	Study Design, Outcomes	Main Results
Critically ill children transported to two PICU's in Albany, NY (specialized transport team) and Syracuse, NY (standard care): 1992-94[12]	Level 3, Level 2	Significant decrease adverse event related to intensive care for patients transported with specialized team compared to standard care: 1/47 (2%) vs. 18/92 (20%), $p<0.05$ For physiologic adverse events the decrease was minimal and not significant: 5/47 (11%) vs. 11/92 (12%) $p>0.05$
Intubated newborns transported by specialized doctor/nurse team (increased training and experience) to NICU in Nottingham, England: 1994-95, and historical control period during which non-specialized (*ad hoc*) doctor/nurse team transported patients to the same NICU: 1991-93[10]	Level 3, Levels 2&3†	Nonsignificant reduction in endotracheal tube-related events (blocked or dislodged endotracheal tubes): 0/146 (95% CI: 0-3.2%) patients transported by specialized teams vs. 3/73 (4.1%, 95% CI: 1.1-12.3%) by ad hoc teams Reductions also observed in adverse physiologic end-points; such as abnormal ph ($p<0.05$) and abnormal temperature ($p<0.001$)
Critically ill adults transported to a university ICU in London: 1996-1997; specialist team with mobile ICU compared with emergency ambulance with medical escort[11]	Level 3, Levels 1&3	Mortality within 12h of arrival at the receiving facility: 5/168 (3%, 95% CI: 1.1-7.2%) vs. 7/91 (7.7%, 95% CI: 3.4-15.7%) 70% reduction in number of patients arriving in serious metabolic acidosis when transported by a specialist team ($p=0.008$): pH<7.1: 5/168 (3%) vs. 10/91 (11%) 50% reduction in number of patients arriving in a dangerously hypotensive state when transported by a specialist team ($p=0.03$): MAP<60mmHg 15/168 (8.9%) vs. 16/91 (17.6%)

Table 47.2 Manual versus mechanical ventilation for intrahospital transportation

Study Setting	Study Design, Outcomes	Main Results
30 ventilator dependent, critically ill adults in ICU: manually ventilated with self-inflating bag group, manually ventilated self-inflating bag with volumeter, and mechanically ventilated group (Federal Republic of Germany)[31]	Level 1, Level 3	Pre/post transport: $PaCO_2$ decreased from 41±2 to 34±2 ($p<0.01$) and pH increased from 7.40±0.02 to 7.46±0.03 ($p<0.05$) after manual ventilation, and $PaCO_2$ decreased from 40±1 to 35±2 ($p<0.01$) and pH increased from 7.42±0.01 to 7.47±0.01 ($p<0.01$) after using transport ventilator. No differences were observed in the group that received manual ventilation with a volumeter.
28 critically ill adults and adolescents transported from emergency department for diagnostic procedures in a University Hospital: manual ventilation versus transport ventilator (US)[32]	Level 1, Level 2&3	Pre/post transport: $PaCO_2$ decreased from 39±4 to 30±3 ($p<0.05$) and pH increased from 7.39±0.03 to 7.51±0.02 ($p<0.05$) after manual ventilation as compared to conventional ventilation. No differences between transport mechanical ventilation and conventional ventilation. No significant changes in oxygenation, heart rate or blood pressure in either group. 2/14 patients had supraventricular tachycardia (no clinical significance) during transport in the manually ventilated group and none in the transport ventilator group.
51 pediatric postoperative cardiac surgery patients who were transported within hospital while intubated: manually ventilated versus mechanically ventilated (US)[30]	Level 1, Level 2&3	Pre/post transport: Statistically significant decrease in $PetCO_2$ [32±1.6 to 26±1.4] in manually ventilated as compared to mechanically ventilated [35±1.1 to33±1.7] patients ($p=0.02$). No significant difference in other ventilatory parameters, airway pressure and hemodynamic parameters. Minute-to-minute variations: greater amount of fluctuation and lower mean values in $PetCO_2$ ($p<0.05$) in the manually ventilated group when compared to the mechanically ventilated group. No clinical changes reported.

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