Intrahospital transport of critically ill patients

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Background: This review on the current literature of the intrahospital transport of critically ill patients addresses type and incidence of adverse effects, risk factors and risk assessment, and the available information on efficiency and cost-effectiveness of transferring such patients for diagnostic or therapeutic interventions within hospital. Methods and guidelines to prevent or reduce potential hazards and complications are provided.

Methods: A Medline search was performed using the terms 'critical illness', 'transport of patients', 'patient transfer', 'critical care', 'monitoring' and 'intrahospital transport', and all information concerning the intrahospital transport of patients was considered.

Results: Adverse effects may occur in up to 70% of transports. They include a change in heart rate, arterial hypotension and hypertension, increased intracranial pressure, arrhythmias, cardiac arrest and a change in respiratory rate, hypocapnia and hypercapnia, and significant hypoxaemia. No transport-related deaths have been reported. In up to one-third of cases mishaps during transport were equipment related. A long-term deterioration of respiratory function was observed in 12% of cases. Patient-related risk indicators were found to be a high Therapeutic Intervention Severity Score, mechanical ventilation, ventilation with positive end-expiratory pressure and high injury severity score. Patients' age, duration of transport, destination of transport, Acute Physiology and Chronic Health Evaluation II score, personnel accompanying the patient and other factors were not found to correlate with an increased rate of complications. Transports for diagnostic procedures resulted in a change in patient management in 40–50% of cases, indicating a good risk:benefit ratio.

Conclusions: To prevent adverse effects of intrahospital transports, guidelines concerning the organization of transports, the personnel, equipment and monitoring should be followed. In particular, the presence of a critical care physician during transport, proper equipment to monitor vital functions and to treat such disturbances immediately, and close control of the patient's ventilation appear to be of major importance. It appears useful to use specifically constructed carts including standard intensive care unit ventilators in a selected group of patients. To further reduce the rate of inadvertent mishaps resulting from transports, alternative diagnostic modalities or techniques and performing surgical procedures in the intensive care unit should be considered.

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Introduction

The safest place for the critically ill patient is stationary in the intensive care unit (ICU), connected to a sophisticated ventilator with all infusion pumps running smoothly, complete monitoring installed, and with a nurse present to care for the patient. Unless there are nursing, diagnostic or therapeutic procedures going on, the patient is in a more or less calm and controlled environment. In the case of an emergency, a team of well-trained nurses and physicians is available with all the necessary equipment at hand.

There may be situations when the patient has to leave these secure surroundings to be transported to the radiology department, the operating room or to some other department within the hospital, however. This transport may create an increased risk for mishaps and adverse events by disconnecting such critically ill individuals from the equipment in the ICU to some kind of transport gear, shifting them to another stretcher, and reducing the personal and the equipment around.

This article gives a review on the current literature of the intrahospital transport of critically ill patients. Its objective is to provide the reader with information about type and incidence of adverse effects, risk factors and assessment, and the efficiency and cost-effectiveness of

ICU = intensive care unit; pCO_2 = partial carbon dioxide tension; APACHE = Acute Physiology and Chronic Health Evaluation.

transferring such patients for diagnostic or therapeutic interventions within hospital. Furthermore, methods and guidelines to perform such transports safely are addressed, covering the personnel accompanying the patient, the equipment for monitoring the patient and treating complications, and the ventilator to be used.

A Medline search including the terms 'critical illness', 'transport of patients', 'patient transfer', 'critical care', 'monitoring' and 'intrahospital transport' was performed, and all information concerning the intrahospital transport of patients was considered, excluding review articles. Only studies published in the English or German language were used, however.

Adverse effects

Adverse effects may affect a variety of organ systems, may be related to the movement of the patient (dislocation of installations, drips, etc) or may be caused by equipment malfunctions. Furthermore, the reduced availability of personal, equipment and monitoring away from the ICU may be detrimental. These adverse effects may be of short-term or long-term duration, or require interventions.

The first indications that transport within hospital is a potentially dangerous undertaking were provided in the early 1970s, when arrhythmias were encountered in up to 84% of transports of patients with high-risk cardiac disease, which required emergency therapy in 44% of cases [1]. Significant complications such as bleeding and hypotension were observed in seven out of 33 transports of patients from the operating room to the ICU [2]. An early report compared the transport of postoperative patients from the operating room to the ICU with that of patients transferred from the ICU for diagnostic tests [3]. No complications or haemodynamic deteriorations were noted in the latter group, whereas the postoperative patients were subject to hypotension, hypertension or arrhythmias in 44% of the cases.

In more recent reports [4–9] the overall incidence of adverse effects during intrahospital transport was found to range from 6 to 71.1% (Table 1) [3–13]. An exact description of the severity of these complications is lacking in many studies and definitions differ in the others. However, major adverse effects with life-threatening disturbances that require interventions such as administration of vasoactive drugs, fluid boluses or even cardiopulmonary resuscitation, as well as those related to the disconnection of ventilatory, intravenous or intra-arterial lines, may be as high as 8% [4,6,9,10].

The majority of the studies were done with trauma and surgical patients, but medical patients and children were included in some. Although the highest rate of adverse events was noted in the one study with children [4], no clear relation of frequency and type of complication with the case-mix can be deduced. Neither the indication leading to the diagnostic evaluation nor the type of diagnostic procedure performed have been found to correlate with the type, number or severity of complications during transport [7,9]. In most of the studies the patient was accompanied by at least one nurse and one physician, who were sometimes supplemented with a respiratory therapist. The number of personnel involved in the transport was not found to influence the rate of complications [4]. Smith *et al* [6] observed a trend towards a reduced incidence of adverse effects if a physician was present during transport. In a recent study [11] a low rate of complications in 15.5% of patients was observed if a specially trained transport team accompanied the patient.

Cardiocirculatory adverse effects were noted in 0–47% of patients [7,9,12,13]. In particular, hypotension (a mean fall in systolic blood pressure of 40 mmHg or more) and arrhythmias were predominant in mechanically ventilated patients of a combined medical and surgical ICU [13]. Those events were closely related to periods of inadvertant hypoventilation or hyperventilation, with changes of the partial carbon dioxide tension (pCO_2) of up to 27 mmHg. In trauma patients transported for diagnostic studies, a change in blood pressure (of more than 20 mmHg) and in pulse rate (of more than 20 beats/min) was observed in 40 and 21% of the transports, respectively [7], which is quite similar to the findings of other investigators (Table 1) [8]. Although the overall incidence of complications was rather low in the study of Szem *et al* [9], they reported three cases of cardiac arrest and one case of pneumothorax that required chest tube placement. In medical patients electrocardiogram changes may occur that cannot be seen with standard electrocardiogram monitoring [14].

Respiratory complications were reported to occur in up to 29% of the transports, including a change in respiratory rate in 20% of the patients and a fall in arterial oxygen saturation in 2–17% of cases [7,8]. In one study [8] no change of pCO_2 and pH was found during transport.

In 125 transports of ventilated and nonventilated patients reported in another study [6], mishaps occurred in 34% of cases. Most of those problems were related to the equipment or the process of monitoring itself. Electrocardiogram lead disconnection (23%), monitor power failure (14%), a combination of those (10%), intravenous line or vasoactive drug infusion disconnection (9 and 5%, respectively), and disconnection from the ventilator (3%) were among the most frequent problems. Most mishaps were noted at the destination site either before or during the procedure, but not during the actual transport. Equipment-related mishaps occurred in 10% of transports in the study of Wallen *et al* [4]. These included malfunction of equipment, or loss of nasogastric or chest

Table 1

Synopsis of investigations studying overall and specific complications during transport

Reference	No. of patients	No. of transports	Destination of transports	Rate of mishaps	Circulatory mishaps	Pulmonary mishaps	Equipment mishaps	Type of ventilation personnel
[3]	11 Postoperative	11	Radiol 11%	0%	0	NR	NR	Manual ventilation in 7 of 11, Personnel NR
[4]	139 Children	180	Radiol 30% OR 49% Others 21%	76.1%	HR 46.7% BP 21.1% Hypothermia 10%	RR 28.9% SaO_2 6.1%	10%	Manual ventilation Nurse and physician 82.2% Nurse only 17.8%
[5]	27 Head injured	35	Radiol 51% OR 49%	51%	Hypotension 9% Rise in ICP 23% Hypertension 14%	Hypoxia 9%	NR	Mechanical ventilator Personnel NR
[6]	NR (all critically ill)	127	Radiol 75% OR 25%	34%	NR	NR	34%	Type of ventilation NR Nurse and physician 45% Nurse and respiratory therapist 58%
[7]	56 Injured	103	Radiol 100%	68%	HR 21% BP 40%	RR 20% SaO_2 17%	0%	Mechanical ventilation Nurse and physician
[8]	83 Surgical/trauma	100	Radiol 100%	66%	HR 27% BP 36%	RR 20% SaO_2 2%	5%	Mechanical ventilation Nurse, physician and respiratory therapist
[9]	175 Surgical	203	Radiol 61% OR 39%	5.9%	Hypotension 1% Cardiac arrest 1.5%	Hypoxia 4%	NR	Mechanical or manual ventilation Physician and respiratory therapist
[10]	237 All critically ill	237	Radiol 100%	15.5%	NR	NR	NR	Specially trained nursing transport team
[11]	36 All critically ill	36	Radiol 100%	53%	Arrhythmia 5.5%	NR	11%	Mechanical ventilation
[12]	20 Medical/surgical	20	Radiol 100%	10%	0%	10%	0%	Manual ventilation Respiratory therapist
[13]	20 Medical/surgical	36	Radiol 100%	NR	Hypotension 19% Arrhythmia 5.5%	Change in pCO_2 56%	5.5%	Manual ventilation in 20 of 36 Nurse, physician and respiratory therapist

Not included are studies that compared specific transport protocols or equipment. BP, change in blood pressure; HR, change in heart rate; ICP, intracranial pressure; NR, not reported; OR, operation room; Radiol, radiology department; RR, change in respiratory rate; SaO_2, fall of arterial oxygen saturation.

tube, or were related to the endotracheal tube or the intravenous lines.

In a group of 27 patients with head injury (35 transports for diagnostic procedures or to the operating room) adverse effects were observed in 51% [5]. These included hypotension (systolic blood pressure below 90 mmHg in 8.6%), hypoxia (oxygen saturation below 90% in 5.7%) and increased intracranial pressure (42.9%, including 17% of cases with a pressure increase of more than 30 mmHg). Similar insults could be recorded in 60% of patients during the 4 h before transport and in 66% during the period after transport, however. It is important to note that, after transport, abnormal values that had not been present before were obtained in 17 patients.

Although much data has accumulated with respect to mishaps during the absence from the ICU, less is known about adverse long-term effects. In one prospective observation study [15] prolonged effects on respiratory function after intrahospital transports of critically ill patients were addressed. In 49 transports gas exchange had significantly decreased from a partial arterial oxygen tension : fractional inspired oxygen ratio of 267 at baseline to 220 1 h after transport. Even 24 h later a slight deterioration was still present. A fall in the partial oxygen tension : fractional inspired oxygen ratio of more than 20% from baseline was noted 1 and 24 h after transport in 42.8 and 12.2% of patients, respectively. Smith *et al* [6] reported that 24% of the patients of a study with 127 transports were considered, after having returned to the ICU, to be in worse condition than before the procedure. In a series of 273 mechanically ventilated patients who were transported from the ICU [16] the incidence of pneumonia was 24.4%, as compared to 4.4% in patients of similar severity of illness that had not been transported. This increased rate of complications could be attributed to the selection of patients that required transports to perform diagnostic (or therapeutic) interventions, however.

Whether the adverse effects observed are actually related to the transport itself or might be typical for critically ill patients irrespective of their location was assessed in only a few studies, and their findings are controversial. Wallen *et al* [4] compared patients over a period of 1–2 h before transport and during the consecutive transport to a diagnostic study. Although hypothermia (11.2%); change in heart rate (15.7%), blood pressure (21.3%) or in the respiratory rate of more than 20% (23.6%); or a change in oxygen saturation of more than 5% (5.6%) was observed in a significant number of transports, no such disturbances were noted during the observation period before transport. In contrast to these findings, Hurst *et al* [8] observed a similar rate of adverse events in a cohort of patients who were stationary in the ICU and matched for severity of illness [Acute Physiology and Chronic Health Evaluation (APACHE) II score] and age with the transport group (60 versus 66%). No difference was found with respect to number or type of physiologic changes.

Fatalities attributed to the transport were not reported in any of the communications reviewed.

Risk assessment and patient-related risk factors

To allow for a risk–benefit assessment, it would be helpful to identify patients with a high risk for the development of complications during or after transport.

In a study of 180 transports of critically ill children [4] it was shown that major corrective procedures during transport were necessary in 34.4% of mechanically ventilated patients, as opposed to 9.5% in nonventilated patients. Furthermore, the Therapeutic Intervention Severity Score and the duration of transport were significantly associated with the requirement for a major intervention or with any physiological deterioration (predominantly equipment related). The latter finding, however, could not be substantiated in several studies of adult patients [5–7,15]. For patients with severe head injuries the overall injury severity score was found to be the only predictor for the development of adverse effects during transport [5].

Not associated with the frequency of mishaps in a number of studies were the following: patients' age, diagnosis of the underlying disease, number of personnel accompanying the transport, duration of absence from the ICU, severity of illness (APACHE II), Glasgow Coma Score, number of lines in place, life-support modalities, destination of the transport (to the operation room versus to the radiology suite) and type of diagnostic procedure [6,7,9].

With regard to longer lasting detrimental effects on respiratory function, the only risk indicator was ventilatory support with positive end-expiratory pressure, whereas age, APACHE II score, duration of transport, destination of transport, pretransport gas exchange or peak airway pressure were not predictive of a respiratory deterioration [15].

Efficiency and cost-effectiveness

In a cohort of 103 consecutive transports for diagnostic evaluation in trauma patients, the results from these studies led to a change of therapy in 24% of the cases within 48 h after transport [7]. Changes in patient management resulting from a transport for a diagnostic procedure amounted to 39% in the experience of Hurst *et al.* [8], who studied surgical patients with trauma, and after major abdominal or vascular surgery. The main reasons for doing the diagnostic procedure were follow up (37%), identification of a septic focus (34%) and identification of the site of bleeding (14%). The examinations with the highest efficiency included angiography and abdominal computed tomography, which resulted in therapeutic consequences in more than 50% of patients, whereas computed tomography of the head and the chest still resulted in a change of therapeutic management in 25%. In a study of 88 abdominal computed tomography examinations of critically ill surgical patients for reasons such as suspected abdominal focus (74%), acute necrotizing pancreatitis (12%) or suspected delayed intra-abdominal organ lesion after trauma (14%) [17] the results of the examination resulted in a change of therapy (operation or other invasive therapeutic intervention) in 43% of the patients. Similar studies of thoracic computed tomography in critically ill patients (predominantly trauma patients) to evaluate a potential pulmonary septic focus or a cause for a deterioration in gas exchange resulted in therapeutic consequences or a change in patient management in up to 70% of patients [18–20].

Thus, the overall yield of diagnostic procedures that require a transport of critically ill patients in terms of a direct and consecutive change of therapy is at least 25% and may be as high as 70%, provided that the decision to perform a specific procedure is based on criteria similar to the ones used in those studies. Unfortunately, little information was provided by investigators regarding why a specific procedure had been done and whether alternative methods would have been available. In summary, the efficiency of transports in trauma and surgical patients, and in search of a septic focus, a source of bleeding, or the identification and follow up of injuries appears to be moderate to fairly high, indicating a good risk:benefit ratio, as long as restrictive criteria are used to order those procedures. No such information is available for medical and pediatric patients. It can be assumed, however, that similar yields can be anticipated while looking for a focus of sepsis.

The cost of a transport was estimated to be $US465 in 1988 [7] and $US452 in 1992 [8]. No calculation of cost-effectiveness was reported in the literature reviewed.

Prevention of complications

Although patient-related risk factors are difficult to identify, equipment-related complications (which occur in up to one-third of transports) might be controlled more easily.

In 1993, guidelines for the transfer of critically ill patients were reported by a consensus committee that was formed by representatives from several major critical care societies [21]. They proposed requirements for the pretransport coordination and communication, for the personnel who accompany the patient, for the equipment needed and for the monitoring during transport.

It has been suggested [21] that a minimum of two people, one of them a critical care nurse, should accompany the patient. A physician is required for patients with unstable physiology who might need acute interventions. It is not clearly stated whether these latter conditions are met by mechanically ventilated patients. It appears justified that intubated patients are to be escorted by a medical doctor, however, on the basis of the large number of significant events that result in the necessity for an acute intervention in this group of patients. In those studies that reported on the personnel involved [4,6], at least two persons went with the patient but a physician was substituted by a respiratory therapist in 17.8–58% of transports. It should also be emphasized that personnel attending transports of critically ill patients may benefit from specific training [22].

Standard equipment includes the following [21]: a cardiac monitor with defibrillator; airway management equipment and a resuscitation bag (to allow for emergency intubation, coniotomy and manual ventilation via mask and tube); sufficient gas supplies; standard resuscitation drugs and intravenous fluids, as well as specific essential medications required by the patient transported (regulated by battery operated infusion pumps); and a portable ventilator for patients receiving mechanical ventilation.

The type of ventilation and the respirator to be used requires some discussion. One reason for the observed adverse effects on gas exchange could be the change from the ICU ventilator to a transport device, or even to manual ventilation. Although manual ventilation by a respiratory therapist has been said to result in a deterioration in blood gases in only 10% of transports [12], this positive experience was not shared by other investigators. Gervais *et al.* [23] compared blood gas variables during transport of 30 ventilator-dependent patients who were ventilated using either a manually operated ventilation bag with or without a volume meter at the exhalation valve of the bag, or a time-cycled, volume-constant, portable ventilator. Interestingly, patients with manual ventilation alone or the transport ventilator were significantly hyperventilated, as opposed to those in whom a volume meter was used to control manual ventilation. This finding was also reflected by an increase in pH in the former two groups. Arterial oxygen tension was not affected in a clinically significant way. In a follow-up study [24], the same group demonstrated that four out of five portable ventilators from different manufacturers produced either severe hyperventilation (particularly at low minute ventilation), or considerable hypoventilation under conditions of reduced compliance, as may be encountered in patients with acute respiratory failure or acute respiratory distress syndrome [24]. In 20 manually ventilated patients (not using a volume meter) mean changes in pCO_2 and pH of 9 mmHg and 0.08, respectively, were observed. Using a portable ventilator these blood gas changes could be significantly reduced to 4 mmHg and 0.05, respectively. Nevertheless, the complication rate in the mechanically ventilated patients was still 44% [13].

One possibility to reduce inadvertent ventilation problems might be the use of improved monitoring equipment, particularly of tidal or minute ventilation (see below). Bearing in mind the limitations of many portable ventilators, the use of sophisticated transport carts equipped with a standard ICU ventilator and the necessary gas supply should be considered [25–28]. Such carts could be hooked to the patient bed and moved fairly easily. Monitoring devices and infusion pumps can be implemented into the cart with its battery. Such equipment is widely used for interhospital transport of critically ill patients between institutions, and is being increasingly applied to intrahospital transport. Controlled studies showing a reduction in adverse events during and complications from transport using such equipment are still lacking, however, although one group did report zero unanticipated problems with such equipment [28]. Although it appears sensible to assume improved patient safety, the cost-effectiveness remains to be shown. Furthermore, suction devices should accompany the patient, as illustrated by a case report of a patient with acute airway obstruction from a mucus plug [29]. A pump-driven suction device appears to be preferable, however.

Minimum requirements for monitoring patients during transport should be continuous electrocardiography, pulse oxymetry and the intermittent measurement of blood pressure, respiratory rate and pulse rate [21]. In specific patients, capnometry, continuous blood pressure reading and further monitoring (such as of intracranial pressure, cardiac output and filling pressures) may be beneficial. Many of the complications reported during transport were caused by equipment not functioning correctly, however. The use of more equipment could result in a higher probability of equipment-related problems that might divert the attention of the personnel from the patient to the device. In one study of capnometry [30] more than 50% of the complications (four out of seven) were due to malfunction of the monitoring and not caused by actual physiologic disturbances.

Of particular importance appears the possibility of measuring the major ventilation parameters such as tidal volume or minute ventilation [23,31]. Unfortunately, this is not possible with most portable ventilators.

In some cases the hazards of transporting a patient could be prevented by performing diagnostic or therapeutic procedures within the ICU or choosing alternative (albeit equivalently effective) procedures that may render a transport of the patient unnecessary. Such interventions may comprise the following: use of chest ultrasound in detecting intrathoracic pathologies [32–34]; the introduction of new mobile computed tomography scanners that can be used in the ICU [35]; the application of conventional or dilatational percutaneous tracheostomy in the ICU, instead of transferring the patient to the operating room [36–38]; the placement of percutaneous endoscopic gastrostomy and of inferior vena cava filters [39]; fiberoptic intraparenchymal pressure monitoring instead of operative ventriculostomy [40–42]; scheduled reoperations for peritonitis with open abdomen in the ICU [43]; and many others [44].

Conclusion

Adverse effects during and after transport of critically ill patients are frequent. On the other hand, a change in patient management results from about half of the procedures that necessitate transport, indicating a good efficiency. Although a few patient-related risk factors can be identified, the rate of equipment-related adverse events may be as high as one-third of all transports. Thus, particular attention has to be focussed on the personnel, equipment and monitoring in use. Standard guidelines have been published. A potential weakness remains the mode of ventilation and the type of ventilator used during transport, as well as the extent of respiratory monitoring. In patients who require ventilation, it appears useful to use either portable ventilators that are equipped with a volume meter, or specifically constructed carts including standard ICU ventilators. To further reduce the rate of inadvertent mishaps from transports, alternative diagnostic modalities or techniques, and performing surgical procedures in the ICU should be considered.

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