Complications in critically ill adult patients' transportations reported in the recent literature

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Abstract

The transport of critically ill patients is a complex process, made up by several phases involving the healthcare professionals. It requires a careful planning for the prevention of potential complications undermining the patients' safety outside critical care environment. Literature review about complications and adverse events reported during intra and inter-hospital transport of critically ill adult patients. Intra-hospital transfers are affected by adverse events rates ranging from 22.2 to 75.7% in the published literature. Major adverse events, defined as life threatening conditions that require urgent therapeutic intervention, vary from 4.2 to 31%. Death is a rare occurrence. Adverse events during inter-hospital have a maximum rate of 34%. Technical incidents represent a typical feature of these transports. Authors reported problems to gas supply, ambulance electric system, equipment. There is a lack of studies about the complications related to rotary wing inter-hospital transports. While extracorporeal membrane oxygenation/extracorporeal life support patients seem to be the most complex category of critically ill to be transported outside the hospital, 11 papers revealed only 29 adverse events ranging from 0 to 17%. No deaths were recorded. Currently, research must explore more accurately how much transports affect the outcome of patients, and what are the most appropriate time-frames to assess the consequences of transfers on patients' clinical conditions.

Introduction

The transport of critically ill patients is a complex process, made up by several phases involving the healthcare professionals, mainly doctors and nurses. It requires a careful planning for the prevention of potential complications undermining patients' safety outside critical care environment. Healthcare transport of critically ill patients can be performed from the pre-hospital setting towards emergency department, inside different areas of the hospital for diagnostic and therapeutic interventions, or from an hospital to another. In this case the aim is usually the centralization, or the need of a more appropriate level of care (inter-hospital transfer).[1]

Currently, the process of critically ill patient transfer is strictly related to risk management. Over the years we have observed a change in the use of words to describe the transport related events, getting closer to the typical terms used in clinical risk management .

More than 20 years ago, Smith and coll., with the term *mishaps*, referred to the equipment related problems.[2] Over the years we read in papers' titles words like *complications* (worsening of general health conditions, for iatrogenic or other causes),[3] and, afterwards *incidents*,[4] *unexpected events*,[5] *audit*,[6] and *adverse clinical events*.[7] To date, performing inter and intra-hospital transfer contemplates an accurate planning, through the analysis of diagnostic and therapeutic needs of the patient, the control of logistical, organizational and clinical variables to prevent complications and adverse events (outcome indicators).

Guidelines and clinical/logistical check lists are the tools to achieve these goal. A lot of scientific associations have published guidelines on intra and inter-hospital transfer of critically ill patients.[8-14] Most of these guidelines are similar. In fact the studies at the basis of recommendations are mainly performed through descriptive and observational designs. It determines a low level of available evidences. Hence the recommendations contained within the guidelines are essentially based on experts' opinions, and so on the common sense. Anyhow, the phases of a transfer planning are summarized in Table 1. Effective standards of safety during patients' transportation can be only achieved through an update knowledge of potential complications and adverse events reported by international scientific literature.

We performed a literature review about complications and adverse events reported during intra and inter-hospital transport of critically ill adult patients, analyzing original research papers and significant reviews published in the last decade (from 01-01-1995 to 03-01-2013). We deliberately focused only intra and inter-hospital, excluding the issues related to pre-hospital transport because features are very different from the other settings. We searched articles in English and Italian on Medline and Google using keywords as: *inter-hopital*, *in hospital*, *critically ill*, *extacorporeal membrane oxygenation*, *ECMO*, *extracorporeal life support*, *ECLS*, *transport*, *transportation*, *transfer*. We found 831 records. Thirty three papers were included in this review. Some older papers were retrieved to integrate and discuss the results of this review.

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Intra-hospital transport complications

Fanara *et al*.[16] and Day[17] have published, at the same time, in 2010, two extensive literature reviews about intra-hospital transport of critically ill patients. These two papers, even if using slightly different terms and classifications, show all the range of adverse events reported in international literature of last ten years (Table 2; adverse events related to intra-hospital transport).

The differences of terms used by the authors in literature make often difficult to discern between an incident and an adverse event that can be caused by. Moreover they limit the opportunity to compare and standardize the results in a definitively way. Finally, the endeavor to differentiate major and minor events is carried on only by few researchers that provided arbitrary definition.[16] Minor events seem to be featured by a physiologic decline higher than 20% of the baseline values before the transport, or equipment related problems. A major event is defined as a life treating condition that requires urgent therapeutic intervention.[16]

In this view, the transport planning gains a relevant meaning, because it allows to identify a series of mandatory safety check points,

starting when a minor event occurs before it turns into a major adverse one. These check points can be, for example, the decision moment to transfer the patient, the phase of preparation and organization.[16,17] The main risk factors for adverse events during intra-hospital transport are summarized in Table 3, though not all are confirmed by statistical significance data. Moreover some authors state that the causal links between patients' clinical conditions, equipment, environment, transfer management and the occurrence of adverse events have to be clearly investigated.[16]

In 1999 Waydhas published a literature review on complications related to intra-hospital transport. Adverse events varied between 10 and 69%. Only one study reported a rate of 1.5% of cardiac arrests but without adding data on mortality.[18] Equipment related incidents ranged from absence up to 34% of all transports across studies. 4 out of 10 studies in adult patients reported the performance of manual ventilation rather than mechanical ventilation during intra-hospital transportation.[18]

Eleven years after, the review of Fanara and colleagues carried out on studies of the later period, shows overall adverse events rates ranging from 22.2 to 67.9%.[16] Indeed, the major adverse events amount to values ranging from 4.2 to 31%.[16] The equipment was involved by incidents from a 10.4 to 45.9% of transports, while organizational problems often emerge as a matrix of adversity (up to 61%).[16] In this review, the author revealed an important improvement in ventilation modes during transports, since among 8 studies, seven reported the use of a mechanical ventilator.[16] Cardiac arrests were recorded between 0.34 and 1.5%,[16] while, regarding mortality, the Australian incident reporting published by Beckmann *et al*.,[4] included in the review of Fanara *et al*.,[16] showed 4 reports related to patients' death (2%), on 176 incident reports during intra-hospital transport.[4] In this case we cannot really know the real number of death occurred during transports. In fact the report, being anonymous, could be drawn up by more than a person in staff who performed the same transfer. Apart from the studies included by Fanara *et al*. in their review, few other

Table 1. Phases of critically ill patients transfer's process. Based on Bambi.[15]

Phase	Variable
Logistical planning	Architectural features Timing Destination service/hospital Equipment Vehicle
Organizational planning	Personnel performing the transport Destination service/hospital staff Communication/coordination Documents
Clinical planning	Potential complications Monitoring level Patient's preparation/stabilization

Table 2. Adverse events related to intra-hospital transport. Based on Fanara *et al.*[16] and Day.[17]

Typology	Incident	Vital function	Adverse event
Equipment related	Monitor shutdown Ventilator Disconnection/ventilator failure O_2 supplies exhaustion SpO_2 sensor failure Tangled or kinked tubes ECG wires disconnection	A	Airways loss Extubation Airways obstruction due to breathing circuit kinking or mucus plugs Inhalation
Personnel related	Gaps in monitoring Medication administration failure Accidental extubation Hypoventilation Hyperventilation Chest drain loss Venous or arterial catheter loss Intracranial monitoring or ventriculostomy drain loss	B	Respiratory arrest Desaturation Hypoxemia, lowering of PaO_2/FiO_2 ratio Ventilator associated pneumonia Hypertensive pneumothorax Bronchospasm Patient-ventilator asynchrony Selective intubation Derecruitment
		C	Cardiac arrest Hemodynamic instability Increasing of O_2 consumption Bleeding Gas embolism Tachycardia Bradycardia Arrhythmias Hypotension Hypertension Death
		D	Spine destabilization Intracranial pressure elevation Agitation Pain
		E	Hypothermia

ECG, electrocardiography.

papers have been published,[16] and they do not add much information compared to the framework just outlined, except for some types of accidents related to the unavailability of equipment *ad hoc*. This was the case of 2 episodes of airways obstruction from secretions developed by patients in 32 intra-hospital transfers in absence of portable suction devices.[6] Actually, data from Brazil, reported a rate of adverse events of 75.7% on 48 intra-hospital transports of patients on mechanical ventilation, which exceed the maximum percentages reported in the previously published studies.[19] Conversely, in Italy, Lucchini *et al*. have tested a transport system based on the use of a radio transparent spinal board coupled to a device for the housing of electrical equipment. They performed 68 intra-hospital transports (8% with extra corporeal membrane oxygenation) without any complication related to dislocation of medical equipment (infusion lines, chest drains, artificial airway), as well as low percentages of hemodynamic instability (9.4%) and respiratory problems (4%).[20] However, educational programs and check lists for the transport preparation seem to lower incisively the rates of severe unexpected events, as in the research of Choi *et al*., where the percentage decreased from 9.1 to 5.2%.[21] Furthermore, Kue *et al*. have demonstrated that a specialized team for the transport management, produce very few adverse events (1.7% out of 3383 transfers).[7]

Finally, there are no consistent data about the intra-hospital transport influence on primary outcomes as incidence of ventilator associated pneumoniae, hospital lenght of stay, and mortality rate (as previously outlined), that need a more accurate monitoring system.[16]

Inter-hospital transport complications

As previously highlighted by the review of Fan *et al.*, researches about adverse events related to inter-hospital transportations are numerically scarce.[22] In Table 4 we summarized the results of perspective and retrospective studies on inter-hospital transfer complications published from 1996 till nowadays. As in the studies on intra-hospital transport, we cannot properly compare the results of various researches in the literature on inter-hospital transfer complications. This problem is due not only to the differences of definitions about problems and adverse events, but also to the mode of transports (*e.g.* mobile intensive care units), while noting a prevalence of ground transportations.

We recorded rates of adverse events till 34% of studied transfers,[27] and technical problems up to 15.5%.[31] Mortality, where reported, reached always low rates. McGinn *et al*. found

Table 3. Risk factors for development of adverse events during intra-hospital transfer. Based on Fanara *et al.*[16]

Category	Risk factor
Equipment	Infusion line number Mechanical ventilation (ventilator change or ventilator setting) Sedation (starting, maintenance, variation)
Transport team	Lack of training Lack of expertise Equipment not adjusted for the aims of transport
Coordination/organization	Communication/coordination between services or wards Transport length Emergency or elective transports
Patient	Patient's severity of clinical conditions Respiratory or circulatory supports Emergency or elective transports

Table 4. Summary of studies about inter-hospital transfer complications.

Authors	Design	Period	Sample	Transport mode	Adverse events
McGinn *et al*.[23]	Descriptive, perspective	4 and a half years	1305	Ground; air; dedicated team	One death
Gebremichael *et al.*[24]	Descriptive, perspective	2 years	39	Ground; MICU	2 major complications (5%), among which one death, and 2 deaths within 6 hours from the arrival time (leukemia/sepsis)
Uusaro *et al.*[25]	Cohort, retrospective	6 years	66	Ground; dedicated team	No technical or clinical major complications
Gray *et al.*[26]	Descriptive, perspective	1 year	257	Ground; 29 ED	47 critical incidents in 38 patients (15%)
Ligtenberg *et al*[27]	Audit, perspective	14 months	100	Ground	Adverse events in 34% of transports (about 30% due to technical problems)
Markakis *et al.*[28]	Observational, perspective	1 year	128	Ground	14 patients (10.9%) encountered Major complications (no deaths)
Lee *et al*[29]	Descriptive, perspective	28 months	79	Ground; ED; dedicated team	Adverse events in 16 transports (20.3%)
Wiegersma *et al*[30]	Descriptive, perspective	10 months	74	Ground; MICU	9 incidents (all due to technical problems), with minor changing of vital signs
Droogh *et al.*[31]	Audit, retrospective	30 months	353	Ground; MICU	55 technical problems

MICU, mobile intensive care unit; ED, emergency department.

one lonely death in a series of 1305 transported patients[23] and two patients (among 39 critically ill transportations) died within 6 h from the arrival to the referral hospital reported by Gebremichael *et al.*[24] Basically, major complications occurring during inter-hospital transports, especially those related to clinical condition,[28] are nearly superposed to the events reported in papers about intra-hospital transfers (Table 2). Conversely, technical incidents represent a typical feature of inter-hospital transport. Authors reported problems to gas supply, ambulance electric system, equipment, and electric supplied trolley.[31] The most frequent problems recorded were leakages from gas supply,[30,31] dysfunctional gas tube connectors, blown fuses, minor defects on doors and electrical or mechanical damages to the trolley.[31]

Among the most important adverse event related to technical problems there was a case of body temperature lowering from 37.8 to 34.8°C, due to the breakage of an electrical warmer during a transport.[30] A critical feature emerged from the perspective audit performed by Ligtenberg *et al*. on 100 ground transportations.[27] The 70% of adverse events could have been prevented with a better preparation phase.[27] Moreover in 50% of cases the clinical indications given by the intensivist physicians at the moment of departure, were disregarded by the transfer personnel.[27]

In the literature there is a lack of studies about complications related to inter-hospital transports performed through rotary wing. Seymour *et al.* published a retrospective cohort study of 191 patients on mechanical ventilation, transferred by helicopter during 36 months.[32] They recorded only minor events

Table 5. Summary of studies on inter-hospital transport complications of extracorporeal membrane oxygenation/extracorporeal life support patients.

Authors	Design	Sample	Team	Transport mode	Adverse events
Rossaint *et al.*[36]	Cohort, perspective	8	2 intensivist physicians	MICU and a trained nurse	All transfers performed successfully; only one event: breakdown of a port in the higher zone of ECMO oxygenator
Lindén *et al.*[37]	Observational	29	Dedicated team: one physician, one nurse, and one coordinator	Ambulance, helicopter, airplane	No death related to transport; 2 technical problems in 30 transports: a breakdown to ambulance's suspensions, and a failure to helicopter's electrical supply system
Foley *et al.*[38]	Observational, retrospective	100	2 physicians, 2 ECLS specialists, 2 paramedics, and one nurse for ground transports; One pilot and 2 nurses for air-transport	Ambulance, helicopter, airplane	All transfers performed successfully; 17 technical problems: ambulance electrical supply (10 cases), ECLS battery circuit (4 cases), loss from ECLS circuit port or tube (3 cases)
Huang *et al.*[39]	Observational, retrospective	31	One Cardiovascular surgeon, one ECMO specialist	Ambulance	All transfers performed successfully; 2 technical problems: 1 failure of ambulance electric system, and 1 tyre breakdown.
Zimmermann *et al.*[40]	Observational, retrospective	8	One intensivist physician, one paramedic, one perfusionist	Ambulance, helicopter,	All transfers performed successfully; one transient ischemia of the lower limb, immediately after transportation
Coppola *et al.*[41]	Descriptive, retrospective	68	One director/mission commander, one pediatrician, one ECMO , coordinator one pediatric cardiologist, one surgeon, 2 ECMO specialists, 2 pediatric nurses, 1-2 respiratory therapist, other technicians or trainees	Ambulance o military ground vehicles, airplane	No deaths during transports; 6 technical problems: oxygenator clogging (2 cases), electric supply problems (2 cases), loss from heat-exchanger (1 case), circuit breakdown due to a roller pump problem (1 case); all failures were repaired without severe interruption of ECMO
Wagner *et al.*[42]	Observational, retrospective	23	One intensivist physician, one heart surgeon, one ICU nurse, (not dedicated team)	Ambulance, airplane, militar airplane	No deaths or major complications due to transports
Haneya *et al.*[43]	Observational, retrospective	38	One intensivist physician, one perfusionist, one nurse, one heart surgeon,	Ambulance, helicopter	During transports for distances greater than 350 km a stop was needed because the oxygen supply was insufficient; a case of replacement of an oxygenator due to partial clogging of the membrane
Clement *et al.*[44]	Descriptive, retrospective	112	One ECMO coordinator, one pediatric heart surgeon,	Helicopter, airplane, ambulance	No deaths during transports; one assistant surgeon, one intensivist physician no detailed information about adverse events during transfers
Ciapetti *et al.*[45]	Descriptive observational,	12 ARDS cases, among which 4 transported with ECMO	One intensivist physician, one heart surgeon, one cardiologist, one perfusionist, one nurse	Ambulance, airplane, helicopter	All transfers performed successfully; absence of noteworthy incidents
Lucchini *et al.*[46]	Observational, retrospective	42 ARDS cases, which 29 with ECMO	Two intensivist physician, one perfusionist, one nurse	Ambulance, airplane	All transfers performed successfully; absence of noteworthy incidents

MICU, mobile intensive care unit; ECMO, extracorporeal membrane oxygenation; ECLS, extracorporeal life support; ICU, intensive care unit; ARDS, acute respiratory distress syndrome

Table 6. Key information for planning transports of critically ill patients.

1.	There is no evidence that the occurrence of accidents related to transport is directly proportional to the time spent outside critical care environment[2,47]
2.	The emergency transports involve a higher risk of critical incidents compared to those that are pre-planned[47]
3.	There are no differences in the occurrence of adverse events related to equipment between transport organized in emergency or elective conditions[48]
4.	75% of mishaps occur during radiological investigations and three-quarters of these during CT scanning[2]
5.	The appearance of alterations of vital signs during preparation phase of transport could have predictive power for complications during the transfer[29,49]
6.	It is possible that some alterations of monitored vital signs may occur independently by the transport performance[50,51]
7.	Transport ventilators provide greater stability with respect to pH and $PaCO_2$ of patients than manual ventilation[52-54]

CT, computed tomography.

(22% of cases), showing that this mode of transport can be performed safely.[32] Also the secondary transfers of 173 patients with intra-aortic balloon pump by plane, helicopter or mobile intensive care unit were substantially free from relevant clinical and mechanical complications. Adverse events were defined as rupture of the intra-aortic balloon, pump malfunction, low level battery, catheter displacement, bleeding, loss of trigger signal, or cardiac arrest.[33] Sometimes complications related to transfers may arise from inappropriate practices of the transport team. The survey of Hauswald *et al*., published in 2000, was conducted on 37 inter-hospital air transport services, to explore the use of spinal board during transport. Twenty nine out of 30 respondent services, used spinal board also in long-distance transfers.[34] Eighteen services routinely re-immobilized the patient even if the case of radiological exclusion of spinal injuries. Two services reported cases of pressure ulcers due prolonged immobilization.[34]

Finally, while remaining on the theoretical plane, Karkada *et al*.[35] have proposed a suggestive hypothesis for an unrecognized complication of inter-hospital transfers. They use a mathematical model to describe the possibility of spreading throughout the United States highly resistant microorganisms carried by critically ill patients transferred from a state to another.[35]

Inter-hospital transport complications of extracorporeal membrane oxygenation-extracorporeal life support patients

The transports of patients undergoing cardiopulmonary bypass [extracorporeal membrane oxygenation (ECMO) and extracorporeal life support (ECLS)] are probably the most complex to be carried out for the intensive care staff. In fact the support offered by ECMO/ECLS determine organizational and logistical criticalities, and, above all, it is characterized by a high instability of respiratory and circulatory functions that requires the management of specialist referral centers. The transfer of patients in ECMO/ECLS can be carried out by ground or air. The results of studies on the safety of these kind of transfers are summarized in Table 5. Outside the aim of this review, Table 5 reports also research papers on neonatal and pediatric population, when being part of the case mix (with adults) studied by the authors.

The 11 studies published from the late 90's till now, collect a series of 451 transports of neonatal, pediatric and adult patients treated with extracorporeal cardiopulmonary support for respiratory failure (328 patients), and cardiac failure (123 patients). The transports were performed by ambulance (63%), airplane (17%), helicopter (20%). The whole of these papers revealed only 29 adverse events in a range that varies, according to the authors, from the absence to a maximum of 17%. No fatal accidents to the patients were recorded. Problems encountered were related to power supply (15 cases), components of the extracorporeal circuit (13 cases), and vehicles (2 cases). Technical problems that occurred to ECMO/ECLS during transport were: blood loss, problems with batteries, clotted oxygenator, ECMO pump failure, broken ports, and losses from the heat exchanger.

Conclusions

This literature review shows that, at present as in the past, the risk of occurrence of adverse events relating to the transport of critically ill patients is concrete and depend on the setting, the teams and the kinds of patients and transports carried out. In that regard some key messages are summarized in Table 6. This concepts, arising from old and new papers, are useful for the planning of intra ad inter-hospital transfers. The will to understand whether inter-hospital transport is potentially safer than intra-hospital is inappropriate. In fact there are important methodological limits to the studies published, mainly carried out with retrospective observational and descriptive designs. Furthermore we cannot exclude a general underreporting of incidents and adverse events related to transports, with consequent publication biases.[55]

However, inter-hospital transports of ECMO patients seem to be substantially the safest, due to lack of major events and outcomes. Conversely, intra-hospital transports are more burdened by the risk of complications and accidents. One possible explanation may lie in the composition of the team carrying out the transport. In fact, during ECMO/ECLS transfers, there are more healthcare workers and a higher skill mix. Indeed the best results in terms of prevention of complications are reached also in intra-hospital transfer when performed by dedicated teams.[7,21] Currently, research must explore more accurately how much transports affect the outcome of patients, and what are the most appropriate time-frames to assess the direct consequences of transfers on patients' clinical conditions.

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