Mobile Intensive Care Unit: Technical and clinical aspects of interhospital critical care transport
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Chapter 1

Introduction & outline of thesis
With the introduction of critical care as a specialized part of medicine in the late seventies, transport between intensive care units of hospitals has become its inextricably part. Due to regionalization of advanced care the use of interhospital transport after stabilization in a regional hospital is increasing. This trend is supported by association between volume and improved outcome in specialties such as trauma and critical care. Transplantation medicine is an example of supra-regional concentration of care, even among referral centers, in order to deliver high quality care with efficiency. Neonatal and pediatric care stimulated research on transport facilities for many pediatric patients are referred from regional hospitals. These pediatric transport services in Europe and the US, are hospital based or executed by regional emergency medical services, either public or for profit. These specialized transports have a tailor made approach of providing advanced care from departure in the sending hospital by specialized transport paramedics or physicians until patient hand off in the receiving referral center.

THE DUTCH APPROACH

In the Netherlands critical care transports between hospitals started in the late nineties. Dutch emergency medicine by private or public services experienced great professionalism by federal regulations and the introduction of evidence or practice based medicine in the preceding decades. National protocols on emergency medicine standardized the level of care in prehospital emergency medicine. In the early nineties, this approach with broad implementation of one national multi-disciplinary protocol, covering all major prehospital emergencies, and approved by all medical societies involved in emergency medicine, raised the bar in Dutch evidence based emergency medicine. One national education program and legal regulation of the special professional authority of paramedics supervised by medical directors of licensed emergency medical services turned out to be successful preconditions for high quality prehospital care.

It has stimulated prehospital research on many topics, e.g., initial treatment of out of hospital myocardial infarction induced ventricular fibrillation with lidocaine. The introduction of Helicopter Emergency Services (HEMS) in the Netherlands raised a political and financial debate which might have been an explanation for the delay in the development of interhospital critical care transport. With their recent advancements in both education, equipment and protocols, transport of critically ill patients was executed by EMS in a modern but regular ambulance. Paramedics, who were often trained as critical care nurses in their past, escorted those transports. In a minority of cases, patients were accompanied by a physician of the sending hospital, many times not trained in critical care medicine, let alone certified to use ambulance equipment. Ambulance equipment was not suitable for mechanical ventilated patients on spontaneous breath-
ing or high end-expiratory positive pressure ventilation \(^3\). Safe and secure delivery of intravenous medication with ambulance syringe pumps was impossible, resulting in pumps from the sending hospital which could not be attached safely to the ambulance interior. Furthermore, equipment standards on the type of cardiovascular monitor of Dutch ambulances lacked invasive pressure and end-tidal CO\(_2\) monitoring \(^{24}\). The combination of unsuitable equipment, insufficient training in critical care and lack of workspace for the escorting team resulted in unsafe transports \(^{22,28}\). In those times, assessment by an intensivist considering patients’ benefit versus transport related risks eventually resulted in a not-fit-to-transport verdict. In 1997, two Mobile Intensive Care Units (MICU) were available for critical care transport in the Amsterdam and Nijmegen regions. These units were initiatives of intensivists and pediatricians, who reconstructed a regular ambulance stretcher into a mobile ICU bed to securely fit a high-end mechanical ventilator, invasive monitoring and syringe pumps [fig. 1 & 2]. Such a stretcher could only be transported in special, high-volume ambulances [fig 3]. The overall interhospital critical care transport was coordinated and escorted by a critical care nurse and an intensivist. But nationwide demand for transports could not be matched adequately by these two units.

Fig 1. MICU-trolley, 2001 Radboud UMC, Nijmegen, the Netherlands (© J. v.d. Wiel)
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Fig 2 A & B. MICU-trolley, 1997 Academic Medical Center, Amsterdam, the Netherlands (© E.J. van Lieshout)

Fig 3. MICU-trolley & intra-aortal balloon pump in a high volume ambulance, 1999 Academic Medical Center, Amsterdam, the Netherlands (© E.J. van Lieshout)

In 1997, the IC-transport committee was initiated within the Netherlands Society of Intensive Care (NVIC) by several intensivists, who recognized this clinical problem nationwide. It obstructed regional cooperation between intensive care units to have critically ill patients being admitted in an ICU of the right level. The first Dutch guideline on critical care transport was published to set the bar for definitions, personnel, equipment and responsibilities. At the same time, there was an ongoing need for increased availability of ICU beds. In 2001, this became apparent after New Years’ fire disaster in Volendam causing over hundred casualties. Several months later, the report “Plaats in de herberg”
on ICU availability in the Netherlands was published 29. Alarming results on accessibility of critical care resulting in a federal taskforce gathering all relevant parties, including the state department of health, NVIC and associations of hospitals, ambulance services and health insurance companies 30. One of the sub taskforces was installed to handle the obstacles of critical care transport. The sector organizations of ambulance services (Ambulancezorg Nederland), health insurance companies (Zorgverzekeraars Nederland), NVIC, and the state department of health initiated a regional system of Mobile Intensive Care Units, based in university medical centers and two teaching hospitals 31.

A temporary regulation on MICU transport and seven licenses for regional interhospital transport issued by the state department were combined with reimbursement conditions by the Dutch Healthcare Authority 32. In 2008, after clearing all obstacles seven centers provided regionally executed critical care transport, almost 24/7.

EQUIPMENT AND EXPERTISE VERSUS RISKS

Interhospital transport of a critically ill patient may be indicated if additional care, whether technical, expertise, or procedural, is not available at the present location 1-4,18,22,33. The risks associated with interhospital transport should be weighed against its potential benefit for each individual critically ill patient 6,13,16,18,22,34-41. Many studies demonstrated that critical events are related to equipment, staff or logistics. The nature of critical care transport is that clinical deterioration is more or less expected as it might even have occurred without transportation as progress of disease. Comparing critical incidents during a certain time frame between patients in ICU or during transport seems challenging but hampered by different kinds of bias, e.g. case-mix and indication of transport. Much focus was and is placed on the use of appropriate equipment ranging from high end ventilators of smaller design to cardio-respiratory monitors with multiple invasive pressure channels, all on batteries and with better performance. The greatest challenge in modern critical care transport is to keep pace with bedside organ function replacement therapy. Fortunately, their manufactures acknowledge the fact that critical care medicine is not practiced on one spot. Radiology, OR, cath-lab and other departments with advanced lifesaving interventions demands intrahospital transport. Therefore, devices are supplied with batteries and mountable for trolley’s fixed bedside enabling transportation. Extra Corporeal Membrane Oxygenation (ECMO) is the latest but not the last addition in the palette of life saving devices. The complexity and increased risks in ECMO, with high diameters intravascular cannulas, remains challenging and both time and labor consuming. The increased use of ECMO might be correlated with insights in ventilator associated lung injury in combination with the burden of respiratory failure, even in immune competent patients with H1N1 influenza pneumonia 5,42-53. Referral centers, hospital or
non-hospital based ground and air medical critical care transport systems should cooperate closely to facilitate seamless and timely transfers. Mode of interhospital transportation, i.e. ground versus air medical by rotor or fixed wing aircrafts, seems to be influenced by distance and time saved. Medical technology assessment of the most appropriate mode to demonstrate better patient outcome and efficiency in terms of costs is hard to execute. It is assumed that ground transport is preferable, if the interfacility distance is within 50 km. Helicopter transport is most efficient within a range of 50-250 km and beyond that distance, fixed wing aircraft is considered the vehicle of choice. In the Netherlands, neonatal interhospital transport is sometimes executed by helicopter services but most critical care transport is by ground ambulance. The lack of certified landing sites on hospital roofs forces helicopters to land away from emergency rooms or ICU’s. This forces time consuming secondary transport from the landing site to hospital entrance by ambulance.

The use of specialized teams and appropriate equipment might reduce transport related risks. In neonatal and pediatric transport the use of retrieval teams, manned by dedicated professionals, is common practice in many countries. Studies demonstrated their additional value. However, different kinds of biases are troubling transport studies. Randomized controlled trials comparing physician versus non-physician staffed transport are lacking for many reasons, including differences in case mix or indications and difficulties in pre-transport randomization. It is, however, conceivable that if modes of therapy are continued during transport, they should be matched by the level of escorting expertise. Case control studies confirm this assumption by demonstrating a decreased number of critical events during transport, e.g., less cardiovascular incidents, and even mortality directly after transport.

Information and communication technology (ICT) for telemedicine has been introduced in critical care medicine to simultaneously deal with appropriate use of bedside intensivists and around the clock expertise with conflicting results. Its use in critical care transport might decrease the use of specialized retrieval teams. However, ICT in critical care medicine and during transport should be preceded by assessment of safety of the technology itself. Auto identification techniques, e.g. Radio Frequency Identification (RFID), have potential benefits in healthcare. Automated wireless bedside patient identification would enhance medication safety and render barcode scanning obsolete. Safety of blood transfusion management is greatly influenced by RFID with active RFID tags capable of temperature monitoring. But safety issues of electromagnetic interference of RFID antennas, which broadcast radio signals in a critical care environment,
remained to be elucidated. It could especially endanger moving objects with life-saving equipment, like a MICU trolley.

Although guidelines have been developed to increase safety of interhospital transports of critically ill patients, clinical evidence is lacking on factors determining the transportability of these patients. Despite balancing risks versus benefit in an individual critically ill, transportability as an optimal state before transportation is poorly defined. Indications for transport might be related to cardiac or vascular emergencies requiring advanced therapy in a referral center. In the meantime trying to stabilize circulatory and respiratory functions is crucial but may at times be impossible. The difference between planned and well prepared interhospital/inter-ICU or emergency transports, when speed is more crucial, is hard to assess from a clinical perspective. The use of checklists to evaluate pre-transport conditions might improve outcome after transport but again, studies in this field of medicine are hampered by methodological obstacles. Despite their drawbacks, checklists have proved their effectiveness in handoffs in emergency medicine and surgery and therefore their applications in critical care transport should be welcomed. Meanwhile checking off items without focus should be anticipated and solved by teamwork.

FUTURE

In the Netherlands an electronic health record in all regional MICU’s is just a matter of time and technology. The subsequently use of transport data in the National Intensive Care Evaluation (NICE) would further stimulate quality improvement in Dutch critical care medicine. Regional differences in ICU availability or referral indications could be analyzed and benchmarking of critical events during transport should stimulate quality improvement programs in Dutch MICU centers. Hospital Failure Mode Effect Analysis (HFMEA) could serve as a valuable tool in prospective risk analysis to reduce transport related risks. These analysis should give directions in the continuous search for better transport trolleys, which are still not standardized, not even within seven Dutch regions (fig 4). The same holds for critical care ambulances, which have not yet reached their final design. Risks analysis should lead to interventions as checklists or communication protocols, enhancing patient handoffs including digital information, e.g., laboratory results and imaging. The initial goals of the NVIC IC transport committee was to improve emergency transports by implementing definitions, protocols and resources for interhospital critical care transport. A clear definition of emergency vs. critical care MICU transport did facilitate ambulance dispatch centers in the last decade but MICU transports reaped more benefits. It is now up to Dutch emergency medicine, together with emergency medical services, to initiate protocoled interhospital emergency transport.
OUTLINE OF THE THESIS

In 2006 new mobile phone technology was introduced in interhospital critical care transport to enable telemedicine in order to support the escorting team with additional expertise. However, the electromagnetic compatibility of this technique, both GPRS & UMTS (3G+ technology), with critical care equipment was not assessed and studied in chapter two.

Although guidelines have been developed to increase the safety of interhospital transport of critically ill patients, clinical evidence is lacking on factors determining the transportability of these patients. Decision-making in interhospital transport involves appraisal of several determinants including patient characteristics, indication for transport, level of escort, and transport facilities. The process of appraisal of these variables by Dutch intensivist is studied in chapter three.

Applications of auto identification technologies such as radio frequency identification (RFID) in every day live include security access cards and electronic toll collection and applications in health care may have potential positive impact on patient safety and “track & trace” of medical products. Safety of RFID technology itself including potential harmful electromagnetic interference within the health care environment was never studied and is discussed in chapter four.

The combination of a registered critical care nurse and a paramedic as a specialized retrieval team in critical care transports is more common in the USA than in Europe where a team including a critical care physician is general practice. The first randomized controlled trial on the added value of a critical care physician as part of the transport team is studied in chapter five.
Risks of transportation seem manageable using an experienced escorting team and adequate equipment. Given the impact of mechanical ventilation settings on outcome of patients with or without Acute Respiratory Distress Syndrome (ARDS), continuation of reliable mechanical ventilation during transport is imperative in this patient category. Therefore, transport ventilators should be able to ventilate critically ill patients with accuracy comparable to intensive care unit (ICU) ventilators, despite their compact design and challenging conditions during transport. An update on the performance of new generation, gas-driven or turbine equipped, transport ventilators, especially with oxygen from cylinders instead of an oxygen wall outlet, is reported in chapter six.

Despite the recognized safety issues of in-hospital patient and equipment hand offs, studies on a systematic, prospective analysis of those hand offs in interhospital critical care transports are lacking. The development and before-after evaluation of safety checklist items based on Hospital Failure Mode Effect Analysis (HFMEA), integrated in a redesigned transport form followed by a questionnaire guided implementation are described in chapter seven.
REFERENCES


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