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

van Lieshout, E.J.

Publication date
2016

Document Version
Final published version

Chapter 8

Summary

The increased use of interhospital critical care transports from regional to referral hospitals is considered to be caused by regionalization of care. Risks associated with critical care transports are significant and reduced by using expertise and dedicated equipment. In the Netherlands, such transports were professionalized by a nationwide system of Mobile Intensive Care Units (MICU) with special retrieval teams, advanced mobile equipment and the use of dedicated IC-ambulances in the last decade.

This thesis comprises studies on technical and clinical aspects of interhospital critical care transport by a Mobile Intensive Care Unit.

New technology including ICT have been introduced in critical care transport to improve its quality and efficiency. Mobile phone technology enables telemedicine in critical care including remote monitoring by additional expertise to support clinical decision making. Introduction of new ICT in the field of critical care medicine and interhospital transport is scarcely accompanied by studies on safety of the technology itself.

In **chapter two**, electromagnetic interference (EMI) by second- and third-generation mobile phones on critical care medical equipment was assessed. Two type of signals (General Packet Radio Service (GPRS) and Universal Mobile Telecommunications System (UMTS) were investigated using maximal transmittance power as might happen in daily practice. Those signals were generated under controlled conditions in the proximity of 61 medical devices. A new clinical classification of events was defined to evaluate EMI with focus on patient safety instead of technical definitions. A total of 61 medical devices in 17 categories were investigated ranging from infusion pumps and mechanical ventilators to hospital beds and external pacemakers. Twenty six devices (43%) demonstrated 48 incidents. These were classified as light (25%), significant (42%) or hazardous (33%). Hazardous was defined as "direct physical influence on the patient by an unintended change in equipment function", e.g. total stopping of a mechanical ventilator or syringe pump. In 2007, the GPRS signal was used for data transfer in GSM networks and induced the most EMI incidents (41%). 3G technology like the UMTS signal induced 13% of the incidents. The median distance between antenna and medical device for EMI incidents was 3 cm but ranged from 0.1 to 500 cm. One hazardous incident occurred in a mechanical ventilator at 300 cm. Critical care equipment appeared to be still vulnerable to EMI by new-generation wireless telecommunication technologies but most incidents occurred around 3 cm. The policy to keep mobile phones *1 meter* from the critical care bedside in combination with easily accessed areas of unrestricted use still seems warranted.

Auto identification techniques, e.g. Radio Frequency Identification (RFID) have many applications in everyday life including security access cards, electronic toll collection and antitheft clips in retail clothing. Automated wireless bedside patient identification would enhance patient safety, i.e. medication or blood transfusion management, and render barcode scanning obsolete. A RFID antenna (e.g., anti-theft posts at shop entrances) is

continuously transmitting radio signals which creates an electromagnetic field. If a corresponding RFID tag enters this field, it is activated and able to identify itself. Difference between passive and active tags is that the latter is battery-driven. This enables it, apart from self-identification, to collect data like temperature or humidity outside the electromagnetic field of the corresponding antenna. However, electromagnetic interference of this field could especially endanger a moving object. A MICU trolley with lifesaving equipment might enter such a RFID-field.

In **chapter three**, electromagnetic interference (EMI) by RFID on medical devices was studied for the first time. A new clinical classification of events with focus on patient safety was used. Two different RFID systems transmitted at maximal output were tested according to an international test protocol in the proximity of 41 medical devices in 17 categories. The passive 868-MHz RFID signal induced a higher number of incidents (63%) compared with the active 125-kHz RFID signal (20%). The median distance between the RFID antenna and the medical device was 30 cm, ranging from 0.1 to 600 cm. It was demonstrated that RFID could induce potentially hazardous incidents in medical devices. Therefore, implementation of RFID in the critical care environment should require on-site EMI tests and updates of international standards of medical devices.

The use of specialized retrieval teams and dedicated equipment are thought to reduce the risks related to interhospital critical care transport. Clinicians weigh those risks against its potential benefit for each individual critically ill patient. Assessment of the patient's clinical condition by an intensivist includes the degree of , for example, dependence on invasive mechanical ventilation or supportive cardiovascular medication. This finally leads to a "fit or not fit" to transport verdict. The decision process is executed without clear guidelines or definitions on clinical stability. In **chapter four**, the relative importance of clinical and transport-related factors in this physicians' decision process were assessed. The medical heads of all 95 ICUs in the Netherlands were surveyed with a questionnaire using 16 case vignettes to evaluate preferences for transportability; 78 intensivists (82%) participated. The vignettes were descriptions of critically ill patients. Within those 16 vignettes, eight factors with regard to severity of illness and transport conditions varied. By use of conjoint analysis, the relative weights of those factors in the decision process could be objectified. The type of escorting personnel (e.g., paramedic only) and transport facilities (e.g., standard ambulance) had the most negative effect on preference for transportability. Determinants reflecting severity of illness turned out to be of relative minor importance (e.g., dose of vasopressor medication, arterial oxygenation). Age, cardiac arrhythmia, and the indication for transport had no significant effect. When escorting personnel and transport facilities are optimal, even severely critically ill patients are considered able to undergo interhospital transport. Further clinical research should tailor transport conditions to optimize the use of expensive resources in those inevitable road trips.

Despite circumstantial evidence of the beneficial effect of specialized retrieval teams, optimal staffing of ground critical care transport has not been evaluated. In **chapter five**, the results are reported of the first prospective, randomized, open-label, blinded-endpoint non-inferiority trial in interhospital ground critical care. Transported patients were randomized between transport staffed by a dedicated team comprising a critical care nurse and paramedic (nurses group) or a dedicated team including a critical care physician (nurses + physician group). The primary outcome was the number of patients with critical events, both clinical and technical, during transport. Clinical events included decrease in blood pressure, oxygen saturation, or temperature, blood loss, new cardiac arrhythmias, or death. Those events were recorded by an electronic health record in addition to written documentation to include those events who might have been overlooked. Patients were randomized and allocated to the nurses group (n = 147) or nurses + physician group (n = 151). In the nurses group, a critical care physician accompanied every transport for safety reasons but was not physically present in the patient compartment of the ambulance to avoid unsolicited medical advice or intervention.

The percentages of patients with critical events were 16.3 % (24 incidents in 147 transports) in the nurses group and 15.2 % (23 incidents in 151 transports) in the nurses + physician group, not statistically significant for non-inferiority. Critical events occurred in both groups at a higher than the expected (0–1 %) rate. In the nurses group consultations for physician assistance were requested in 8.2 % (12 in 147 transports), all of which were performed prior to transport. It was concluded that the number of patients with critical events did not markedly differ between critical care transports staffed by a critical care nurse and paramedic compared to a team including a critical care physician. However, as a result of an unexpected higher rate of critical events in both groups recorded by an electronic health record, non-inferiority of nurse-led interhospital critical transport could not be established.

A definitive answer on the appropriate patient selection and team composition might arise from larger multi-center trials or meta-analysis. Until then, the results might not change the present policy of physicians escorting critical care transports in Western Europe and could fuel the discussion on critical care paramedics in the US.

Given the dependency of critically ill patients on mechanical ventilation, it is of vital importance that transport ventilators perform at the same level as ICU ventilators. In **chapter six**, accuracy of six new generation transport ventilators were assessed under different simulated pulmonary conditions, ventilator settings and modes of oxygen supply. Two ICU ventilators were tested as references. The pulmonary conditions simulated healthy lungs, Acute Respiratory Distress Syndrome (ARDS) and Chronic Obstructive Pulmonary Disease (COPD). Accuracy of tidal volume (V_T) was measured by a calibrated pneumotachograph.

Inaccuracy in V_T delivery was demonstrated mainly in gas-driven transport ventilators (Medumat Transport 66010 in 8 of 10 experiments, 80%, Oxylog3000 in 70%, Hamilton Raphael 350 in 40%) as well in one turbine-equipped ventilator (Elisée 350 in 60%). Pulmonary conditions (healthy, ARDS or COPD) did not consistently influence inaccuracy in V_T. The impact of oxygen supply by cylinder on V_T inaccuracy was present only in two gas-driven ventilators under ARDS-conditions. It was concluded that transport ventilators differ in accuracy of delivering tidal volume demonstrating better performance in turbine-equipped models. The use of gas-driven ventilators in critical care transport should be questioned considering their performance even though its present use in some MICU's in the Netherlands.

Despite the recognized safety issues of in-hospital patient and equipment hand offs, studies in interhospital critical care transports of those hand offs are lacking. In **chapter seven**, Hospital Failure Mode Effect Analysis (H-FMEA) with a questionnaire guided implementation to improve patient and equipment hand offs in interhospital critical care transport are studied. H-FMEA of all hand offs in the MICU process was performed by a multidisciplinary team of experts. They assigned scores and calculated risk priority numbers (RPN) of hand offs: scores of frequency *times* severity *times* safeguard. The severity scale, for example, from ranged from 1 (near miss, no harm) to 10 (catastrophic event, serious injury or death). A pre-intervention questionnaire among critical care transport nurses and physicians was used to evaluate safety issues perceptions. Protocol adherence was observed *before* and *after* the introduction of a redesigned transport form including new patient and equipment hand off checklist items. A majority of the questionnaire respondents (85%) agreed on the statement that checklists would improve quality of critical care transports. Twenty five interhospital critical transports could be observed *before* and *after* the intervention (n=50 in total). Ten out of nineteen items (53%) demonstrated an improvement in hand offs after the intervention, whereas three items already showed maximal positive scores before intervention. Five out of six hand off items with high RPN scores (> 300, considered as clinically most important) improved after intervention.

It is appreciated that the combination of H-FMEA, a questionnaire guided implementation and a transport form which supports workflow, resulted in improved patient and equipment hand offs in interhospital critical care transport.