ABC IN DUTCH HELICOPTER EMERGENCY MEDICAL SERVICES

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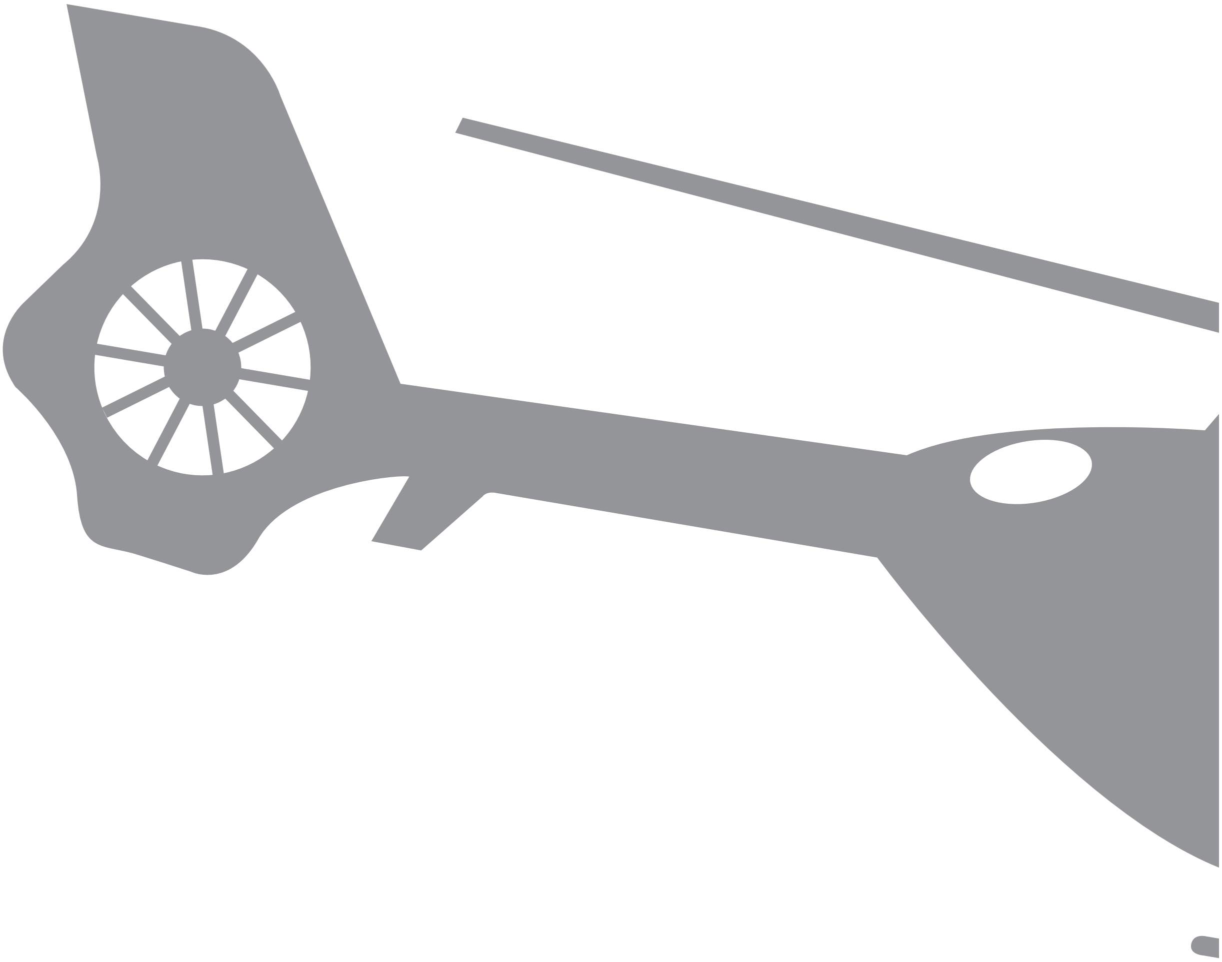
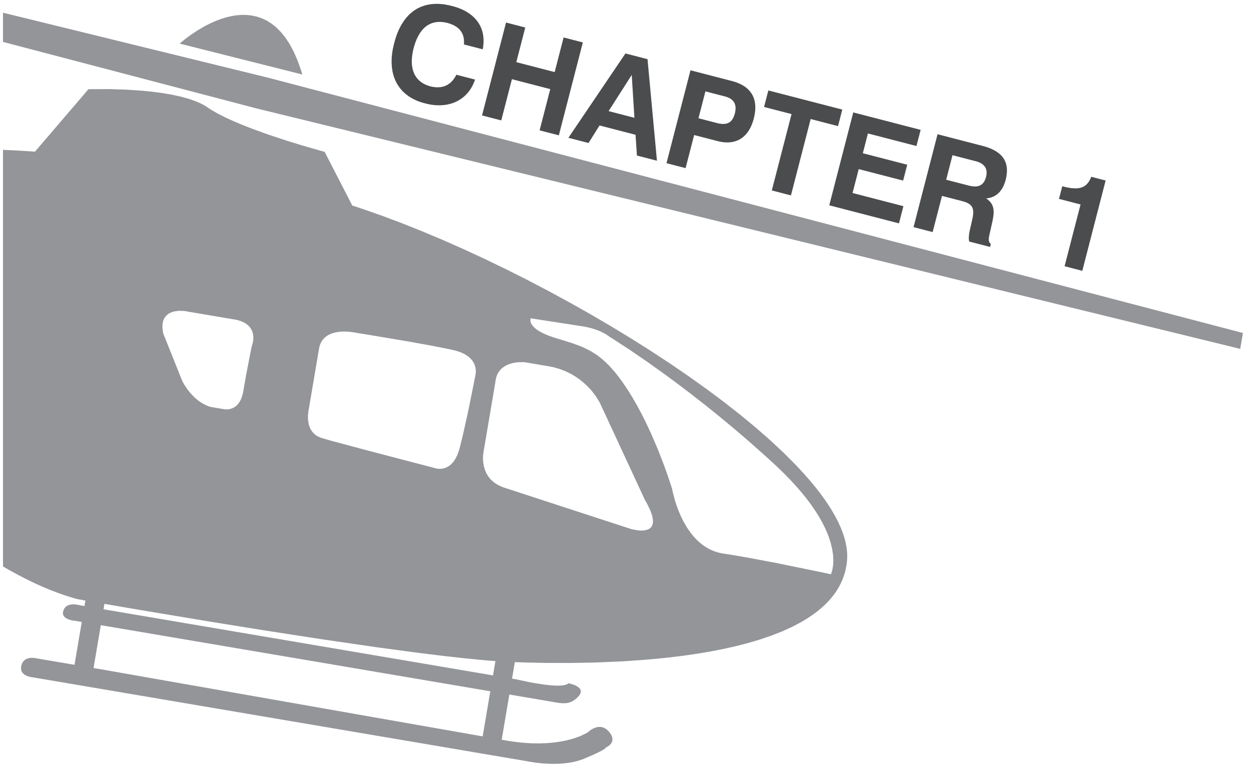


CHAPTER 1



Introduction and Outline of the Thesis

INTRODUCTION

In this thesis, two concepts of medical care are merged. The principles of Advanced Trauma Life Support (ATLS) are combined with research on interventions performed by a physician-staffed Helicopter Emergency Medical Service (HEMS). In the ATLS doctrine, a structured approach is advocated using the letters “A”, “B”,”C”,”D” and “E”.[1] These guidelines simplify and give structure to the management of (intensive) care, improving treatment for trauma patients.[2-4] The injuries that need the most urgent attention are addressed first.[1] These ATLS guidelines also apply to HEMS operations and are helpful in the often complex treatment of critically ill patients.

Prehospital HEMS treatment consists of more than airway management, for instance. It is also essential to prevent ongoing blood loss, perform surgical interventions, triage adequately and so on. Dutch HEMS brings consultant-level medical care to the accident scene or to the critically ill patient. Hospital-level care is made available for the patient even prior to arrival at the hospital. Limited time, suboptimal working environments and resources demand a high level of training and preparation. Prehospital healthcare is often more complex and demanding and can be considered as working in an austere environment.[1] This work is often more challenging than the basic medical specialties of the HEMS physician (i.e. anesthesiology and trauma surgery).

This thesis consists of a wide variety of subjects, all structured and simplified using the familiar guidelines of ATLS denoted by “ABCDE”.

After more than two decades of HEMS operation in the Netherlands, the Mobile Medical Team (equipped with a Eurocopter EC-135 yellow helicopter) has become a familiar image in association with all sorts of severe healthcare problems.

Despite initial skepticism regarding the costs and necessity of this helicopter service, the Dutch HEMS is a cost-efficient advantage to prehospital care, saving approximately 5 lives per 100 patient contacts.[5, 6]

To maintain and improve this level of care, the critical evaluation of current performance, in addition to continuous education and innovation is necessary. In this thesis processes of our HEMS operation are analyzed and evaluated, with the intention of increasing the level of prehospital healthcare. Recommendations for implementation in prehospital care, and future research resulting from this thesis are presented in **chapter 14**.

INJURY AND TRAUMA IN PERSPECTIVE

Worldwide, almost 6 million people die each year as a result of injuries. This accounts for 10% of the world's deaths, far more than the number of fatalities from malaria, tuberculosis, and HIV/AIDS combined.[7] Figure 1.

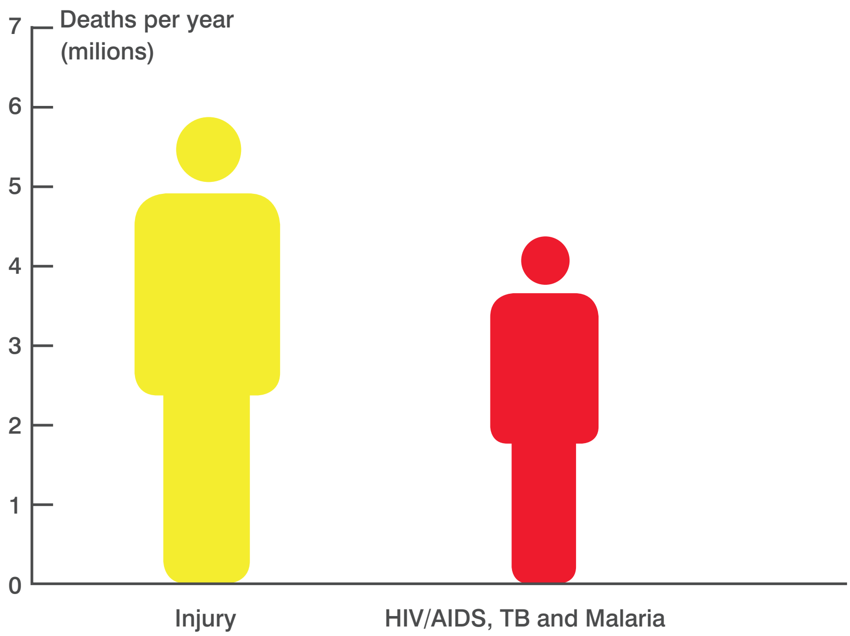


Figure 1: Injury deaths compared to other leading causes of mortality worldwide [7]

Within the group of people who die from injuries, a further specification was made by the World Health Organization (WHO) as visualized in figure 2. In their report "Injuries and violence: the facts" a prediction is made regarding the three leading causes of death in the injured patients: road traffic crashes, homicide and suicide. The WHO anticipates an increase in these injury-related deaths in the next decades. Figure 3.

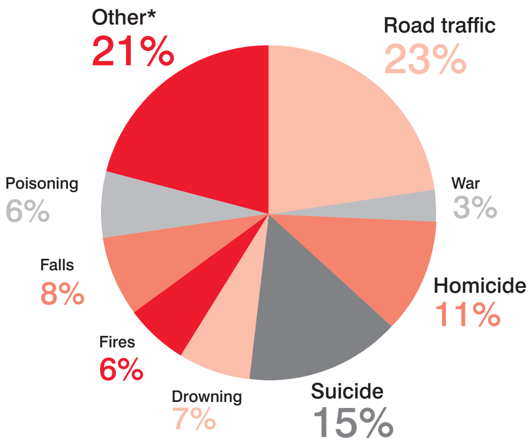


Figure 2: Causes of injury deaths worldwide [7]
**'Other' includes smothering, asphyxiation, choking, animal and venomous bites, hypothermia and hypertherm*

Total 2004	Total 2030
1 Ischaemic heart disease	1 Ischaemic heart disease
2 Cerebrovascular disease	2 Cerebrovascular disease
3 Lower respiratory infections	3 Chronic obstructive pulmonary disease
4 Chronic obstructive pulmonary disease	4 Lower respiratory infections
5 Diarrhoeal disease	5 Road traffic crashes
6 HIV/AIDS	6 Trachea, bronchus, lung cancers
7 Tuberculosis	7 Diabetes mellitus
8 Trachea, bronchus, lung cancers	8 Hypertensive heart disease
9 Road traffic crashes	9 Stomach cancer
10 Prematurity and low birth weight	10 HIV/AIDS
11 Neonatal infections and other	11 Nephritis and nephrosis
12 Diabetes mellitus	12 Suicide
13 Malaria	13 Liver cancer
14 Hypertensive heart disease	14 Colon and rectum cancer
15 Birth asphyxia and birth trauma	15 Oesuphagus cancer
16 Suicide	16 Homicide
17 Stomach cancer	17 Alzheimer and other dementias
18 Cirrhosis of the liver	18 Cirrhosis of the liver
19 Nephritis and nephrosis	19 Breast cancer
20 Colon and rectum cancers	20 Tuberculosis
22 Homicide	

Figure 3: Ranking global causes of death, including predictions for 2030 [7]

For each human that dies because of injury, a multitude of people have been injured, leading to hospitalization, disability, health care costs and burdens to society. The WHO illustrates this in pyramid-shaped form. Figure 4.

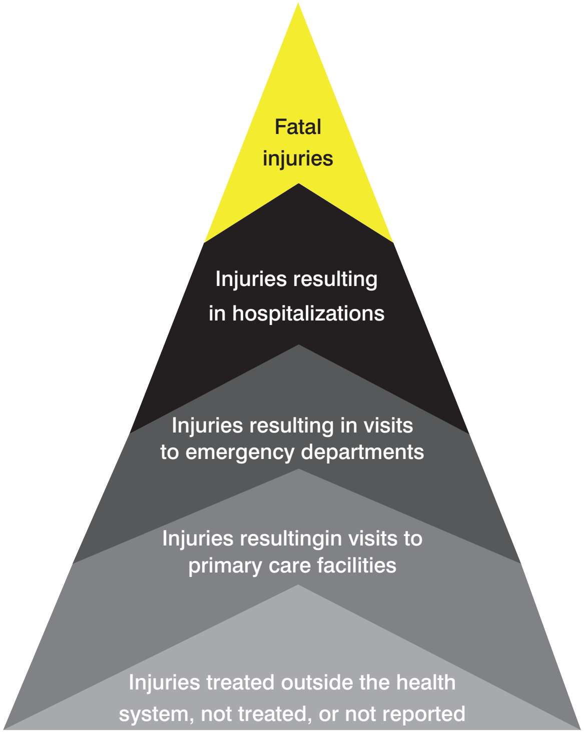


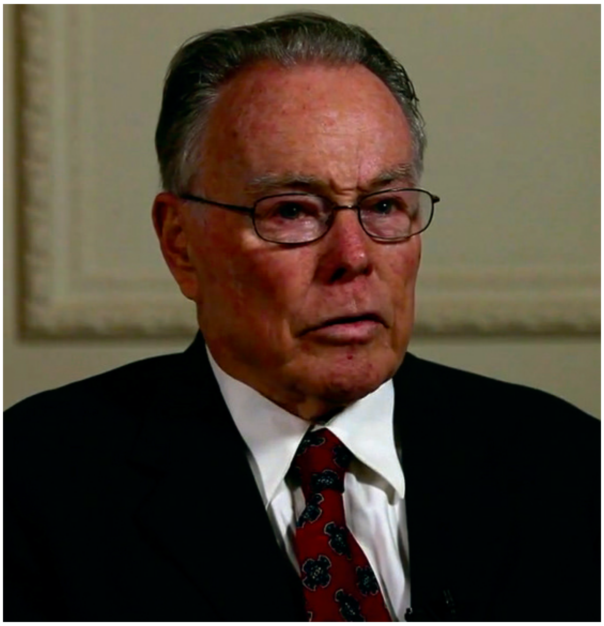
Figure 4: Demands on society due to injury [7]

Trauma is the leading cause of death among young people aged 15—29 years. Worldwide, about 1.25 million people die each year as result of road traffic crashes. Between 20 and 50 million more people suffer non-fatal injuries, with many incurring a disability as a result of their injury.[8]

In the Netherlands, 7,241 people died in 2015 because of non-natural causes, of which 630 were road traffic accidents. A total of 3,475 persons died as a result of a fall and 1,871 persons committed suicide.[9] In 2014, more than 1.1 million ambulance dispatches were recorded. Two-thirds of these dispatches were urgent in nature.[10]

ADVANCED TRAUMA LIFE SUPPORT

In 1976, an American orthopedic surgeon named James K. Styner. (picture 1) flew his private airplane from Los Angeles to Lincoln, Nebraska after a wedding. On board were his wife Charlene (aged 32) and their four children (aged between 3 and 10). After 5 hours of flight, they got disoriented and lost altitude, eventually crashing into a row of trees in a rural Nebraska cornfield. Picture 2. Charlene was ejected from the plane on impact and died instantly. Three children lost consciousness and were extracted from the plane by the wounded surgeon. Hours after the crash, they were able to reach a car in the remote area and it brought the survivors to a nearby hospital. This hospital was closed, and personnel had to come from their homes to take care of the injured family.



Picture 1: James K Styner

Picture 2: Styner's crashed plane

Dr Styner criticized the fact that the doctors had little experience and training in the treatment of severely injured patients. For instance, they paid no attention to the protection of the cervical spine. (He obviously focused on this, being an orthopedic surgeon). He arranged helicopter extraction to a large trauma center and the rest of the family survived. An impressive report on this event by the Styners can be seen on Vimeo.[11]

Styner later stated: *"When I can provide better care in the field with limited resources than my children and I received at the primary facility, there is something wrong with the system and the system has to be changed."* [12, 13]

This led to the development of a structured approach in trauma care, initiated by Styner and colleagues. The first ATLS® course was held in 1978 in Auburn, Nebraska. The course was adapted by the American College of Surgeons Committee on Trauma in 1980.[14]
The core of the ATLS is the structured approach using "ABCDE", based on the principle: *"Treat first what kills first"*.[1] The assessment of the patient is performed in a phased fashion, indicated by the first five letters of the alphabet. Life-threatening injuries are identified and treated before ascertaining other injuries. This method offers inexperienced healthcare providers a guide to fall back on if confronted with patients having multiple injuries, while offering a "common language"

for all healthcare professionals involved in the care of those who are injured, enhancing efficient communication. A short summary of the ATLS "ABCDE":

A: Airway: Make sure the airway is secured, in combination with cervical spine protection
B: Breathing: Adequate ventilation
C: Circulation: Stop bleeding and restore adequate tissue perfusion
D: Disability: Evaluate the neurological status
E: Exposure/Environment: Complete inspection of the patient for injuries, with hypothermia prevention.

In 1995, the first ATLS course in the Netherlands was organized. Dutch ATLS courses are licensed to the Dutch Trauma Society.[15] ATLS courses are offered in over 60 countries and over a million doctors attended ATLS training globally.[16]

HEMS IN THE NETHERLANDS

Prehospital medical care using a helicopter was introduced in the Netherlands in May 1995. The first Dutch trauma helicopter operation was a cooperation of the Amsterdam VU Medical Center and the “Algemene Nederlandse Wielrijders Bond” (ANWB). [17] The ANWB provided the helicopter and a helicopter pilot and the hospital supplied the HEMS nurse and physician (either an anesthesiologist or a trauma surgeon). Worldwide, not all HEMS operations are physician staffed. For instance, in the United States, not a physician but a flight nurse or paramedic is on board to provide medical care in most operations. In these settings, the focus is more on transportation from a location to an adequately equipped trauma center. The primary goal of Dutch HEMS is to transport experts in providing hospital-level medical care to critically ill patients from the hospital to the patient on scene. In this way, interventions such as Rapid Sequence Induction (RSI), thoracocentesis, and chest tube drainage are available on scene. In addition to these medical skills, other important factors are adequate patient triage, communication, and decision making.
In our setting, HEMS is an adjunct to ambulance services in the majority of cases. Dutch ambulances are equipped with ambulance nurses who perform their task according to strict protocols and guidelines.[18] A physician associated with the ambulance service is accountable for the level of care and actions taken by the ambulance nurses, therefore strict adherence to protocol is mandatory. HEMS dispatches are undertaken according to guidelines including both the vital status and the mechanism of trauma.[19]

In addition to the HEMS operation in Amsterdam, Dutch HEMS was extended to three other locations (Rotterdam, Nijmegen, and Groningen), dividing the Dutch territory into four regions. [20] Picture 3

Picture 3: Location of Dutch HEMS

After a successful pilot program in 2006, Nijmegen HEMS expanded its flight times to a 24/7 helicopter service, performing night-flight dispatches.[21] This service has been available nationwide since 2010.

Dutch HEMS (n=4) had 8,114 helicopter dispatches in 2016.[22] Physician-staffed HEMS are a valuable evidence-based addition to the Dutch ambulance system, saving approximately 5.3 lives per 100 dispatches.[5]

OUTLINE OF THE THESIS

The majority of patients treated by Dutch HEMS are in need of definitive airway management. This can be obtained by placing an endotracheal tube between the vocal cords and inflating the tube's cuff. In the Netherlands, ambulance paramedics are not allowed to use medication such as high dose anesthetics or muscle-relaxant drugs to facilitate intubation. Intubation attempts without these medications should be limited to reduce stress, raise intracranial pressure and limit the risk of aspiration. RSI and endotracheal intubation must be performed by experienced care providers, particularly in the suboptimal and often difficult prehospital environment.[23, 24]
In **chapter 2,** a study is presented comparing the success rate of the first intubation attempt under RSI conditions. The first-pass intubation success rate of ambulance staff is compared to HEMS nurses and HEMS physicians.
The prehospital conditions are different compared to the in-hospital situation. In the hospital, patients require an empty stomach prior to intubation, obviously in contrast with the HEMS patients. Alcohol and drugs in trauma patients are also factors that increase the risk of aspiration and contribute to more difficult airway management. The key is to limit the number of intubation attempts and to provide ventilation and secure the airway. Failure to do so is associated with negative outcomes and death. If RSI fails and a supraglottic airway device (SAD) is not sufficient to ventilate and oxygenate the patient, the next step is to create an emergency surgical airway (ESA). In cases of extensive facial trauma or swelling of the upper airway due to anaphylactic reactions, an ESA can be the first method of choice in obtaining a definitively secured airway. In **chapter 3,** the indications and results of ESA by a physician-staffed HEMS are presented and compared to data available in international literature.
A secured airway includes a cuff-insufflated distal to the vocal cords. This cuff is essential to prevent gastric contents and blood entering the lower airways and lungs. HEMS patients that need prehospital RSI and airway management are critically ill and vulnerable and often remain intubated in the Intensive Care Unit (ICU) for a considerable amount of time. High pressure in the tracheal cuff can lead to mucosal ischemia and associated complications such as tracheal stenosis and fistula.[25] Cuff pressure must be sufficient to maintain the seal, it must be as low as possible to prevent these complications. In **chapter 4,** an overview is presented concerning cuff pressure after prehospital intubation. Results are presented differentiating between ambulance and HEMS tube placement.

After securing the airway, adequate ventilation is essential. Ventilation abilities may be compromised after trauma. In these cases, a pneumothorax may be diagnosed. A pneumothorax may develop into a tension pneumothorax (TP), especially in patients who are ventilated with positive pressure. In TP, pressure builds up inside the pleural cavity and diminishes gas exchange, venous return and cardiac output. These events can lead to rapid patient deterioration and, if untreated, death.

In prehospital settings, patients with traumatic cardiac arrest (tCA) have high mortality rates and treatment needs immediate focused action. One of the most common management errors in tCA is the inability to diagnose and decompress a TP. Treatment of a TP in a tCA setting is a potential life-saving action and may restore circulation. Early treatment of TP in tCA is advocated and can be performed by opening the affected thoracic orifice by making an incision and thereby releasing intrathoracic pressure. A thoracostomy is a simple intervention to treat or exclude a TP as a cause of tCA.[26] **Chapter 5** describes the indications and results of a prehospital thoracostomy in tCA from a physician-staffed HEMS.

Ongoing blood loss after trauma may lead to exsanguination. Massive hemorrhage is recognized as a leading cause of preventable deaths. Stopping this blood loss as early as possible is an essential step in improving survival and outcomes. Prehospital hemorrhage control can be achieved by simple compression of the bleeding. More advanced materials have recently been introduced using coagulation-promoting factors that enhance clot formation. **Chapter 6** describes a cohort of patients with significant blood loss who were treated using hemostatic bandages. An alternative to this hemostatic bandage is the application of a wound-closure clamp. This clamp can be used to quickly adhere wound edges to limit ongoing blood loss. The results of this temporary hemostatic device in a prehospital setting are presented in **chapter 7.**

Hypovolemic shock is common in trauma patients and, when not adequately treated, leads to cellular hypoperfusion and death. This mechanism is described in "trauma lethal triad of death".[27] External bleeding must be stopped by means of bandages, pressure application, tourniquets etc. Some examples are previously described in **chapters 6** and **7**. Internal bleeding is more difficult to treat in prehospital settings and quick extraction and transport to an appropriate hospital which is equipped adequately enough to perform surgical intervention is necessary. Because of the entrapment of the patient or the prolonged transport time to an adequate hospital, the bleeding patient might need suppletion of blood products. The prehospital uncrossmatched, type O red blood cell transfusions by a physician-staffed HEMS are described in **chapter 8**. The aim of this study was to establish the efficacy and safety of this transfusion compared to a patient cohort that did not receive blood prior to hospital admission.

When deploying a physician-staffed HEMS, expertise is brought to the accident scene. This also includes resuscitative surgical interventions such as amputation, perimortem caesarean section and thoracotomy.[28-36] The outcomes of a multicenter HEMS cohort of patients with on-scene resuscitative thoracotomies are presented in **chapter 9**.

Patients in a HEMS setting frequently have associated traumatic brain injuries (TBI) to a various extent. Early diagnostics and, if necessary, prompt intervention is essential in the treatment of these patients. The adequate triage of TBI patients in well-equipped level 1 trauma centers with neurosurgical intervention options is vital. In addition to the physical examinations and evaluations of the neurological functioning (Glasgow Coma Score, GCS) of patient, a portable near-infrared spectroscopy (NIRS) device is developed to quantify TBI in prehospital setting. The feasibility of this NIRS device in HEMS trauma patients are presented in **chapter 10**.

Approximately a fifth of Dutch HEMS patients are children. Because of their age and physiological constitution, these patients are extremely vulnerable and often need specialized treatment in medical centers with pediatric intensive care facilities. Most hospitals in the Netherlands lack this facility, as it is only available in the university level 1 trauma centers. Helicopter transportation of these children to the appropriate center is an option. To evaluate the safety of this form of air transport, we investigated all the children our HEMS delivered to the hospitals by helicopter. In **chapter 11,** the results of this survey are presented.
During the first years of HEMS operation, flight conditions were restricted to daytime operations. During night time, ground transportation of the team by car was available limiting reaction time, dispatch areas and availability. Since 2006, Nijmegen HEMS has expanded its helicopter-based work from a daytime operation to a full 24/7 service. For night flights, night vision goggles (NVGs) are used by both crewmembers to enhance vision. On the other hand, the use of NVGs may lead to disorientation, physical complaints, and hardware interaction problems, which may cause safety issues. Despite the low-light conditions and their ensuing limits on vision, patients are transported by helicopter as well. To evaluate the safety-related issues related to these patients during night transport, we reviewed the HEMS database. In **chapter 12,** we present the results regarding the safety of these nightly transport dispatches.

Chapter 13 consists of a general discussion, reflecting on the data presented. Recommendations resulting from this thesis are presented in **chapter 14**. The summaries, discussion and recommendations as presented in these chapters are printed in Dutch in **chapter 15**. The various abbreviations in this thesis might confuse the reader, therefore these are explained in the **appendices**.

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CHAPTER 2a

AIRWAY

First-pass intubation success rate during rapid sequence induction of prehospital anaesthesia by physicians versus paramedics

ABSTRACT

Introduction:

Endotracheal intubation is a frequently performed procedure for securing the airway in critical injured or ill patients. Performing prehospital intubation may be challenging and intubation skills vary. We reviewed the first attempt tracheal intubation success rate in a Dutch prehospital setting.

Methods:

We studied our database for all intubations performed by helicopter emergency medical services (HEMS) physicians, HEMS nurse and ambulance paramedics under HEMS supervision between January 2007 and July 2012. Primary outcome was success rate, number of intubation attempts and alternative airway procedures.

Results:

1399 Patients were in need of a secured airway. In 571 (40.8%) of these cases ambulance paramedics did a first intubation attempt under HEMS supervision. If necessary RSI medication was administered. In comparable patient groups first intubation success rate was significantly lower in ambulance paramedics compared to helicopter physicians (46.4 vs. 84.5%, $p<0.0001$). Overall physician intubation success rate was 98.4% after one or more intubation attempts. In 19 cases a surgical airway was created and in three cases an alternative ventilation method was used.

Conclusions:

Prehospital intubations had a significantly higher success rate when performed by helicopter physicians. We promote a low threshold for HEMS deployment in cases of a potentially compromised airway.

INTRODUCTION

Airway compromise has been identified as a preventable cause of poor outcomes and death in trauma and cardiac arrest patients. Rapid sequence induction (RSI) is generally accepted as the technique of choice for securing the airway in these seriously ill or injured patients[1]. Emergency tracheal intubation (ETI) may be challenging, especially in often suboptimal prehospital conditions.

Controversy exists about who provides best prehospital medical care. Some European emergency medical services (EMS) are physician staffed while others rely on paramedics alone.[1-3] Reported success rates for prehospital ETI range from 50 to 100%.[4-8] Data from different countries vary and are influenced by local prehospital care organization, training, patient selection and skills. Therefore results are difficult to compare.[9] Failure to establish a patent airway in the field and inability to position an endotracheal tube correctly are associated with negative outcome.[10-12]

In the Netherlands, four helicopter emergency medical services (HEMS) function as an adjunct to paramedic ambulance services. A HEMS team consists of a pilot, a specially trained flight nurse and a physician. This team is capable of delivering hospital-level medical care in the field. HEMS is available 24/7 for trauma and non-trauma cases.

By law, Dutch ambulance paramedics are not allowed to administer RSI or Drug Facilitated Intubation (DFI) medication to facilitate ETI. This means they only perform non drug assisted intubations, as in cardiac arrests. These intubation conditions are different from drug assisted intubations and put the operator under different degrees of pressure.

Some support the more liberal use of prehospital paramedic RSI.[13] Others find this difficult to advocate and point out serious complications as cardiac arrests and hypotension during RSI as deteriorating factors worsening outcome.[14] The San Diego Paramedic RSI trial showed an increase in TBI associated mortality in the ETI group.[15] The question remains if paramedics are adequately trained and skilled to perform safe RSI.

In most cases Dutch HEMS physicians performed the intubation. Sometimes the ambulance paramedics were given one opportunity to perform an intubation attempt after RSI drug administration by the HEMS physician.

We studied the first pass intubation success rate of Dutch paramedics after HEMS physician RSI medication administration.

PATIENTS AND METHODS

We reviewed our retrospective HEMS database from the Radboud University Medical Center in the Netherlands which contains essential data from all dispatches. This database also contains data about indication for RSI, by whom the intubation was performed, the number of intubation attempts and success rates.

An intubation attempt was defined as the preparation for RSI, including medication administration, visualizing the vocal cords and if possible placement of the tracheal tube. If tube placement was not successful and the laryngoscope was removed from the oropharynx this ended the intubation attempt. During this procedure vital parameters were monitored preventing periods of hypoxemia. Hypoxemia was prevented by limiting intubation time and continuing mask/bag ventilation after a failed attempt.

Malpositioning of the tracheal tube and alternative airway access maneuvers were scored, including considerations for decision-making. Tube position was verified by depth of tube placement,foggin, symmetrical thoracic movement, auscultation of breath sounds and capnography.

All HEMS patients (pediatric and adult) in need for a secured airway at HEMS arrival were included. Patients intubated prior to HEMS arrival were excluded because of the lack of proper documentation. After each dispatch the data is entered by the HEMS physician and double checked by the HEMS nurse to ensure data integrity.

Data were analyzed using SPSS (IBM, SPSS version 20). A p-value of < 0.05 was considered to be statistically significant.

RESULTS

Between January 2007 and July 2012 a total number of 1399 patients were in need of a secured airway. Patient age was 40.1± 23.7 years The majority of patients (n=1095, 78.3%), had a Glasgow Coma Score (GCS) of 8 or less, with a median GCS of 5 (range 3-15). In 95 cases (6.8%) pain relief or the need of (helicopter)transportation was the indication for intubation in patients with a GSC above 8. Other patients were in shock because of trauma or critical illness, or had other reasons for intubation.

In 1399 cases the HEMS physician decided to obtain a secured airway. This was successful in 1377 patients (98.4%). In all cases the first tracheal intubation attempt was performed after HEMS arrival and performed by HEMS (physician/nurse) or ambulance personnel. After administration of RSI medication by HEMS, ambulance paramedics were given a chance to perform an intubation under supervision of the HEMS physician 571 times (40.8%)

Because our location is near to the German border, we also included 29 patients (2,1%) intubated by German HEMS physicians.
Ambulance paramedics had a first pass intubation success percentage of 46.4%. HEMS physicians successfully intubated 84.5% of the patients on the first attempt. Data are summarized in Table 1.

First intubation attempted by	Number	First attempt successful	First attempt success rate
Ambulance paramedic	571	265	46.4%
HEMS nurse	96	56	58.3%
HEMS physician	732	619	84.5%

Table 1: Success rates for first endotracheal intubation attempt using RSI.

We noticed a significant difference ($p<0.0001$) in first attempt success rate between intubations performed by ambulance paramedics under HEMS supervision in comparison with HEMS physicians. HEMS nurses performed better on first attempt ($p=0.034$) in comparison with ambulance paramedics. Overall median number of intubation attempts was 1 (range 1-6). In 15 patients (1.1%) the number of intubation attempts exceeded 3 (median 4, range 4-6).
Demographics and intubation grades according to Cormack and Lehane are summarized in table 2. Only the patients with complete data are listed ($n=1094$, 78.2%). There was no significant difference in ages, sex or incident type. A significant difference was seen in number of grade 1 and 4 intubations between paramedics and physicians.

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	Physician	Paramedic	Total	p-value
Age (years)	39.6 ± 25.1	40.7 ± 21.6	40.1 ± 23.7	0.475
Sex				
M	491	337	828	0.117
F	143	123	266	
Incident type				
Trauma	509	353	862	0.177
Non trauma	125	107	232	
Intubation grade				
Grade 1	369	296	665	**0.040**
Grade 2	179	128	307	0.882
Grade 3	60	29	89	0.059
Grade 4	26	7	33	**0.014**
Numbers	634	460	1094	

Table 2: Demographic data and intubation grades

In 22 (1.6%) patients it was impossible to obtain a secured tracheal airway. Various reasons are listed in Table 3. One patient was ventilated using a Laryngeal Mask Airway (LMA) and one with bag-valve-mask ventilation. Resuscitation of one patient with circulatory arrest was terminated prior to obtaining a secured airway. In 19 patients an emergency surgical airway was needed by performing a prehospital cricothyroidotomy. In our database we recorded 9 surgical airways after failed intubation attempts (0.6%). Ten surgical airways were performed primarily without attempt of ETI, due to extensive damage to upper airway structures.

Reason for failure to obtain airway	Number of patients
Suction not efficient for adequate view	1
Previous mandibular fixation	1
History of radiation for cancer in area	1
Severe facial burns	1
Obstructing tumor	1
Medication for RSI not effective, no relaxation	1
Penetrating trauma to face/neck, gunshot wounds	5
Blunt trauma to upper airway/facial structures resulting in continuous bleeding	11

Table 3: Reasons for inability to acquire a secured airway by endotracheal intubation.

DISCUSSION

Obtaining a secured airway under prehospital conditions may be challenging. Especially in trauma patients with the risk of cervical spine injuries, with manual in-line immobilization of the cervical spine. In recent years, various supraglottic airway devices have been introduced such as the LMA and larynx tubes, but still the tracheal tube with insufflated cuff is the preferred device for securing a patent airway in vitally compromised patients.[16] ETI requires skills with continuous training since it is potentially lethal when tracheal tubes are malpositioned.[17-19]

Dutch paramedics are not authorized to administer RSI medication including muscle relaxants in prehospital setting. Suboptimal medication leads to suboptimal conditions in paramedic ETI. Some promote more liberal use of RSI medication or DFI as this appears to increase paramedic intubation success rates.[8, 19] When anesthesia including muscle relaxants are administered by the HEMS physicians, the intubation circumstances for paramedics are optimized to intubate. After RSI medication there is still a significant difference in the ability to perform ETI between paramedics and HEMS physicians as can be seen in first intubation success rates. No randomized controlled trials exist comparing prehospital intubation performed by physicians or paramedics. Bernard et al. reported a prehospital paramedic intubation success rate using RSI in brain injured patients of 97%.[13] This is similar to our reported HEMS physician intubation success rate of 98.4%. Increased training, exposure and skills of the paramedics in the above study is likely to be a contributing factor.

The decision between facilitating ambulance paramedic intubation vs. primary HEMS intubation was not motivated in the database. It is tempting to assume it concerns those cases with a low suspicion of encountering a difficult airway, thus selecting the cases less difficult to intubate for paramedics. The actual difference between both groups may therefore be even more distinct.

Success rates for first intubation attempts done by HEMS nurses are significant better than those of ambulance paramedics (58.3 vs 46.4%). A possible explanation may be the that HEMS nurses have had more exposure to critically ill patients and have years of prehospital experience prior to their HEMS training. They often have a background as registered nurse anesthetist, increasing their intubation expertise.

After an unsuccessful first intubation attempt a second effort must be done to secure the airway, leading to more risk of aspiration and insufficient ventilation. Each laryngoscopic instrumentation causes increased intracranial pressure through sympathetic stimulation. In traumatic brain injury this may cause further secondary brain damage.[20] Trauma patients with Glasgow Coma Scores (GCS) of 13 or 14, if agitated, have a 12.5% change of requiring neurosurgical intervention.[21] This group of patients also benefits from early optimal ventilation, stress reduction and optimal preservation of cerebral perfusion pressure (CPP). This can only be achieved using proper RSI and minimizing the number of (unnecessary) intubation attempts. In 15 patients (1.1%) the number of intubation attempts was over 3 (median 4, range 4-6). This number of attempts is more than usually accepted by HEMS and needs to be reduced by selecting an alternative airway device or a cricothyroidotomy in an earlier stage. Because of recent introduction of the video laryngoscope and start of HEMS team training we expect this number to decrease in the near future.

More Cormack and Lehane grade 1 and grade 4 intubations were seen in the physician group. The difference in grade 1 views can be explained with physicians' intubation skills. The better the technique the better the view. More grade 4 in the physician group may be explained by the selection of the most difficult cases for HEMS physician intubation.

Outcome parameters were not reported in this study. Our database doesn't include medical details of patients after admittance to various hospitals. Because of legislation issues, we were not allowed to complete these data without written permission of patients or legal representatives.

HEMS ETI was successful in 98.4%. Due to extensive facial/neck trauma ETI was not attempted or unsuccessful in some cases. In 19 cases a surgical airway had to be performed to ventilate the patient. This number may be reduced by using a video laryngoscope which increases visualization while maintaining in-line mobilization.[22, 23]

Experience in intubation skills of ambulance paramedics vary, as does the number of prehospital intubations performed. In the Netherlands approximately 5500 prehospital ETI are performed yearly (mainly on patients with cardiac arrest) by approximately 2200 ambulance paramedics. This results in an average of less than three intubations per paramedic per year. This is below the suggested number for gaining experience (n=57 for 90% success).[24, 25] This raises the question if skills for prehospital ETI are sufficient in Dutch ambulance paramedics.

We conclude that there is an added value of physician staffed HEMS in the Netherlands, and plea for liberal HEMS deployment in all patients with a potentially compromised airway.

CONCLUSION

The first attempt intubation success rate is significantly higher for Dutch HEMS physicians compared to ambulance paramedics in prehospital setting. This emphasizes the additional value of physician staffed HEMS. The threshold for HEMS deployment, in cases of a potentially compromised airway, must be low.

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European Journal of Emergency Medicine 2017; 24(1): 77

CHAPTER 2b

AIRWAY

Reaction to “letter to the editor”

Letter to the Editor

Phelps S.
European Journal of Emergency Medicine. 2017;24(1):76-77.

Regarding the recent article "*First-Pass Intubation Success Rate During Rapid Sequence Induction Of Prehospital Anaesthesia By Physicians Versus Paramedics"* by Peters, et al., it not surprising that when field paramedics, who do an average of 3 intubations per year and have no experience with rapid sequence intubation (RSI) perform significantly worse (46.4 vs. 84.5%) than EMS flight physicians who do approximately 45 RSI intubations per per year.*

The authors consistently recognize that there is a relationship between experience and successful endotracheal intubation (noting that 57 intubations yields a success rate of 90% for future performance), and their numbers clearly demonstrate the relationship between experience and success. The authors also note that other studies found prehospital paramedic intubation success rate using RSI in brain-injured patients of 97%, which are parallel to the physician experience found here.

Therefore, their conclusion that "there is an added value of physician-staffed HEMS in theNetherlands" is surprising. While few would argue that physicians have much deeper clinical judgement than paramedics, that is not the issue here. In fact, all the evidence presented indicates that if ANY of the clinicians mentioned here- paramedic, nurse, or physician did a significant amount of RSI-facilitated intubation, they would have similar high first-pass success rates. It is bootstrapping to say that "physician-staffed HEMS add value"-it is not being a physician that is adding value, it is the legal roadblock against other clinicians administering RSI or drug facilitated intubation medication to facilitate ETI. The call should be for the law to be changed.

What this paper does bring up, "whether skills for prehospital ETI are sufficient in Dutch ambulance paramedics," merits significantly more attention. Paramedics with sufficient training and clinical exposure can clearly produce success at rates equal to physicians, yet we see a nearly 40% difference in Dutch paramedics. The most important take-away from this paper is that clinicians with low clinical exposure to a skill need a comprehensive program including regular, ongoing training (either in another setting like the OR or via simulation), equipment and checklists which maximize the opportunity for success and minimize the opportunity for failure, and regular assessment of clinical competency. Anything else is extremely dangerous.

* There are 4 helicopters with probably 5 full time equivalent physicians each = 20 physicians doing 571 + 306 paramedic failure first pass + 40 nurse failure first pass = 916 intubations – 22 surgical airways = 894 physician intubations or an average of ~45 intubations/physician/year.

Dear Editor,

We like to thank professor Phelps for the reaction to our article regarding first-pass intubation success rates. We agree with him regarding the relation between experience and successful (first-pass) endotracheal intubation (ETI).
However, the presented calculation regarding numbers of annual HEMS physician intubations is not accurate and underestimates the total numbers of actual intubations per individual HEMS physician. All Dutch HEMS physicians have in hospital jobs, in most cases as anesthesiologist. They intubate patients daily on elective operation cases, multiplying the suggested number of ETI and airway management experience.
We are convinced of the added value of HEMS physicians in our prehospital setting. Not because we have skills or do a trick that cannot be learned by other professionals. It is because his type of care is delicate and relatively scarce. Clustering these patients and knowledge, is in our opinion key to improve care and outcome. These patients deserve the best care available.

Removing the legal roadblock against non physician application of RSI-facilitated intubation is not the answer in Dutch setting, and may even be dangerous. Because under RSI conditions in our study non-physician first-pass success rates are low. Failure to eventually secure the airway in this condition may cause disability or fatality. Again it is not just the trick, it is being able to have options when the initial plan fails, including being able to perform a emergency surgical airway. This also needs extensive experience and training.
Like Professor Phelps, we endorse a comprehensive training program including regular assessment of clinical competency. But not with the intension to train thousands of healthcare providers for a high risk, possible lethal intervention that is not frequently performed. This effort must be focused on those that are able to gain and maintain sufficient skills to obtain the best care possible, the HEMS physicians.

Peters JH, Bruijstens L, van der Ploeg J, Tan ECTH, Hoogerwerf N, Edwards MJR.

Injury 2015 May; 46(5): 787-790

CHAPTER 3

AIRWAY

Indications and results of emergency surgical airways performed by a physician staffed Helicopter Emergency Service

ABSTRACT

Background:

Airway management is essential in critically ill or injured patients. In a "can't intubate, can't oxygenate" scenario, an emergency surgical airway (ESA), similar to a cricothyroidotomy, is the final step in airway management. This procedure is infrequently performed in the prehospital or clinical setting. The incidence of ESA may differ between physician- and non-physician-staffed emergency medical services (EMS). We examined the indications and results of ESA procedures among our physician-staffed EMS compared with non-physician-staffed services.

Methods:

Data for all forms of airway management were obtained from our EMS providers and analyzed and compared with data from non-physician-staffed EMS found in the literature.

Results:

Among 1,871 patients requiring a secured airway, the incidence of a surgical airway was 1.6% (n=30). Fourteen patients received a primary ESA. In 16 patients, a secondary ESA was required after failed endotracheal intubation. The total prehospital ESA tracheal access success rate was 96.7%.

Conclusion:

The incidence of ESA in our patient population was low compared with those reported in the literature from non-physician-staffed EMS. Advanced intubation skills might be a contributing factor, thus reducing the number of ESAs required.

BACKGROUND

In the Netherlands, four Helicopter Emergency Medical Services (HEMS) function as an adjunct to paramedical ambulance services. A Dutch HEMS team consists of a pilot, a flight nurse and a HEMS physician. This team is capable of delivering hospital-level medical care at a senior level (all HEMS physicians are consultants), including damage control resuscitation, general anesthesia, advanced airway management and surgical interventions (amputations, thoracostomies, post-mortem cesarean sections), in the field.

HEMS are available 24/7 nationwide for acute critically ill or injured patients according to dispatch guidelines [1]. Similar to prehospital care systems in several European countries, our HEMS are physician staffed (pHEMS). These physicians are experienced trauma surgeons or anesthesiologists who are trained in emergency surgical procedures. Nijmegen pHEMS operate in a generally rural area in the south and eastern regions of the country on a 24/7 basis, serving approximately 4.5 million inhabitants. Regional ambulance services are dispatched according to uniform guidelines and work accordingly.

In airway management, adequate oxygenation and ventilation are essential to prevent poor outcome and death in trauma and cardiac arrest patients [2-4]. In a “can’t intubate, can’t oxygenate” (CICO) scenario, an emergency surgical airway (ESA) is the final step in difficult airway management [5]. An ESA is a potentially lifesaving procedure infrequently performed in prehospital or clinical settings. Dutch ambulance nurses are precluded from performing surgical airway procedures. In a CICO scenario, a percutaneous needle cricothyroidotomy is the last resort for airway management. Because of the small size of the patient groups, no statistically significant difference exists in the literature in favor of one specific emergency cricothyroidotomy method (needle or open) [6]. Dutch ambulance nurses are not legally allowed to use drugs to facilitate intubation. Therefore, all patients intubated by the ambulance service prior to HEMS arrival are intubated without sedatives or muscle relaxing drugs. Internationally, the incidence of prehospital emergency tracheal airways is as high as 10.9% [7]. Several factors influence this rate, including staff experience and training, confidence and proficiency in skills, the recognition of a possible difficult airway, the anticipation of airway-related complications and the clinical setting.
The incidence, indications and results of ESA performed by our pHEMS were studied. We hypothesized that the threshold for performing ESA by a pHEMS is lower compared with that for non-physician EMS. As a consequence, the incidence of ESAs performed by pHEMS is potentially increased. Our data were compared with international data from paramedic-staffed prehospital emergency services certified to perform invasive procedures.

PATIENTS AND METHODS

We studied the dispatch database from the Radboud University Medical Center, the Netherlands. Indications for airway management and vital parameters before and after treatment were noted.

After the endotracheal intubation (ETI) tube position was verified by capnography, thoracic movement and auscultation of breath sounds were assessed. All ESA were performed using the open surgical technique with a scalpel and an endotracheal tube.

All dispatches between January 2007 and December 2013 were analyzed. The cases of adults and children who underwent ESA by pHEMS were reviewed. The incidence and success rate of endotracheal intubations and ESA as well as survival in the first hours after the intervention were assessed.

Data were collected prospectively in the cohort database and retrospectively analyzed using SPSS (IBM, SPSS version 20).

RESULTS

In the period from January 2007 to December 2013, a total of 1,871 patients required a secured airway. This group consisted of 1,382 (73.9%) males and 489 (26.1%) females between the ages of 0 and 93.1 years (median 37.5). Of all the patients requiring a secure airway, 493 received an endotracheal tube by ambulance nurses prior to pHEMS arrival. In 42 cases (8.5%), these tubes were repositioned by pHEMS because of esophageal intubation. The total number of pHEMS intubation patients in this study group was 1,406.

The overall HEMS ETI success rate was 98.4%, and the overall median number of intubation attempts was 1, including ambulance attempts when applicable (range 1-6). Additional information regarding the first intubation success ratio of our pHEMS was presented in a separate article [8]

In seven cases, ETI was not successful, and no surgical airway was attempted or created. Alternative (non-surgical) airway methods were performed in four patients, including bag-valve mask ventilation (n=2) and supraglottic airway device (SAD) (n=2; 1 laryngeal mask, 1 laryngeal tube). In three cases, treatment was discontinued due to non-survivable injuries before a secured airway was obtained (Figure 1).

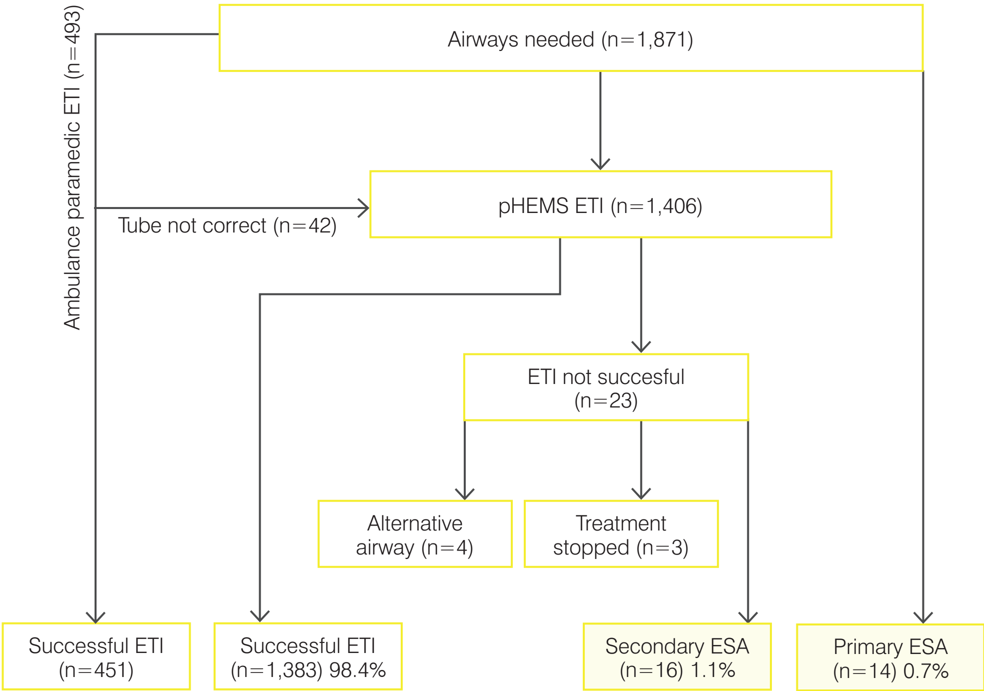

Figure 1: Prehospital Airways and management

A total of 30 ESAs were performed (28 cricothyroidotomies and 2 tracheotomies) in 24 males (80%) and 6 females (20%). The median age of these patients was 43.6 years (0.8 – 79.4). Nineteen ESAs (63%) were performed by HEMS physicians with an anesthesiological background, and the other eleven were performed by a surgeon on HEMS duty. Approximately 70% of the HEMS shifts were staffed by anesthesiologists.

Fourteen patients received a primary ESA without a prior pHEMS endotracheal intubation attempt (0.7%). These patients had perforating airway lesions, extensive facial damage or upper airway swelling/obstruction. In those cases, the HEMS physician determined that an ETI was not possible. Another sixteen patients received an ESA after failed ETI, representing 1.1% of pHEMS intubations (secondary ESA). The indications for ESA are listed in Table 1.

Indication	Number of patients	Percentage
Facial trauma	17	56.7%
Upper airway obstruction	6	20.0%
Facial/airway burns	2	6.7%
Carcinoma obstruction	1	3.3%
Penetrating airway trauma	4	13.3%
Totals	30	100%

Table 1: Indications for emergency surgical airway

Three patients could not be ventilated after an ESA was created. The first patient was an 8-month-old infant with circulatory arrest, and no access to the airway could be created after tracheotomy due to an obstructing airway tumor. The second patient was a blunt trauma patient who could not be ventilated through ESA because of a proximal leakage of air after cuff insufflation. No return of spontaneous circulation was observed after bilateral thoracostomy. This patient was suspected to have a tracheal rupture without ventilation options, and treatment was ceased. The third patient was an elderly patient with an airway obstruction distal to the incision because of ingested food, making ventilation impossible. In summary, in these last two cases, the upper airway was accessible and an ESA was created, but ventilation was not possible.
Twenty-eight cricothyroidotomies and two tracheotomies were performed. Tracheotomies were performed in the 8-month-old child described above and an adult patient with a traumatic tracheal lesion facilitating tube insertion due to a knife cut.

In fourteen patients, an ESA was created while cardiopulmonary resuscitation (CPR) was performed at HEMS arrival. Only one of these patients regained spontaneous circulation after cricothyroidotomy and ventilation; the others died at the scene.

In our total group of 30 ESAs, six patients survived hospital admission (20%). All survivors displayed spontaneous circulation prior to intervention. Eight patients died in the emergency department or intensive care unit, all after discontinuation of treatment due to extensive non-airway-related injuries.

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DISCUSSION

Adequate airway management prevents poor outcomes and death in trauma cardiac arrest patients [2-4]. Therefore, advanced airway management is essential. Success rates in prehospital airway management vary, and a meta-analysis of prehospital care providers comparing paramedic and physician ETI revealed significant differences in success rates in favor of physician-staffed services [9, 10]. The ETI success rate of physicians in our group was 98.4%. This is comparable with data from other physician-staffed EMS series (99.1%) and with recent data from the United Kingdom (99.4%) [9, 11].

Analysis of paramedic airway management in the USA indicated an overall ETI success rate of 85.3%, with a rapid sequence induction (RSI) ETI success rate of 93.1% [12]. Recent published data from Washington paramedics EMS demonstrated an ETI success rate of 99% after one or more attempts with the ability to use RSI medication, but this study was limited to patients older than twelve years of age [13]. Prehospital intubation of children with low coma scores by ambulance nurses is not recommended due to a high rate of complications in the Dutch setting [14]. Physician-staffed HEMS obtain high intubation success rates in children younger than 16 years [15].

In 8.5% (n=42) of the patients who were intubated by ambulance nurses prior to HEMS arrival, the tube was judged to be in the esophagus and was repositioned. This number is unacceptably high. Because of the current availability of capnography in all ambulances, this number is now likely to be lower. Many ambulance nurses in the Netherlands do not attempt ETI anymore but instead use SAD or wait until the HEMS arrive. Further analysis of this percentage and success rate is mandatory to optimize Dutch prehospital healthcare.

A total of 30 ESAs were described in this study. Of these, 14 were performed without attempted laryngoscopy by the HEMS physicians. This primary ESA rate (0.7%) is comparable with the rate of 0.6% reported by Lockey [11]. To compare these figures, the indications and standard operation protocols for performing these interventions must be evaluated. The assessment of whether it is possible to intubate using laryngoscopy is subjective and depends on factors such as intubation expertise and familiarity with the alternative (surgical) options. In our HEMS operation, trauma surgeons participate alternating with anesthesiologists. The number of ESAs performed by the surgeons is not substantially higher than those performed by anesthesiologists, who performed 63% of the ESA procedures. However, we have not tracked the HEMS shifts since 2007 to determine what percentage of ESA procedures were performed by an anesthesiologist. Instead, when scoring the background of the physicians since 2007, we found that approximately 70% of the shifts were staffed by anesthesiologists. One may conclude that a surgeon that is well trained in advanced airway management in the prehospital setting is not more likely to need a

ESA to secure the airway. Because of the combination of different HEMS physician backgrounds and the combined cadaveric trainings, the threshold for an anesthesiologist to perform a primary ESA might actually be decreased in our service.

In one young patient with an obstructing tumor, no access to the upper airway could be created. The airway access success rate in our ESA group was 96.7%, and this result is comparable to the success rates reported in the meta-analysis by Hubble et al., which described a physician prehospital ESA success rate of 97.1% compared with approximately 90% among non-physicians EMS [16-18]. Diggs et al. recently presented different data comparing the results of American paramedic surgical airway management in 2008 and 2012, in which ESA success rates for combined open and needle-guided techniques dropped from 87.1 to 34.3% with an increase in incidence (from 70 to 1,332) [12]. For reasons related to time saving and efficiency, our HEMS exclusively uses the open surgical technique and no needle-guided methods. Previous results also indicated increased success rates and quicker procedure times with the open surgical technique [16, 19]. A review on the topic was not able to demonstrate a significant difference between open surgical and needle-guided methods because of the limited number of patients assessed [6].

In our study, the median number of ETI attempts was one, but the range reached up to six when paramedic intubation attempts were included. This rate is higher than the accepted number of ETI attempts, and difficult airway algorithms advise against consecutive intubation attempts using the same technique. Indeed, moving forward to the next step is essential in preventing fixation error and entering a CICO scenario. Alternative airway methods or an ESA should be selected rapidly because after three failed attempts, the chance for successful tube placement is limited and does not warrant the risks and side effects of subsequent ETI attempts [20]. Strict adherence to guidelines, the use of a SAD (i.e., laryngeal masks) and the use of video laryngoscopes in our HEMS operation likely contributed to the low number of ETI attempts and ESAs.

One ESA was performed in an 8-month-old child. In small children, identifying the cricothyroid membrane is challenging, and percutaneous insertion of a tube to ventilate is difficult or even impossible [21-23]. Therefore, a cricothyroidotomy is not recommended in children under the age of 5 years and is doubtful under the age of 10 years [24, 25]. Other ventilation methods, such as the insertion of a SAD, are preferable. Problems with percutaneous needle-guided techniques include the risk of perforating the posterior tracheal wall and inadequate ventilation. In the absence of an adequate oxygen source, ventilation through a small bore catheter can be catastrophic [26]. When a secured airway is needed, an emergency open surgical tracheotomy may be the only option in small children.

In fourteen patients, an ESA was performed in patients without spontaneous circulation during CPR. Only one patient regained circulation after ESA and subsequent ventilation, and mortality in this group was high. However, when treating hypoxemia as a potential cause of circulation arrest, performing an ESA is a potentially lifesaving procedure.

The incidence of an ESA after failed ETI was between 10-15% in several older paramedic EMS studies but was much lower in a recent study that selected patients over twelve years of age (0.4%) [13, 27-30]. The introduction of a SAD in the prehospital field has brought an additional option to elective and difficult airway algorithms. Over the past 20 years, the laryngeal mask has gained popularity for difficult airway management both in the prehospital theatre and emergency department. Prehospital airway management by physician-staffed services exhibited a lower number of ESA (between 0.3-7.7%) [31, 32]. However, these data were collected from heterogeneous groups and are therefore difficult to compare.

In our study, we found a secondary ESA percentage of 1.1%. When including primary ESA, the total percentage of SA was 2.1% (n=30) for patients who required a secure airway. This result was reduced compared with the overall number described for non-physician-staffed emergency services in the literature (3-15%) [27-30, 33]. In contrast to what we hypothesized, the presence of a physician on an EMS does not increase the number of ESAs.

CONCLUSIONS

The surgical airway is an infrequently performed and potentially lifesaving procedure. In a physician-based EMS system, relatively low incidences of ESAs were reported compared with data from non-physician-based emergency services. After evaluating our data, our theory is that advanced airway management training and experience in both technical and non-technical skills prevent the necessity of ESA, which limited the incidence in our pHEMS setting.

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CHAPTER 4

AIRWAY

Prehospital endotracheal intubation;
need for routinely cuff pressure measurement?

ABSTRACT

A secured airway includes an insufflated cuff distal to the vocal cords. High cuff pressures may lead to major complications occurring after a short period of time. Cuff pressures are not routinely checked after intubation in the prehospital setting, dealing with a vulnerable group of patients.

We reviewed cuff pressures after intubation by Helicopter Emergency Medical Services and paramedics noted in a dispatch database. Initial cuff pressures are almost all too high, needing adjustment to be in the safe zone. Dutch paramedics lack manometers and therefore only few paramedic intubations are followed by cuff pressure measurements. We recommend cuff pressure measurements after all (prehospital) intubations and therefore all ambulances need to be equipped with cuff manometers.

INTRODUCTION

Endotracheal intubation provides a definitive and secured airway, preventing gas leak and gastric aspiration.[1] Tracheal occlusion needs to be maintained by insufflating a cuff distal to the vocal cords. High cuff pressure is not only associated with other complications such as sore throat.[2] More important, the pressure on the tracheal wall equals the pressure inside the cuff and when insufflated the tracheal cuff may compromise mucosal perfusion, thus leading to ischemic complications.[2,3] Normal tracheal capillary perfusion pressures of about 30 cm H_2O pressure can easily be compromised by hyperinflation, possibly leading to ischemic changes, stenosis or tracheo-esophageal fistula. Cuff pressures therefore need to be below this threshold of 30 cm water pressure.[4-9] Mucosal damage has been detected in animal models occurring only 15 minutes after insufflation.[10] This is of special interest in patients with critical illnesses or trauma patients, since a substantial amount remains ventilator depended for a longer period of time. Furthermore, since these categories of patients may have significant circulation disorders, it can be stated that the mucosal blood perfusion in these patient groups is potentially more vulnerable to external pressure.
Minimizing cuff insufflation, remaining below mucosal perfusion pressure but assuring adequate air leak prevention, may prevent discomfort and the incidence of tracheal mucosal ischemia. Palpation of the proximal balloon is insufficient to detect high cuff pressures.[11]

Endotracheal cuff pressures are not routinely measured in the prehopital setting or in the Emergency Department.[12,13] In the Netherlands four Helicopter Emergency Medical Services (HEMS) function as an adjunct to paramedical ambulance services. Dutch HEMS are equipped with a staff including a special trained Flight Nurse and a HEMS physician. This team is capable of delivering hospital-level medical care on the accident site, including Rapid Sequence Intubation (RSI), chest drainage and fracture reduction. HEMS is available on a 24/7 base. If time permits cuff pressures are measured after RSI on accident site or during transport using a manometer. Dutch ambulance services are not equipped with such devices and thus do not check cuff pressures after endotracheal intubation.
We investigated the use of prehospital cuff pressure measurements in this potential vulnerable group of patients.

METHODS

We reviewed our retrospective HEMS database. The HEMS database from Nijmegen University Medical Center, the Netherlands, consists of all essential data derived from the various dispatches. The database includes information of the indication for RSI, by whom the intubation was performed, the measured cuff pressure after insufflation and the cuff pressure after possible correction. In addition, possible gas or cuff leakage was registered in the database. Time of actual cuff pressure monitoring was not noted in the database. Cuff pressures after paramedic intubation could only be noted in a combined dispatch, in patients already intubated prior to HEMS arrival.

RESULTS

Between January 2007 and November 2011, 3767 patients were screened on 3370 accident locations and treated when necessary. A total of 1037 needed definitive airway support. A total of 296 patients were given an endotracheal tube by paramedics prior to the arrival of the HEMS team and 741 got definitive airway support by a HEMS team member.
Because not equipped with measuring devices no cuff pressure were checked by paramedics after intubation. After arriving HEMS team members checked 12.2 percent of the paramedic cuff pressures, with values varying from 15 till 125 cm water pressure (median 60). After HEMS intubation 64.5 percent of the cuffs were checked for pressure, with a median value of 50 ranging from 0 till 170 cm H_2O pressure. (figure 1)

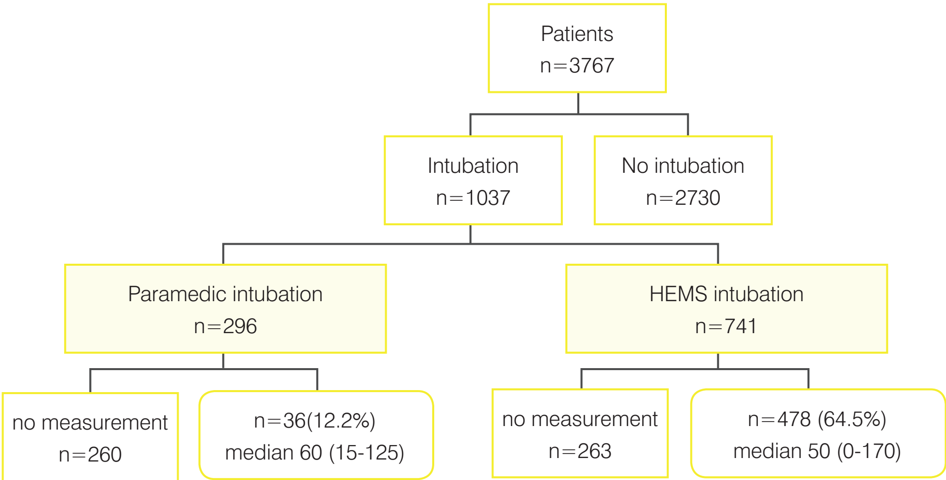
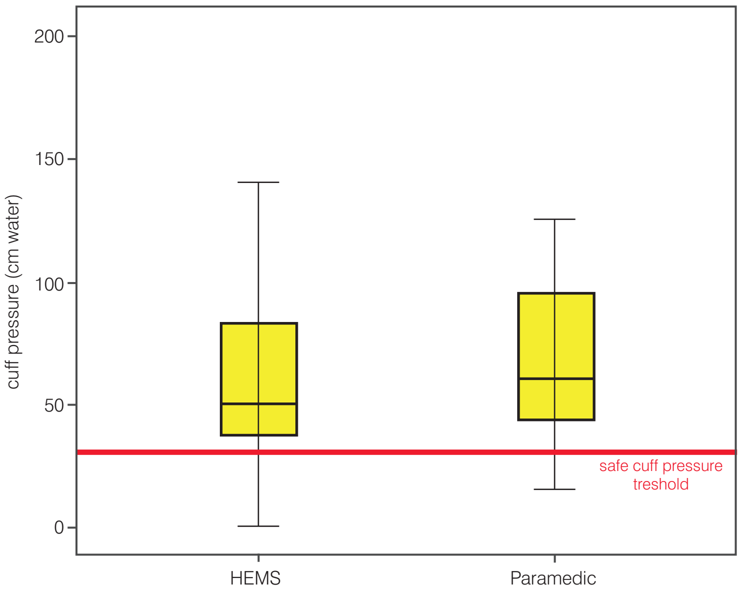


Figure 1: Patients treated and measured cuff pressures after intubation (cm H_2O).

Of all the cuffs checked in patients intubated by paramedics only 2 (5.6%) had an initial cuff pressure below 30 cm water pressure. Cuffs checked for pressure after HEMS intubation had values below 30 cm water in 87 persons (18.2%). (Graph 1)



Graph 1: Cuff pressure (cm H_2O) after intubation.

All cuff pressures were lowered after this manometer measurement. After adjustment 96 (18.7%) cuffs remained over pressured, with a mean pressure of 37 cm H_2O (31-70). Reason for this remaining high pressure is not documented in all cases but main reasons involved air leakage and ventilation difficulties due to aspiration or pulmonary contusion.

DISCUSSION

Too high cuff pressures after endotracheal intubation potentially causes mucosal ischemia, stenosis and fistula.[4-9] Less serious complications are feelings of discomfort and a sore throat.[3] Adjusting the cuff pressure to a normal range may prevent these serious complications. One study showed that damage could occur after 15 minutes.[10] Therefore, an early measurement and possible adjustment of the cuff pressure should be performed. In our pre-hospital setting we investigated the cuff pressure in trauma patients after on scene Rapid Sequence Intubations. Our study showed that almost all patient had severely increased initial cuff pressures. Only a few pressures were in the normal range immediately after intubation. Because Dutch ambulances lack cuff manometers, a very small number of pressures are measured after a tube intubated by the ambulance paramedics. Most endotracheal tubes are placed by paramedics without the HEMS team involvement, e.g. in cardiopulmonary resuscitation (CPR) settings. In 2010 more than 5500 prehospital endotracheal intubations were performed by paramedics in the Netherlands.[14] In this period only 5 of these cuffs

were checked for pressures by the Nijmegen HEMS team (one of the four Dutch HEMS). It is likely that the vast majority of the cuff pressures of these 5500 patients were too high.
Only 64.5% of HEMS endotracheal intubations resulted in a documented cuff pressure measurement. Paramedic intubations prior to HEMS arrival resulted in only 12.2 percent of cuffs checked. Hectic scenes and instable patients may be a reason for rapid action and skipping cuff pressure measurements. Special attention is necessary to stress the importance of this measurements and increase HEMS team awareness and attention to perform this check after endotracheal intubation.

Trauma patients and patients receiving CPR most often have compromised hemodynamics, especially those in need of prehospital airway management and ventilation support. Lower perfusion pressure may also influence tracheal mucosal circulation and resistance to cuff pressure. Therefore, the adjustment of cuff pressure is of importance in this vulnerable patient group, because the effect of a too high cuff pressure is especially damaging.

Cuff pressure gauges are relative inexpensive (costing around 100 euro each) and do not need maintenance or expensive servicing. A pressure manometer can be used for many years in a row.

CONCLUSIONS

High cuff pressures are potentially dangerous and may lead to severe morbidity, particularly in patients with inadequate perfusion and long term ventilation need. Trauma patients needed to be intubated on accident scene often fit that profile and need to be managed with extreme care to prevent further damage. Almost all patients after intubation and cuff insufflation had pressures that exceeded levels considered as normal. The vast majority needed correction of these high pressures. Only very few patients actually needed higher cuff pressures for ventilation purposes or adequate tracheal occlusion.
Measuring cuff pressures is an easy, fast to perform, inexpensive procedure and should be performed after each endotracheal intubation, whether conducted by paramedics or HEMS team members. In our opinion all professionals performing endotracheal intubation should be able to test cuff pressures. Therefore manometers should be available in all ambulances.

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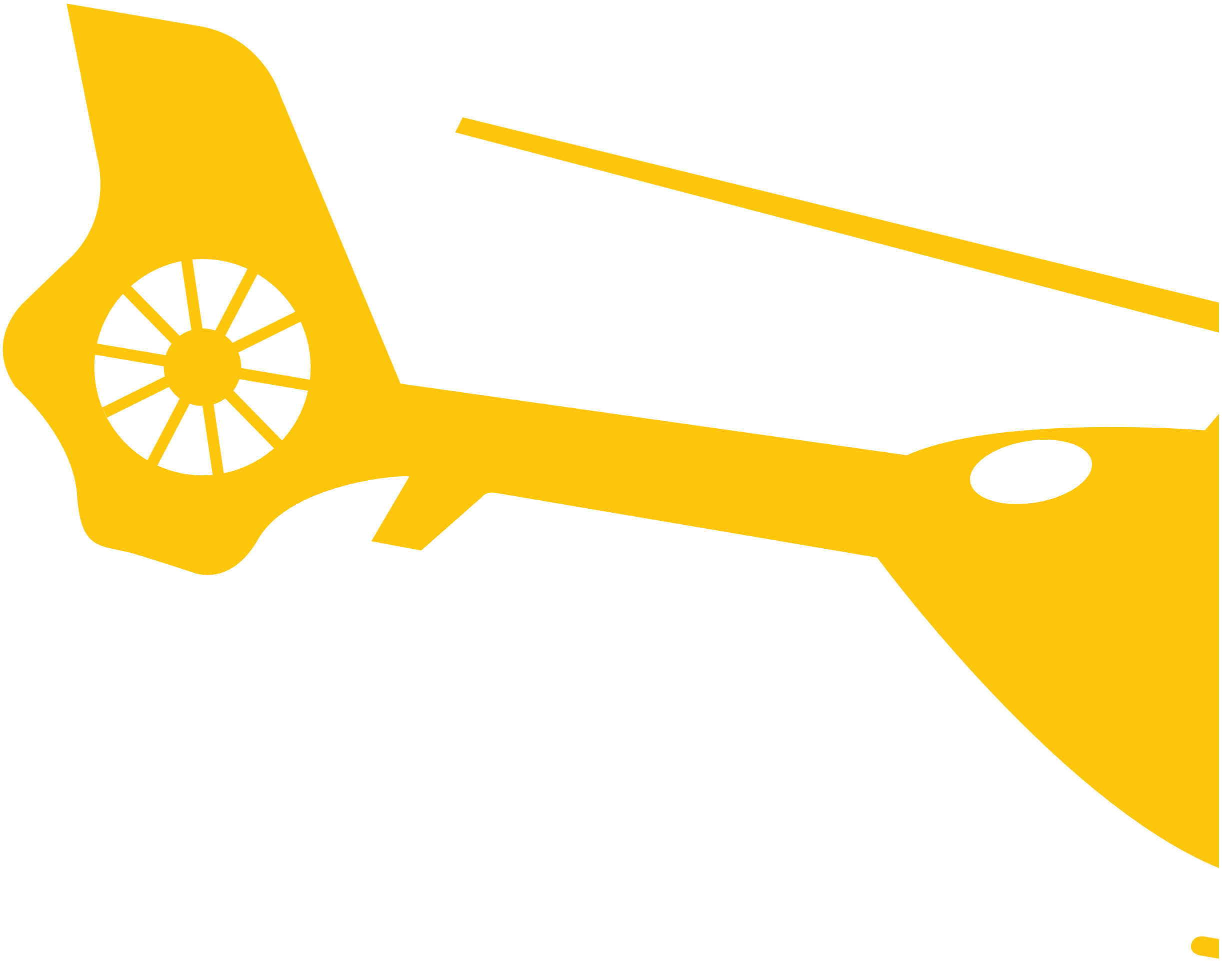

Peters JH, Ketelaars R, van Wageningen B, Biert J, Hoogerwerf N.

European Journal of Emergency Medicine 2017; 24: 96–100

CHAPTER 5

BREATHING

Prehospital thoracostomy in traumatic circulatory arrest. Indications and results from a physician staffed Helicopter Emergency Medical Service

ABSTRACT

Objective:

Until recently, traumatic cardiac arrest (tCA) was believed to be associated with high mortality and low survival rates. New data suggest better outcomes. The most common error in tCA management is failing to treat a tension pneumothorax (TP). In the prehospital setting, we prefer thoracostomies for decompressing a potential TP in tCA cases; however, interventions can only be recommended with adequate information about their results. Therefore, we reviewed the results of thoracostomies performed by our helicopter emergency medical service (HEMS).

Methods:

Our HEMS database was reviewed for all patients who underwent a single or bilateral prehospital thoracostomy in tCA. We evaluated the incidence of TP, the return of circulation in tCA, the incidence of infections, the incidence of sharps injuries and patient survival.

Results:

Two hundred sixty-seven thoracostomies were performed in 144 tCA patients. Thoracic decompression was performed to rule out TP. TP was identified in 14 patients; the incidence of TP in tCA was 9.7%. Two of the tCA patients survived and were discharged from the hospital; neither had clinical signs of TP. No infections or sharps injuries were observed.

Conclusion:

The outcomes of patients with tCA who underwent prehospital thoracostomy were poor in our group. The early identification of TP and strict algorithm adherence in tCA may improve outcomes. In the future, to reduce the risk of unnecessary thoracic interventions in tCA, ultrasound examination may be useful to identify TP before thoracic decompression.

INTRODUCTION

Trauma is the leading cause of death in young adults [1,2]. The rate of immediate mortality after traumatic cardiac arrest (tCA) is reportedly as high as 93% [3,4]. Given the low survival rates (0-2.3%) and the poor neurological outcomes in patients with tCA, attempts at resuscitating such patients are generally believed to be futile [5]. However, published data from a group in Berlin have demonstrated survival rates of 29% and good neurological outcomes in 27% of patients with tCA, but these data were limited to selected patients who were transported to a hospital or who experienced an in-hospital arrest [4]. Resuscitation efforts in tCA are focused on the rapid identification of the reversible causes of arrest. Injuries resulting in hypoxaemia, tension pneumothorax (TP) or hypovolaemia must be addressed immediately [5].

According to the literature, the most common management error in the treatment of tCA is the failure to decompress a TP, an error that has a reported incidence of 13% in tCA patients [4]. Intubated trauma patients who require positive pressure ventilation are more likely to accumulate air inside the pleural space, causing a TP that might result in tCA [6].

TP is a clinical diagnosis that is based on unreliable signs and symptoms. The clinical signs of a TP are subject to debate and depend on the patient's ventilatory status [7]. TP is a syndrome based on clinical manifestations. If a TP is suspected clinically, the release of the air under tension upon intervention combined with improved vital signs is proof of a correct diagnosis.

Needle decompression is the simplest method for relieving intrathoracic pressure. The American College of Surgeons Committee on Trauma's Advanced Trauma Life Support (ATLS) recommends placing a large-gauge, five-centimetre-long catheter in the second intercostal space at the midclavicular line [8]. Recent studies advocate the use of needle decompression in the fifth intercostal space anterior to the midaxillary line because the chest wall is thinner in this area [9-11]. Patients treated with needle decompression should be handled very carefully during transport because catheter kinking or occlusion may cause the TP to recur [12].

Alternatively, the pleural space can be opened via incision and dissection into the pleural cavity, creating a simple thoracostomy. This emergency procedure releases the thoracic pressure in positive pressure-ventilated patients and efficiently decompresses the pleural cavity [5,13]. In tCA, a TP can be excluded when the lung is palpated through the thoracostomy incision.
In patients receiving cardiopulmonary resuscitation (CPR), a thoracostomy is faster than drain insertion. Chest tube insertion may result in complications such as major bleeding, arrhythmia and a persistent TP caused by tube malpositioning [14-17].

B

Performing a thoracostomy only requires basic surgical skills and a scalpel. Although the surgical skills necessary to perform a thoracostomy can be learned, performing an incision in a patient who is undergoing CPR is associated with several potential risks, including the transmission of blood-borne communicable diseases or physical injury to healthcare professionals, especially under stressful circumstances such as tCA.

The aim of this study was to measure the usefulness of thoracostomy in the resuscitation of patients with a prehospital tCA treated by our physician-staffed helicopter emergency medical services (HEMS). Furthermore, we analysed the incidence of confirmed TP in tCA in our cohort. Short-term outcomes such as survival, surgical site infection and hospital discharge were reviewed, as were reports of needle-stick injuries.

METHODS

In the Netherlands, four HEMS teams function as adjuncts to paramedical ambulance services. The HEMS team consists of a pilot, a specially trained flight nurse and a physician. This team is trained and equipped to deliver hospital-level medical care in the field. HEMS is available 24/7 for trauma and non-trauma cases according to national dispatch guidelines [18]. Dutch HEMS physicians are either trauma surgeons or anaesthesiologists at the consultant level. These physicians are trained in surgical procedures, such as performing a trauma thoracotomy on-scene. These skills are renewed on a yearly basis on human cadavers. Thoracostomies are performed with the closest possible attention to preventing infection under the given circumstances. Skin disinfection and the use of sterile gloves and equipment are incorporated into the standard operating procedure, as is the administration of broad-spectrum antibiotics after the return of spontaneous circulation (ROSC). Thoracostomies are performed either via an incision in the second intercostal space at the midclavicular line or in the fifth intercostal space, anterior to the midaxillary line. The anterior incision is often preferred because of accessibility in patients who are immobilised on a long spine board with straps and while wearing clothes at the time of the tCA. Lateral access is typically easier because it involves fewer muscles and less subcutaneous fat tissue.

In this retrospective cohort study, data were collected from the HEMS database, which contains essential information from all dispatches. All patients (both paediatric and adult) who had undergone one or two prehospital thoracostomies were analysed. Demographic data were analysed, including the mechanism of injury. We collected data regarding the indication for treatment, the side of the thoracostomy, the patient’s airway and circulatory status at the time of the incision and the incidence of ROSC. We also reviewed the database for notifications of sharps injuries to healthcare professionals as a result of performing thoracostomies.

The effect of the thoracostomy and associated clinical findings, such as TP/simple pneumothorax, were noted. The release of air under tension on incision combined with improved vital signs after thoracostomy was interpreted as proof of the TP diagnosis.

For patients who survived prehospital treatment, we reviewed the incidence of thoracic infections, the outcomes and other possible complications of the thoracostomy.

RESULTS

Between January 2007 and July 2014, 267 thoracostomies were performed in 144 prehospital tCA patients to decompress the thorax and to rule out a TP as the cause of circulatory arrest. The median patient age was 45.0 years (4.9-89.4). Most of the patients were males (n=122, 84.7%). In 123 patients, bilateral stomas were created. Unilateral thoracostomies were performed in 21 patients (left 16, right 5, not noted 1). All of the patients were mechanically ventilated with positive pressure at the time of the incision. The mechanisms of injury are listed in Table 1. Blunt trauma was responsible for the injury in 91.7% of the patients.

Mechanism	Number of patients	Percentage
Road/traffic accidents	108	75.0%
Fall from height	16	11,1%
Penetrating trauma	12	8,3%
Traumatic asphyxia	8	5.6%
Total	144	100%

Table 1: Mechanisms of injury in tCA patients who underwent HEMS thoracostomy.

TP was present in a total of 14 (9.7%) of the tCA patients; all were decompressed via thoracostomy. Of the 144 tCA patients, 22 had ROSC (15.3%) after advanced life support (ALS) and thoracic drainage. In the 22 patients with ROSC, 6 had a TP (27.3%; Fig. 1).

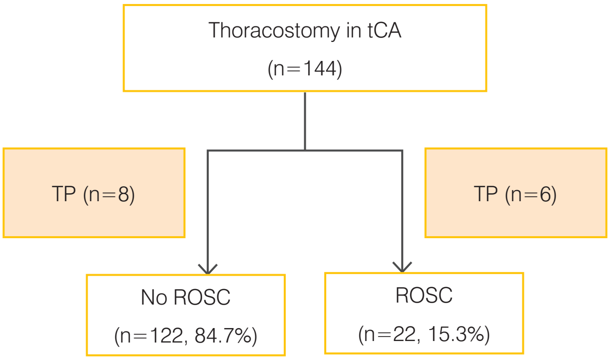

Figure 1: Thoracostomies and tension pneumothorax (TP). ROSC, return of spontaneous circulation; tCA, traumatic cardiac arrest

Four of the 144 prehospital tCA patients survived the initial resuscitation phase (2.8%). Two of those four patients died in intensive care after 9 and 10 days because of severe head trauma. Two patients who had a tCA survived and were discharged from the hospital (1.4%). One of these had a normal neurological outcome; neurological outcomes were not scored for the second survivor. None of the four patients who survived initial treatment exhibited elevated intrathoracic pressure at the time of thoracic drainage as a clinical sign of a TP.(Fig. 2)

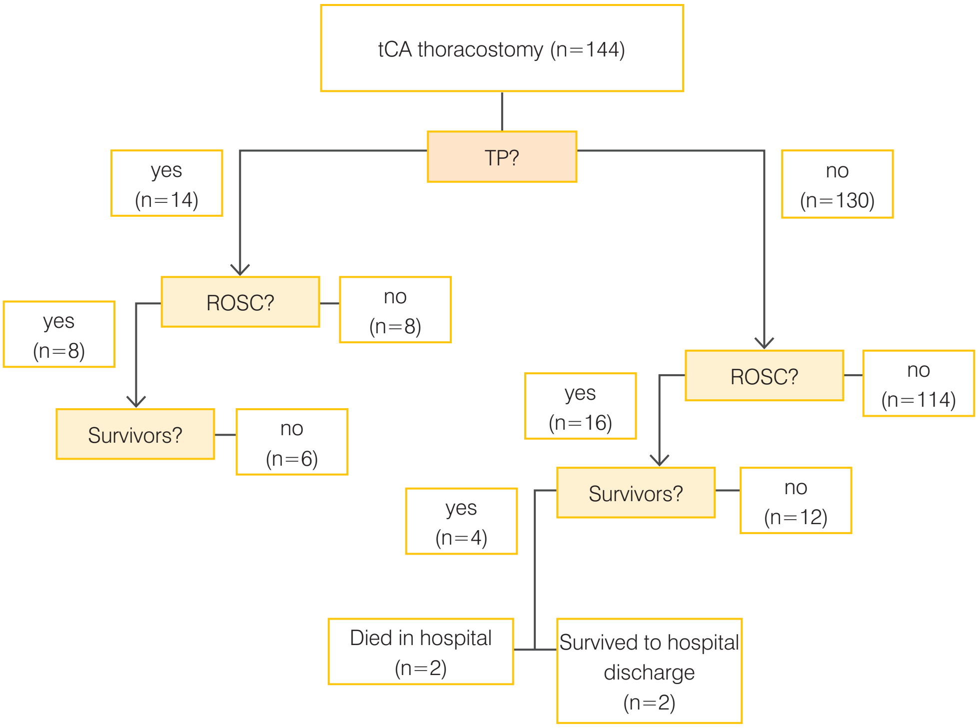

Figure 2: Thoracostomies and outcomes

Short-term follow-up information was available for all tCA patients who had undergone prehospital thoracostomies. In the few patients (n=4) who survived the first hours after resuscitation, no complications or infections of the thoracic cavity were observed on the side of the thoracostomy. In our database, no needle-stick injuries were noted for the 267 prehospital thoracostomies.

DISCUSSION

TP is a life-threatening condition that requires urgent decompression. Identifying patients with a TP using only information from a physical examination can be challenging. Additional diagnostic tests, such as chest x-rays, are associated with a four-fold increase in mortality because of the time needed for the investigation [19,20]. Classical findings (chest pain, air hunger, tachycardia, hypotension, tracheal deviation, unilateral absence of breath sounds, elevated haemothorax, neck vein distension and cyanosis) may be absent or difficult to identify [7]. Other medical conditions, such as severe hypovolaemia, contralateral simple pneumothorax or cardiac tamponade, may mimic the symptoms of a TP. In the prehospital setting, diagnosing a TP is difficult because of limited work space, a limited ability to appropriately expose the patient for the needed examinations and/or procedures, immobilisation and noise (inside an ambulance or helicopter). Incorporating ultrasound examinations in prehospital decision-making for patients with tCA may facilitate the early identification of treatable causes and may prevent unnecessary interventions, thus limiting possible associated risks [21].

In the 267 thoracostomies included in our study, no medical personnel experienced sharps injuries. However, this fact does not imply that using sharp equipment while performing CPR is not dangerous. Sharps are needed both for needle decompression and for performing a thoracostomy, and both procedures carry a risk of injury. Safety-shielded needles may reduce the risk of needle sticks [22,23]. We reviewed our retrospective database for reports of needle-stick injuries. However, under-reporting and under-documentation may result in a falsely low incidence of these injuries.

Circumstances in the prehospital setting are not optimal for performing sterile surgical interventions. Precautions such as disinfection and the use of sterile gloves and materials decrease the risk of thoracic infections, as does the prehospital use of a single-dose prophylactic broad-spectrum antibiotic after the incision. These outcome figures are consistent with the low reported infection rates after prehospital HEMS chest tube placement [24]. Our database did not explicitly specify whether all of these precautions were undertaken. However, the absence of thoracic infections provides reassurance regarding the infection control procedures performed in our practice. No infections after prehospital thoracostomies were observed in this cohort of

tCA patients; however, few patients survived the initial resuscitation (n=4), and their number is likely insufficient to draw conclusions about infections after prehospital thoracostomy in tCA.
In patients with tCA, a TP must be ruled out as the cause of circulatory arrest. If a TP is suspected, immediate treatment is mandatory. As stated previously, we believe that the best method for permanently decompressing a possible TP is a thoracostomy. During resuscitation, thoracostomy is faster than (bilateral) chest tube insertion and is therefore preferable in this setting [25]. We reviewed the thoracostomies performed by our physician-staffed HEMS in patients with tCA. ROSC was achieved in 15% of cases. Because these patients received numerous interventions, such as airway management, volume administration, fracture splinting, pelvic binder placement and epinephrine administration during ALS, it is not possible to state that ROSC was the result of a single intervention.

In this cohort of 144 tCA patients who underwent thoracostomy, 14 TPs were decompressed. The incidence of TP in our group of patients with tCA was 9.7%. The clinical description of air release under pressure when the pleural cavity is opened is the only means to verify a prehospital TP. No objective findings of this clinical presentation, other than the written documentation, were available. The true incidence of TP in our arrest group might differ from the reported value due to faulty interpretations of clinical signs or incomplete documentation. The reported percentage is lower than the percentage recently reported in the Berlin cohort (13%). This fact may be explained by the fact that we only selected patients who had a thoracostomy, and not all tCA patients were included. Consequently, the overall incidence of TP in tCA might be higher than 9.7%.

The outcomes for patients suffering tCA who underwent on-scene thoracostomies were poor in our group. Four patients survived the first hours, and only two survived to hospital discharge (1.4%). These figures differ from recent data that reported better survival rates after tCA (29%) [4]. This difference may have occurred because our data were obtained from a subgroup of the tCA patients treated by our HEMS (i.e., those who underwent thoracostomies), whereas the reported values from Berlin were from a selection of tCA patients who were transported to the hospital and included in-hospital arrests, not limited to prehospital selection.

In tCA cases, a thoracostomy may be considered as a last resort for resuscitation and may therefore be performed late in treatment. The quick identification of TP and rapid decision-making and intervention may improve outcomes. Strict adherence to the newly proposed algorithms for tCA during prehospital resuscitation in trauma patients may improve outcomes and increase outcome parameters [4,12].

The use of thoracostomies in patients with tCA in the prehospital setting has not been clearly investigated. In our population, a total of 267 thoracostomies were performed in 144 tCA patients. Only two patients survived until hospital discharge following prehospital arrest with resuscitation and thoracic drainage via thoracostomy. Neither patient exhibited clinical signs of TP. Therefore, it can be concluded that the thoracostomies did not clearly contribute to their survival. The additive value of thoracostomy in tCA compared with the use of needle decompression to treat TP in tCA remains undetermined.

Early, brief ultrasound examination for TP in patients with tCA could be considered prior to thoracostomy to prevent unnecessary but potentially risky thoracic interventions. Further prospective research on this topic is necessary to evaluate the role of ultrasound in prehospital tCA, and such research is currently being conducted by our HEMS.

In the literature, the efficiency of needle thoracoscentesis is questioned because of the inability to reach the thoracic cavity, particularly from the anterior [9-12]. Special longer needle are available for this purpose and reduce the risk of being unable to treat a TP. Further research comparing needle thoracoscentesis with thoracostomy is required to determine the optimal treatment of suspected TP in tCA.

CONCLUSIONS

The outcome of patients with tCA who underwent a resuscitative thoracostomy to exclude TP was poor in our group. The incidence of TP in our group was 10%. No needle-stick injuries were reported. The low number of survivors makes it difficult to address post-thoracostomy infections. The role of prehospital thoracostomy compared with needle thoracoscentesis in tCA requires further investigation.

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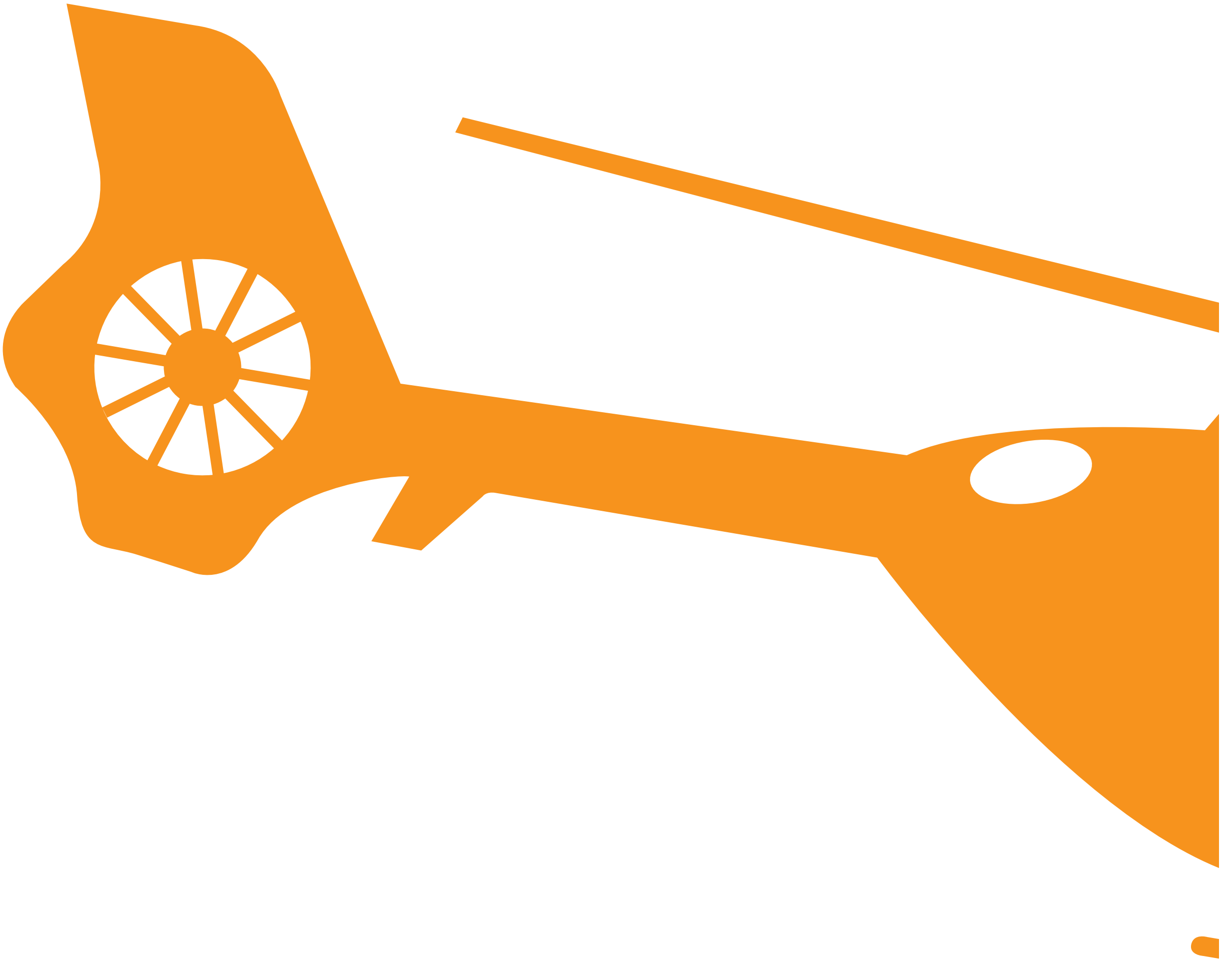

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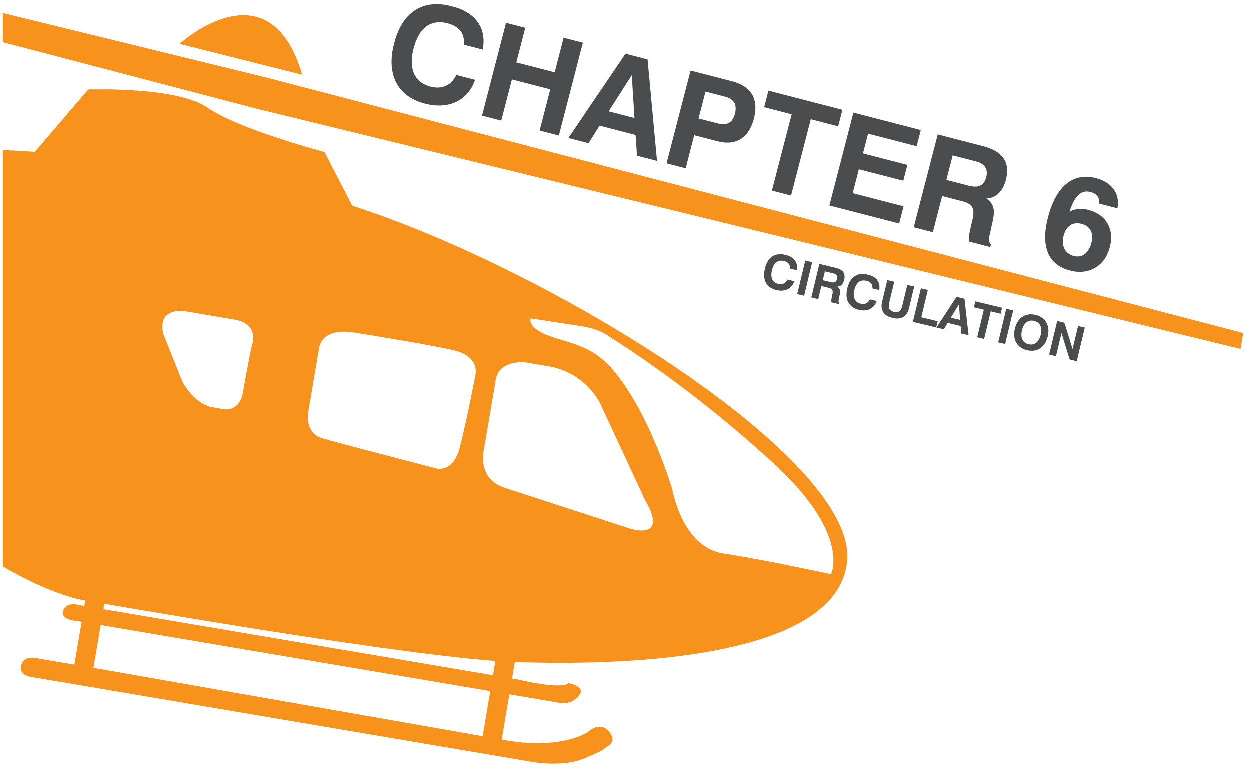


CHAPTER 6

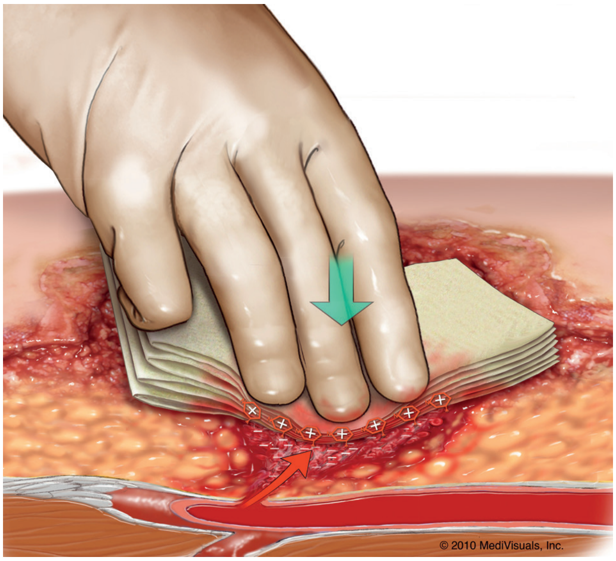
CIRCULATION

Massive bleeding:
The prehospital use of hemostatic bandages

INTRODUCTION

In the Netherlands, approximately 3500 people die because of trauma related injuries annually[1]. Non controllable bleedings are a major cause of death in these patients.[2] In military setting exsanguination is the most important cause of death.[3] Battlefield experience in Vietnam, Iraq and Afghanistan led to introduction of hemostatic bandages for massive bleeding. These bandages have different working mechanisms. Certain bandages concentrate the patient's own clotting factors by an exothermic reaction and fluid absorption to enhance clotting (QuikClot). Other bandages contain materials that adhere to erythrocytes to create a firm cloth. (HemCon, WoundStat en Celox). Some bandages include clotting factors to promote cloth formation (CombatGauze).[4] Animal studies show better and faster hemostasis for these bandages than conventional bandages.[5-11] This better hemostatic results are also suggested in human military studies.[12-16]

Dutch force use HemCon hemostatic bandages since 2009. HemCon contains the biological polysaccharide chitosan, derived from crustacean exoskeletons. Chitosan has a positive charge contracting the negatively charged erythrocytes, forming a cloth that covers the damaged surface. This shortens bleeding time and in theory also forms a barrier to bacteria. Chitosan also activates platelets function and vasoconstriction enhancing wound closure.[19,20] (Picture 1) Chitosan function is not influenced by body temperature and it is also useful in patients using anticoagulants.[16-18] No side effects of chitosan or anaphylactic reactions to this products have been described.



Picture 1: HemCon® – mechanism of action

Four helicopter emergency medical teams (HEMS) are available to support ambulances in Dutch setting. These teams consist of a experienced nurse, and a physician (consultant level anesthesiologist/surgeon). These teams are deployed in trauma and non-trauma cases. Patients with potentially life-threatening blood loss with need for immediate intervention are frequently seen. Quick hemorrhage control prevents loss of clotting factors and erythrocytes. This contributes, in addition to the optimization of the oxygenation, to the prevention of oxygen debt, acidosis, hypothermia, and thereby further coagulation disorders. This phenomenon is known as the "Trauma Triad of Death".[21]

Nijmegen HEMS uses HemCon hemostatic bandages since 2009. We questioned the additional value of these bandages in traumatic bleeding and evaluated the hemostatic effect of HemCon after a minimal application time of five minutes. We also reviewed the usability, bleeding time and possible side effects.

METHODS

Nijmegen HEMS uses HemCon ChitoGauze, a flexible folded bandage measuring 10 centimeters by 3.7 meters in a package of 12 x 14 centimeters. These bandages cost approximately 55 €. (Picture 2)

Picture 2: ChitoGauze™

We use these hemostatic bandages in bleedings that are suspected to be difficult to control using conventional bandages. This includes life threatening bleeding form lacerations, penetrating trauma and traumatic (partial) amputations. We also applied HemCon after unsuccessful use of conventional bandages.

After HemCon use the HEMS team completed a questionnaire, which were collected in a database. We scored patient and dispatch parameters, degree of bleeding control and usability in the prehospital field.
To review the possible side effects of HemCon appliance we analyzed the discharge papers from the receiving hospitals after prehospital HEMS treatment.

RESULTS

Between April 2009 and July 2013 we applied HemCon in 24 patients. (22 males and 2 females) Mean age was 41.3 years (12-80).

In 18 of the 24 patients (75%) the bleeding was stopped after a minimum of 5 minutes of HemCon application. In 6 patients the blood loss was not completely stopped but was considerably less than prior to the use of these bandages. No patients had a bleeding that could not be efficiently treated with HemCon. Table 1.

	Sex	Age (y)	Mechanism of injury	Arterial/venous	Location	Result
1	M	14	Fall bicycle	Veneus	Groin	Dry
2	M	30	Car accident	Veneus	Head	Dry
3	M	53	Arm trapped	Combi	Arm	Controlled
4	M	65	Car accident	Combi	Head	Dry
5	M	51	Fall height	Veneus	Head	Controlled
6	M	29	Car accident	Veneus	Head	Controlled
7	V	41	Fall horse	Combi	Mouth	Controlled
8	M	48	Train	Combi	Legs	Controlled
9	M	66	Fall height	Veneus	Head	Dry
10	M	40	Gunshot	Veneus	Groin	Dry
11	M	26	Car accident	Combi	Leg	Dry
12	M	31	Gunshot	Veneus	Head	Dry
13	M	56	Car accident	Combi	Abdomen	Dry
14	V	80	Bicycle vs car	Combi	Head	Dry
15	M	37	Car accident	Combi	Groin	Dry
16	M	27	Car accident	Veneus	Head	Dry
17	M	60	Fall height	Veneus	Head	Dry
18	M	26	Leg trapped	Combi	Leg	Dry
19	M	17	Car accident	Combi	Head	Controlled
20	M	37	Gunshot	Veneus	Head	Dry
21	M	26	Arm trapped	Combi	Arm	Dry
22	M	52	Car accident	Combi	Head	Dry
23	M	12	Knife	Veneus	Head	Dry
24	M	68	Car accident	Veneus	Neck	Dry

Table 1: HemCon application

Three patients (12.5%) received cardiopulmonary resuscitation (CPR) at hospital arrival. These patients are presented separately in table 2, because the effect of hemostatic dressings in patients receiving CPR is less clear compared with patients with spontaneous circulation.

	Sext	Age	Mechanism	Bleeding location	Description	Outcome
1	M	30	Car accident	Head	Hypovolemic shock.	Surgical airway, dying heart. Treatment stopped on scene.
2	M	51	Fall Height	Head	Severe neurocranial trauma.	Asystolic on HEMS arrival. Treatment stopped in Emergency Department.
3	M	31	Gunshot	Head	Facial destruction	Treatment stopped. Non survivable injury.

Table 2: Patient without spontaneous circulation and HemCon appliance.

A complete follow-up from hospital admission till discharge was available in 17 patients (Figure 1). When the three patients without spontaneous circulation are excluded from follow-up, we have complete data from 18 of 21 patients (85.7%).

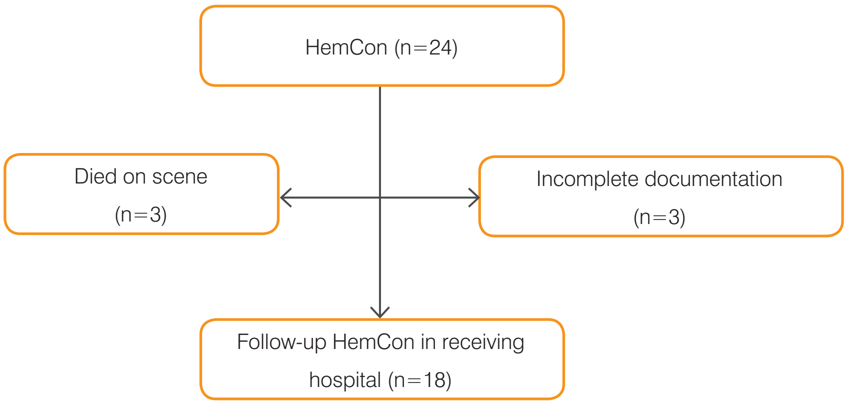


Figure 1: HemCon and follow-up

In these 18 patients there were no complications noted after HemCon usage. There were no problems regarding the removal of the gauzes in the hospitals. No rebleedings after bandage removal were reported. Three infections were found in these 18 patients, none of these were in the area were the hemostatic bandages were used.

DISCUSSION

In these cases all bleedings were controlled after the use of the HemCon hemostatic bandages. In the follow-up no complications or problems were reported that were relatable to the HemCon appliance. Three patients had a circulatory arrest prior to HemCon administration. In these cases it is difficult to related the use of hemostatic bandages to the cessation of blood loss.
No follow-up was available in three patients. These patients were not traceable in the administration of various receiving hospitals. It is therefore not possible to draw definitive conclusive conclusions regarding the long term complications of this hemostatic bandages.

Hemostatic bandages are more expensive than conventional gauzes. Reducing blood loss result in less blood transfusions and hypovolemic complications, and therefore less costs. With the results of this study it is difficult to justify the additional costs of the hemostatic bandages. Further research is necessary.

In conclusion we see the additional value of these hemostatic bandages in our prehospital setting in severe traumatic bleeding. A prospective study is currently conducted in two Dutch regional ambulance services. This study will give further data regarding the cost efficiency of these novel products.

DISCLAIMER

Data presented in this article were previously published in Dutch. Peters JH, Tan ECTH. Prehospitaal gebruik van hemostatische verbandmaterialen. Ned Tijdschr Traum. 2014;22:36-41

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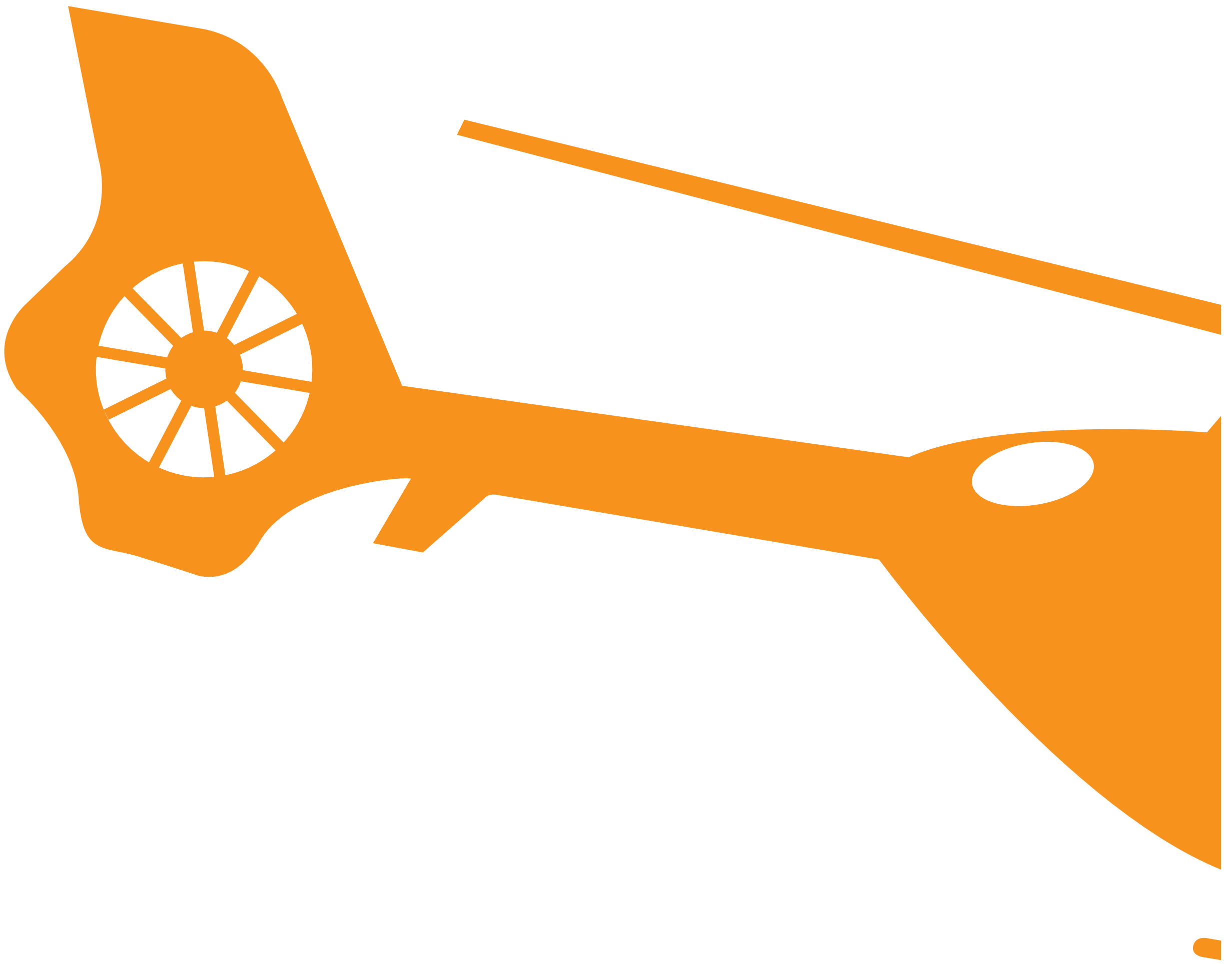
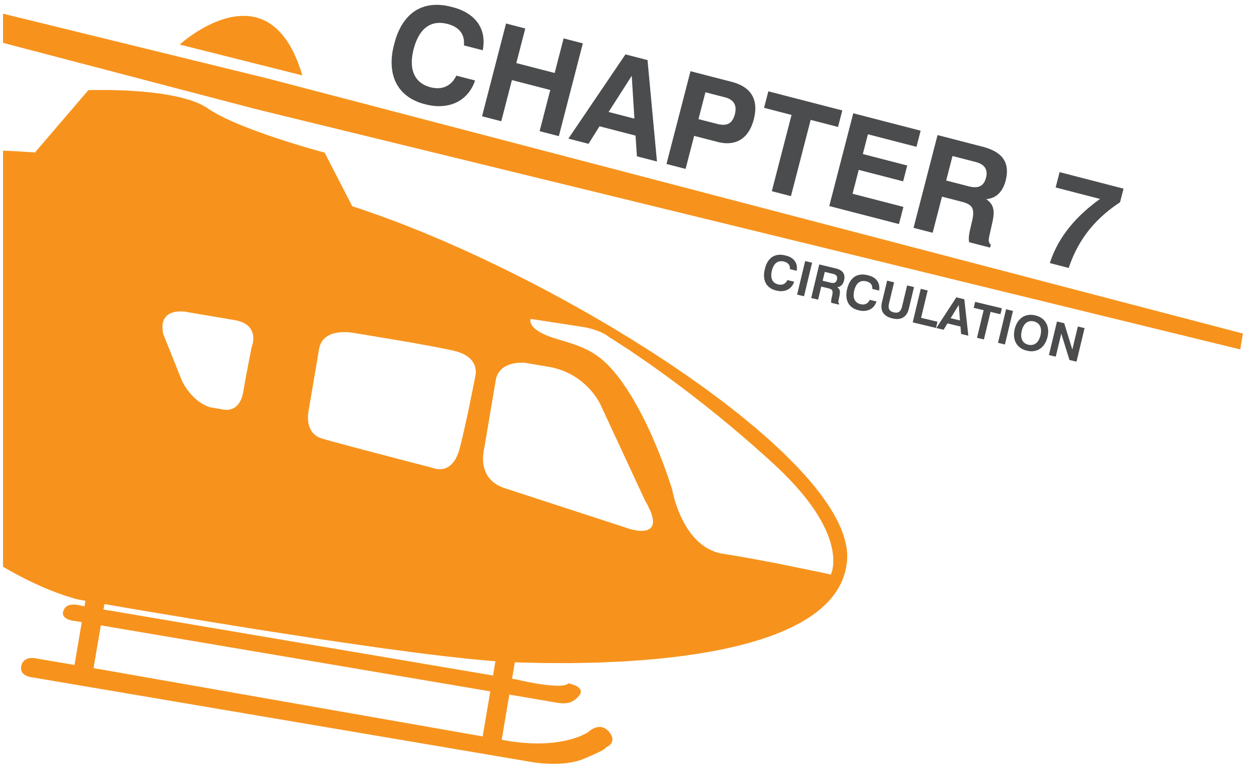


Tan ECTH, Peters JH, McKee JL, Edwards MJR.

Injury 2016 May; 47(5): 1012-1015

CHAPTER 7

CIRCULATION



The iTClamp in the management of prehospital haemorrhage

ABSTRACT

Introduction
Bleeding remains a leading cause of death in trauma patients. The iTClamp is a temporary wound closure device designed to control external bleeding within seconds of injury. We describe our experience using this device on 10 patients in the prehospital environment.

Methods
We have implemented the iTClamp for prehospital use through our physician-staffed helicopter emergency medical service (HEMS). Indications were massive bleeding that could not be controlled with an ordinary compressive bandage or a haemostatic bandage.

Results
Ten patients were treated with the iTClamp. Seven patients had a severe head injury due to various traumas, one patient had a neck injury from a disk cutter, one patient had an open chest wound and one patient had an open femur fracture. After applying the iTClamp, bleeding was controlled in 90% of these patients (n=9), with complete cessation reported in 60% (n=6), partial cessation with adequate control reported in 30% (n=3); in one patient, the bleeding could not be controlled with the iTClamp alone. It took an average of 10 seconds to apply the iTClamp, and the average usage satisfaction score was 7.7.

Conclusion
We conclude that the iTClamp is a safe, fast and useful tool for stopping or controlling external blood loss in our series of prehospital patients. Further studies of the iTClamp are needed to determine which patients might benefit from this device.

INTRODUCTION

Early control of haemorrhage is essential for the survival of trauma patients [1]. In the prehospital phase, haemorrhage contributes to 33–56% of civilian trauma-related deaths [2], and more than 12 million traumatic lacerations are treated in emergency departments each year in the United States [3]. Lacerations to the scalp, neck and hands are most common and are generally attributed to blunt force trauma [4, 5]. Significant research has been performed in developing new technologies to control haemorrhage. This includes the research and development of haemostatic topical agents, tourniquets, and the use of tranexamic acid. However, despite current research direct pressure or tourniquet application remain a first line defence for haemorrhage control in trauma. These rudimentary methods while effective are not without their issues. The application of direct pressure requires at least one member of the medical team to remain devoted to haemorrhage control, potentially being unable to attend to the patients other needs. And while effective on distal extremities, tourniquet application is not a benign intervention. Tourniquets are not only extremely painful, they have been linked to nerve palsies, limb ischemia and iatrogenic amputations [6-8]. Thus, devices that allow practitioners to treat all other compressible regions (scalp, neck, junctional areas, and extremities) and that are faster and less painful to apply should be examined.

One alternative may be the iTClamp (Innovative Trauma Care, San Antonio, TX, USA), a temporary wound closure device, that can be rapidly applied to control severe haemorrhage from open wounds within compressible zones [9], and has demonstrated efficacy in controlling haemorrhage [9-13].

The objective of this study was to examine the effectiveness of the iTClamp in the prehospital setting. In the Netherlands, approximately 3500 people die each year from trauma related injuries, as such, 4 helicopter emergency medical services (HEMS) function as an adjunct to the national paramedic ambulance services. The iTClamp was placed on the HEMS helicopters to examine the value of the iTClamp in the prehospital phase in traumatic haemorrhage. We also evaluated its haemostatic effect, reviewed usability, bleeding time and possible side effects.

METHODS

This study was performed in the regional HEMS, which is located in the southeastern part of the Netherlands, covering approximately 4 million inhabitants. The Nijmegen HEMS operates 24 hours a day, 7 days a week, receiving more than 2000 dispatches annually. The HEMS team consists of an experienced, registered EMS nurse, a physician (consultant level anaesthesiologist/surgeon) and a pilot. These teams are deployed in trauma and non-trauma cases.

For this study Nijmegen HEMS physicians received didactic training on how to use the iTClamp. This training included reading the iTClamp user manual (Directions for Use), watching a brief training video, and hands on training with the iTClamp on a skin pad. Physicians were instructed that the iTClamp could be applied after unsuccessful use of conventional or haemostatic bandages or for external, bleeding wounds that were suspected of being difficult to control. Injuries such as life-threatening bleeding from lacerations, penetrating trauma and traumatic (partial) amputations were given as examples. When an iTClamp was applied in the field, the HEMS physician completed a questionnaire that captured the degree of bleeding control and usability in the prehospital setting (see appendix A).

As standard operating procedure, all receiving hospitals are called post trauma to ascertain definitive diagnosis and other patient details. During this routine follow up the iTClamp removal time and adverse events related to the iTClamp application were also collected. To review possible side effects of the iTClamp, discharge papers from the receiving hospitals were analysed.

Descriptive statistics are reported, as well as a comparison between groups' complete bleeding control (CBC) and adequate bleeding control (ABC). There was also a comparison between bleeding control (CBC and ABC combined) and no bleeding control. Patients with no bleeding control were discussed in detail. Mann-Whitney U test was used for the comparisons, using SPSS (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.), as the data was not normally distributed and there is a small sample size.

RESULTS

Between August 2013 and August 2015, ten patients (8 males, 2 females) had an iTClamp applied at the scene of an incident to control haemorrhage. The mean age was 49.5 ± 23.1 years. 70% of the iTClamp's (n=7) were applied to the head (Figure 1). One incident each of neck, femur and chest application were also reported. The mean time to apply the iTClamp was 10.0 ± 6.6 seconds with bleeding control obtained in 10.7 ± 8.8 seconds. The mean time from HEMS arrival on scene to arrival at the emergency department was 38.7 ± 12.5 minutes with an overall iTClamp positive user satisfaction rate of 7.7 ± 1.7. The most frequent mechanism of injury that required an iTClamp application was some form of motor vehicle collision (70%, n=7). Cyclists were the most common (n=3), followed by passenger vehicle (n=2), then motorcyclist (n=1) and pedestrian (n=1). The remaining 30% included a fall (n=1), struck by an object (n=1) and injured by machinery (n=1). The vasculature involved in these injuries was 50% (n=5) mixed arterial and venous, 40% (n=4) venous and 10% (n=1) was arterial. Bleeding was controlled in 90% of these patients (n=9), with complete cessation reported in 60% (n=6), partial cessation with adequate control reported in 30% (n=3) and continued haemorrhage reported with one patient (complete patient details in Table 1). In the patient where haemorrhage control was not gained immediately, the neck wound was packed with Hemcon Chitogauze, sealed with the iTClamp and direct pressure was applied. Thereafter, haemorrhage control was obtained.. Based on the discharge summaries, no in-hospital complications or problems were reported that were related to the iTClamp, and there were no difficulties or malfunctions reported in the application or the use of the iTClamp.

ID	Mechanism Of Injury	Type of Bleeding	Wound Location	Wound Description and Outcome	iTClamp Haemorrhage Result
	MVC				
1	Cyclist	Venous	Head	Scalp laceration, sutured	Stopped
2	Cyclist	Arterial	Head	Scalp laceration, sutured	Controlled
3	Cyclist	Mixed*	Head	Scalp laceration, sutured	Controlled
4	Passenger vehicle	Mixed*	Head	Scalp laceration, sutured	Stopped
5	Passenger Vehicle	Venous	Head	Scalp laceration, sutured	Stopped
6	Motorcyclist	Mixed*	Femur	Open femur fracture, debrided and sutured	Stopped
7	Pedestrian	Venous	Chest	Chest wall laceration, sutured	Stopped
8	**Fall**	Venous	Head	Scalp laceration, sutured	Controlled
	Struck by Object				
9	Baseball Bat	Venous	Head	Scalp laceration, sutured	Stopped
	Machinery				
10	Diskcutter	Mixed*	Neck	Carotid and vertebral artery injuries, reconstructed surgically	Not controlled

Table 1: Description of Patients treated with the iTClamp
*Mixed arterial and venous bleeding

When comparing complete bleeding cessation (n=6) to adequate bleeding cessation (n=3), there was no significant difference seen in time to apply the iTClamp (p=0.714), time to bleeding control (p=1.000), time to reach the ED (p=0.167), overall satisfaction (p=0.714) or age (p=0.714). For the complete bleeding cessation group 66.6% (n=4) of the iTClamp's were applied to the head/scalp, 16.7% (n=1) were applied to the leg and 16.7% (n=1) to the chest. For the adequate bleeding cessation group 100% (n=3) were applied to the head/scalp. When comparing bleeding controlled (n=9) (complete bleeding cessation combined with adequate bleeding cessation) to bleeding not controlled (n=1) there was no significant difference seen in in time to apply the iTClamp (p=1.000), time to bleeding control (p=0.200), time to reach the ED (p=0.400), overall satisfaction (p=0.200) or age (p=0.400). See Table 2 for complete descriptive statistics.

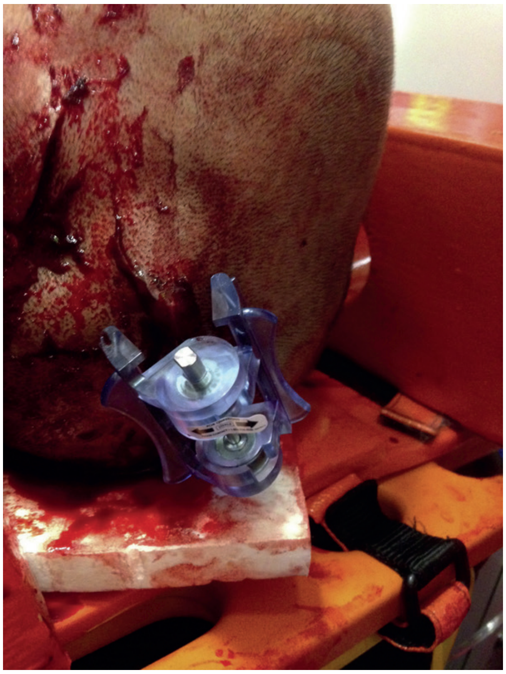


Figure 1: iTClamp application to a scalp laceration to control bleeding

Bleeding Control	Time to apply (seconds) Mean±SD	Time to bleeding control (seconds) Mean±SD	Time to ER (minutes) Mean±SD	Age (years) Mean±SD	Satisfaction (1-10) Mean±SD
Complete Bleeding Cessation (n=6)	12 ± 8	10 ± 9	35 ± 13	49 ± 6	8 ± 0
Adequate Bleeding Cessation (n=3)	8 ± 0	8 ± 6	50 ± 4	59 ± 3	8 ± 1
Bleeding Controlled (n=9)	10 ± 7	9 ± 8	40 ± 13	52 ± 23	8 ± 0
Bleeding not Controlled (n=1)	8	25	27	26	3

Table 2: Descriptive statistics comparing the complete bleeding cessation group to the adequate bleeding cessation group

DISCUSSION

Early control of haemorrhage is not only crucial to patient survival it is also an important aspect in good patient care. Several studies have demonstrated that it is not just transport time that is important in patient survival but there is also a positive correlation between the intensity or quality of pre-hospital care and survival [14, 15]. Unfortunately, the quality of pre-hospital care has shown to be variable across procedures performed and geographic area [16]. When it comes to haemorrhage control a delay in bleeding control is responsible for the majority of preventable death [17]. In addition to the being able to apply direct pressure, haemorrhage control can require tourniquet application, wound packing with hemostatic dressings, wound suturing, wound stapling or even the tamponading of an epistaxis [17]. Even early control of bleeding from ostensibly insignificant wounds is also considered vital [17]. However, these care providers may have modest to minimal technical training and be operating in extreme environments with minimal logistical support [18]. With these factors in mind, finding a device that can be used effectively by even the minimally trained, to control the biggest cause of death is imperative.

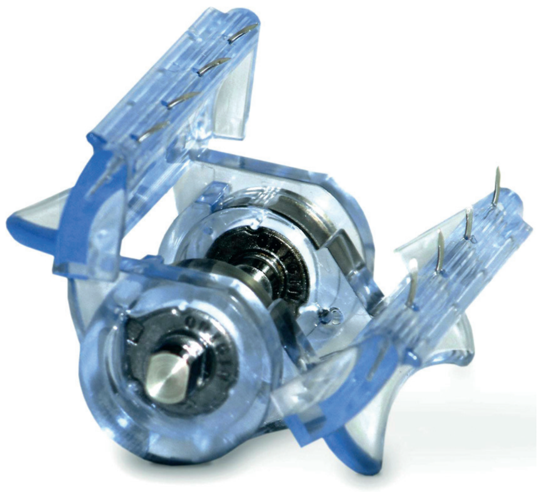


Figure 2: The iTClamp showing pressure bars

The iTClamp seals the skin edges within a pressure bar, creating a haematoma that can form a stable clot until definitive surgical repair (Figure 2). The device provides a temporary solution to external haemorrhage while other priorities are addressed and is removed at the time of definitive wound management. The iTClamp can be used as a first-line device to control haemorrhage from scalp, neck, junctional, and extremity wounds or in combination with other haemorrhage-control strategies, such as haemostatic agents [9-13], tourniquets and tranexamic acid. To date no clinical trials have been performed. While 8 cases have been published in 4 separate case studies [11, 12, 19, 20], this case series of 10 patients is the largest review to date. Recent comparative animal laboratory study of a complex vascular groin injury revealed that all (100%) animals treated with the iTClamp lived through the end of the experiment, compared to 60% treated with standard gauze [9]. The iTClamp has also been reported to improved survival and decreased hemorrhage in both packed and unpacked wounds [13]. A pre-clinical perfused cadaver study demonstrated the iTClamp was effective at controlling blood loss from multiple compressible zones including the scalp, neck, groin, and extremities [10]. Our study shows that the iTClamp can be applied very rapidly (average of 10 seconds), is easy to use, and does not require extensive training. The clamp can be applied in areas that are difficult to control with conventional dressings, such as lacerations to the head or neck, as seen in this and other studies [12, 19] and can be used effectively by even minimally trained care providers [21]. It is important to note however, that the iTClamp can be used following minimal training however, training is still required. According to the directions for use for the iTClamp only trained personnel should apply the device. This ensures that they are aware of the contraindications such as skin that cannot be approximated, lacerations near eyes and delicate structures, as well as the fact that the device will not control haemorrhage in non-compressible sites such as abdominal and chest cavities. The directions for use and training also explain proper handling to avoid needle stick, the fact that a patient with an iTClamp applied must see a physician promptly for definitive care and how to monitor for and deal with expanding haematoma. While the iTClamp does allow a care provider to be hands-free and deal with other patient issues, all basic trauma care guidelines still needs to be adhered to including regular reassessment of <C>ABCDE. For example, if a patient is having airway issues they should be intubated the same as if the wound was packed, wounds should be monitored for re-bleeding and dealt with following the sites protocols for haemorrhage control, including opting to use the iTClamp in conjunction with other devices.

The limitation of our prehospital case series is that it is observational and descriptive with no consistent long-term follow up from which to draw firm conclusions. The low number of participants in the study can also pay a roll in no significant difference being found between the groups. With the results of this small study, it is difficult to evaluate the additional costs versus benefits of the iTClamp. Further research is needed to assess its role in managing major haemorrhage and determine when the device is best deployed. Such research would determine whether the iTClamp is a useful addition for management of trauma, but also whether it is necessary in prehospital care for trauma patients. Therefore, we propose to expand use of the device to all 4 HEMS teams in the Netherlands in a prospective study.

In conclusion, this study shows the additional value of iTClamp use in the control of severe haemorrhage. The iTClamp seems to be a safe and useful tool for stopping or controlling external blood loss. There were no side effects or problems with wound healing that were documented in this short follow up. Future studies will provide us with data about the cost efficiency of these novel products.

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DISCLAIMER

The manufacturer provided the first 10 iTClamps® free of charge. No direct funding was received by our HEMS. One of the authors Jessica Mckee is the Clinical Director for Innovative Trauma Care. Ms. Mckee was not involved in the execution of the study but provided research support.

APPENDIX A: PRE-HOSPITAL SURVEY

iTClamp50 Case Report Form Date: ____________________

Name *(Optional)*: ____

PATIENT *(name and date of birth)*: ____

MMT Inzet nr: ________________________________

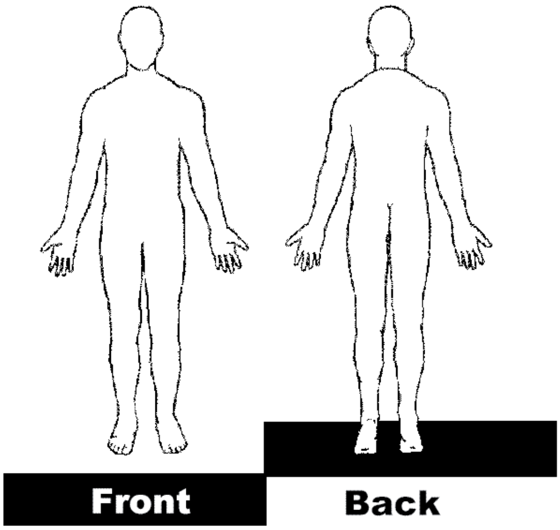
1. Are you
   ______ HCM
   ______ Physician

2. Did you
   Check all that apply
   ______ Apply the device(s)
   ______ Remove the device (s)
   ______ Transport a patient with the device

2b. How many devices were used? ______________________________________

3. In what environment were the device(s) first applied:
   ______ Scene
   ______ Ambulance
   ______ Hospital – Emergency Department
   ______ other: ________________________

4a. Where on the body was the device(s) placed?



Wound characteristics:

Size and Shape of injury:
Major/Minor

____

Source/cause of wound:
Arterial/Venous

4b. What was the indication for placement(s):

______ Hemorrhage control

______ Sucking chest wound

______ other: _________________

Please answer Question 5 if you applied the device:

C

5a. How long did it take you to apply the device(s) (from initially picking up of device package)? Please Circle:

1-5s 5-10s 10-20s 20-30s 30-60s >60s

5b. What was the length of time to control bleeding/close wound? Please Circle:

1-5s 5-10s 10-20s 20-30s 30-60s >60s

5c. After initial control of bleeding was there subsequent re-bleeding? Y / N

Effect of IT Clamp:

☐ Bleeding Stopped
☐ Bleeding Controlled, but not stopped
☐ Bleeding not controlled
☐ Increase of bleeding

5d. Was the device(s) reapplied? Y / N or Unknown

If yes, explain: ____

____

5e. Were other treatments attempted before or after the placement of the device(s)? Y / N or Unknown If yes, explain: ____

____

5f. How much pain was observed upon application of the device(s) to the patient?

1 = No Pain, 10 = Worse possible pain

Please Circle one: 1 2 3 4 5 6 7 8 9 10

5g. How much pain continued after the device(s) was applied?

1 = No Pain, 10 = Worse possible pain

Please Circle one: 1 2 3 4 5 6 7 8 9 10

5h. Were there any difficulties in applying the device(s)? Y/N or Unknown

If yes, explain: ____

____

Please answer Question 6, if you removed the device:

6a. In what environment was the device(s) removed:

Scene
Ambulance
Hospital – Emergency Department
other: _

6b. How much pain was observed upon removal of the device(s)?

1 = No Pain, 10 = Worse possible pain

Please Circle one: 1 2 3 4 5 6 7 8 9 10 N/A

7. Issues associated with the use of the iTClamp50.

7a. Were there any malfunctions with the device(s)? Y/N or Unknown
If yes, explain: ____

____

7b. Were there any adverse events to the patient associated with the device(s)?
Y/N or Unknown If yes, explain: ____

____

7c. Were there any adverse events to the care giver associated with using the device(s)?
Y/N or Unknown If yes, explain:____

____

8. How satisfied were you with the performance of the iTClamp50?

1 = Not Satisfied, 10 = Extremely satisfied

Please Circle one: 1 2 3 4 5 6 7 8 9 10

9. Was the device effective at stopping the bleeding? Y / N or Unknown

10. Please list any suggestions for product improvement.

____

____

____

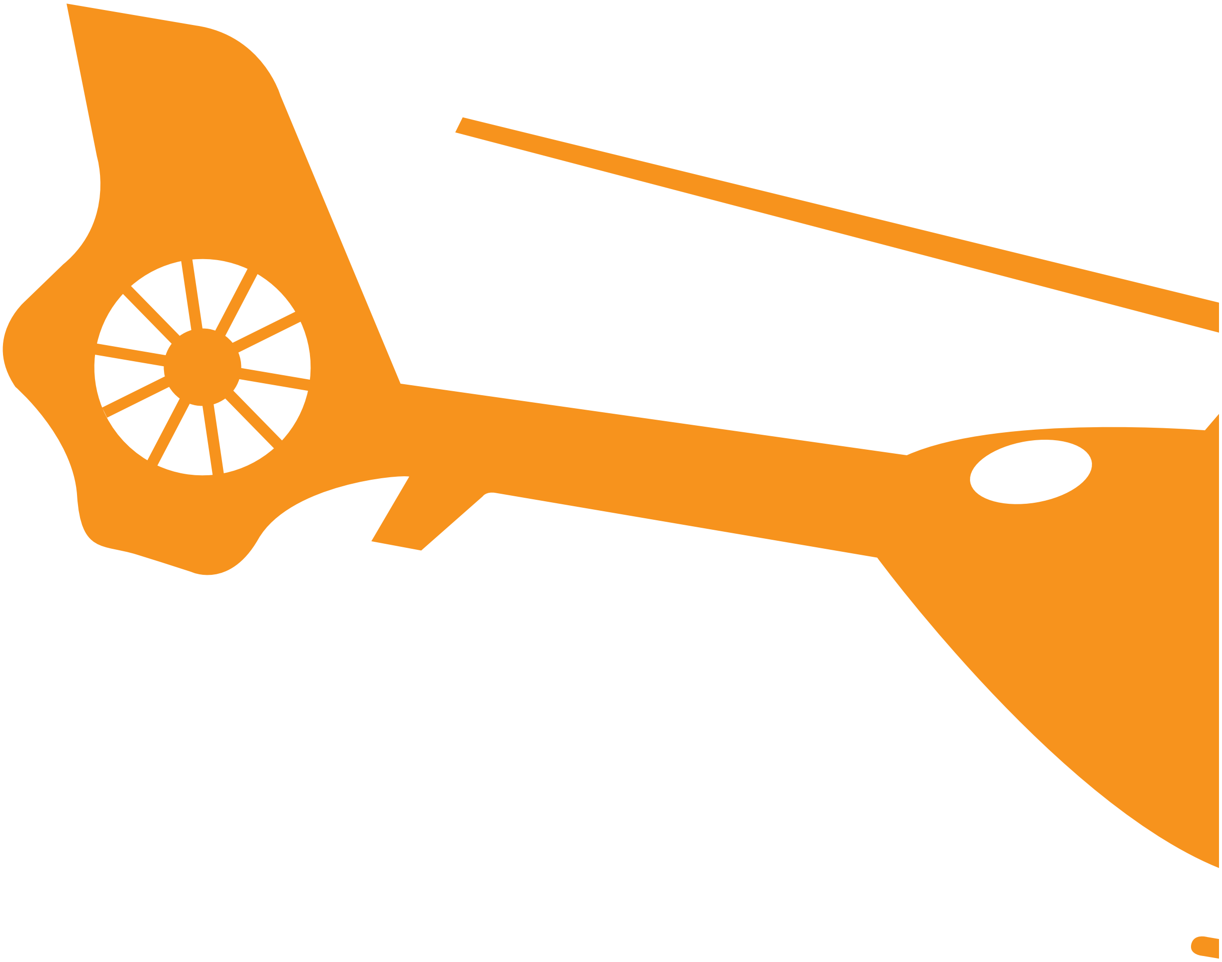
11. Optional: Please provide any additional case details.

____

____

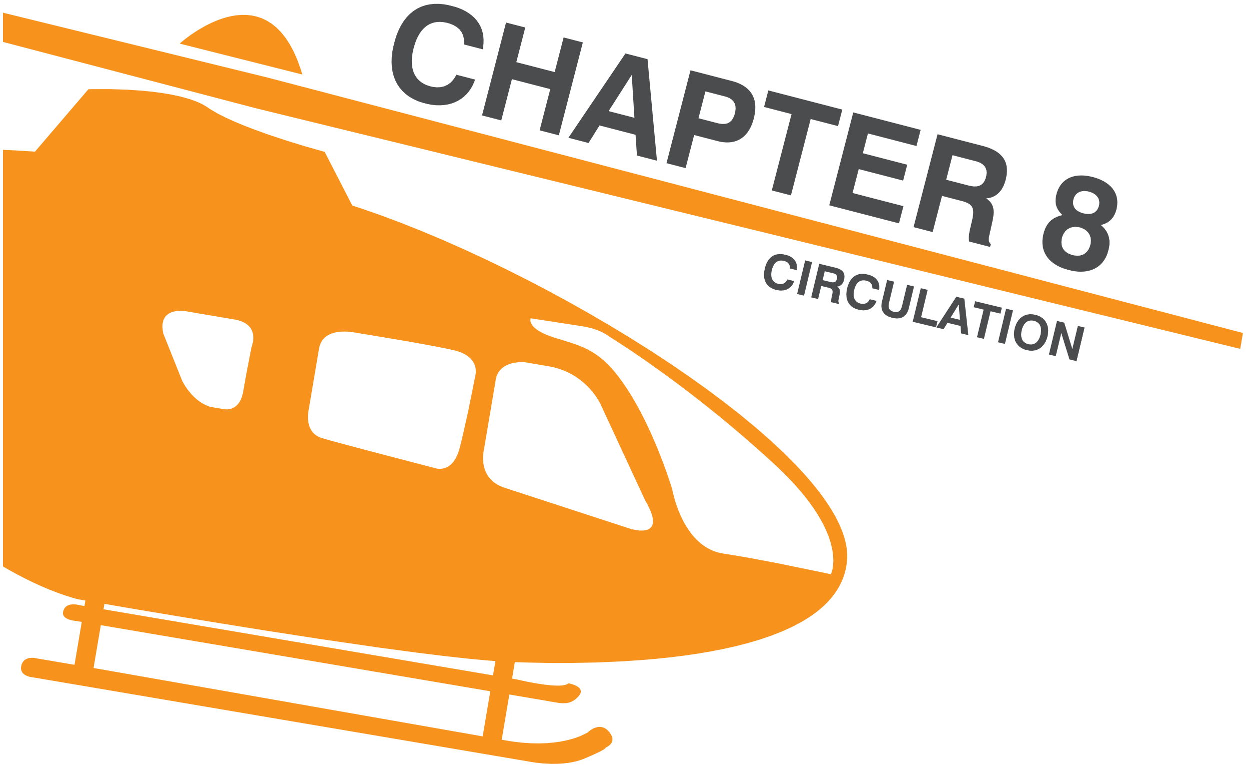
____

____



Peters JH, Smulders PSH, Moors XRJ, Bouman SJM, Meijs CMEM,
Hoogerwerf N, Edwards MJR.

Submitted



CHAPTER 8

CIRCULATION

Are on scene blood transfusions by a physician staffed Helicopter Emergency Medical Service useful and safe?

ABSTRACT

Introduction:

In trauma hemorrhagic shock is a leading cause of mortality. In prehospital setting crystalloid fluids are frequently used as resuscitation fluid. Unlike crystalloids, erythrocytes are capable of transporting oxygen to tissues. The objective of this study was to establish the efficacy and safety of the prehospital use of uncrossmatched type O Rhesus negative packed red blood cells (URBC) by Dutch physician staffed helicopter emergency medical service (HEMS). We hypothesized that prehospital URBC transfusions are safe and more effective regarding survival than resuscitation using solely crystalloid fluids.

Methods:

The effects of prehospital URBC are studied by comparing the cohort of patients, aged 18 and up, treated with a combination of URBC and crystalloid fluids to a matched control group that received crystalloid fluids only.

Results:

Of 73 cases of adult prehospital URBC transfusions, 50 patients (68%) could be included for outcome analysis. No on-scene transfusion reactions were observed. No significant effect of prehospital transfusion on the 24-hour survival, nor the 30-day survival was demonstrated. Hemoglobin levels at ED presentation were significantly higher in the URBC cohort. The in-hospital volume of erythrocytes administered to the treatment cohort was significantly lower to that observed in the control cohort. In both groups a similar cumulative erythrocyte requirement was observed within the first 24 hours.

Conclusion:

No survival benefits, or decreased incidence of shock on admission were found after prehospital HEMS URBC transfusions. This study showed no out of hospital transfusion reactions and therefore URBC transfusions by physician staffed HEMS were deemed to be safe. A prospective randomized study is warranted to evaluate the effect of early administered and preheated URBC on survival of patients with severe prehospital hemorrhagic shock.

INTRODUCTION

In trauma hemorrhagic shock is a leading cause of mortality. When left untreated, bleeding leads to metabolic acidosis, hypothermia, and coagulopathy resulting in death.[1, 2] To stop this viscious circle additional blood loss must be stopped and, if necessary blood (components) should be administered. Any delay in this treatment may lead to patient deterioration and worse outcome.

In a prehospital setting initial, hemorrhage control can be achieved by simple methods, e.g. local pressure, (hemostatic) bandages, tourniquets, pelvic binders or in case of a femoral fracture, the use of a traction splint. The on-scene administration of blood as treatment modality is less straightforward, potentially hazardous and demands more logistical support and evaluation.[3-5]

This study is part of the broader effort to optimize prehospital resuscitation strategies for hypovolemic trauma patients. In prehospital situations with major blood loss, crystalloid fluids are often used primarily. Although these fluids can be an important part of (early) treatment, only erythrocytes are capable of transporting the essential oxygen to tissues, and are therefore considered to be a superior resuscitation fluid. Despite this crucial advantage, it is uncertain if on-scene transfusion of uncrossmatched type O Rhesus negative packed red blood cells (URBC) is more effective (primarily regarding survival) than resuscitation with crystalloid fluids. Recent research demonstrates the safety of prehospital transfusion of URBC, but no positive survival effects could be demonstrated on short and long term in civilian setting.[6-14]

In the Netherlands, only physicians are legally allowed to perform blood transfusions. Consequently, only the physician staffed helicopter emergency medical service (HEMS) can initiate this potentially lifesaving procedure in the prehospital setting.[15] URBC are not yet part of the standard Dutch HEMS equipment. In current setting, when blood is wanted and the on-scene time is prolonged by for instance entrapment of the patient, URBC can be obtained from local hospitals. To facilitate this procedure arrangements have been made with the local blood banks to ensure patient safety and traceability of blood products.[12,6]

The objective of this study was to establish the efficacy and safety of the prehospital use of URBC by the Dutch physician staffed HEMS. We hypothesized that prehospital URBC transfusions are safe and more effective regarding survival than resuscitation using solely crystalloid fluids.

METHODS

Dutch prehospital medical care consist of ambulance teams operated by nurses and four physician staffed HEMS (at consultant level) as adjunct. The four HEMS teams covering the Netherlands are associated with level one university trauma centers. This multicenter cohort study utilizes data from both the Nijmegen and Rotterdam HEMS operations, covering the area in the southern part of the Netherlands.

The effects of prehospital URBC are studied by comparing the cohort of patients treated with a combination of URBC and crystalloid fluids to a control group that received crystalloid fluids only. A search for patients, aged 18 and older, that received prehospital URBC between January 2007 and November 2015 was conducted in both HEMS databases. All patients that received prehospital URBC were included for statistical analysis. Controls were selected from Radboud university medical center records; all control patients were treated by HEMS. Matching criteria were gender, age, shock class and calculated injury severity score (ISS). Data regarding outcome were extracted from the HEMS databases, the local hospital medical records and from reports provided by partner clinics. Approval was obtained from the Local Ethics Committee prior to data acquisition.

ANALYSIS

The primary outcome of this study is 24-hour survival. Secondary outcome measures are 30-day survival, hemoglobin (Hb) concentration determined upon arrival at the Emergency Department (ED), trauma-induced coagulopathy (TIC, defined as an international normalized ratio (INR) upon admission of >1,5), shock upon hospital admission (lactate >4 mmol/L or base excess <-6 mEq/L), 24-hour erythrocyte requirement and registered transfusion reactions.

Missing data have been actively registered and maximum effort was put in trying to complete the dataset. Concise dispatch registration, non-responding partner clinics, and administration errors were found to be reasons for the absence of data.

Pearson's chi-squared test has been used to evaluate the association on dichotomous endpoints and the Mann-Whitney U test for other variables. SPSS software (version 22 Armonk, NY: IBM Corp.) was used for statistical analysis. P-values < 0.05 were considered significant.

RESULTS

The query performed on both HEMS databases recovered 73 cases of adult prehospital URBC transfusions. No on-scene transfusion reactions were observed. Due to incomplete registration and missing follow-up data 50 patients (68%) could be included for outcome analysis .

Patients were predominantly male (90%) with a median age of 33 years (18 - 70). The median ISS of the transfusion group was 34 (9 - 75), while a reliable ISS calculation was unobtainable for 5 patients, due to incomplete data registration.

A majority of patients sustained injuries from motor-vehicle accidents (70%), however HEMS also transfused URBC after falls from heights (10%) and in penetrating injuries (7%). A similar distribution was observed in the control cohort (table 1).

No significant effect of prehospital transfusion on the 24-hour survival ($p = 0.531$) nor the 30-day survival ($p = 0.547$) was demonstrated. Hb levels at ED presentation were significantly higher in the URBC ($p<0.001$). URBC had no significant effect on base excess (BE) ($p=0.628$). There was no observed difference in serum lactate ($p=0.142$), nor in the numbers of patients that presented with shock on ED presentation ($p=0.243$).

INR was determined for 74% of the treatment cohort and 90% of the control group. There was no difference in TIC in both groups: median INR 1,3 (1-10) in URBC and 1,3 (1 - 3.1) in the control group ($p= 0.529$). The in-hospital volume of erythrocytes administered to the treatment cohort was significantly lower to that observed in the control cohort ($p<0.01$). In both groups a similar cumulative erythrocyte requirement was observed within the first 24 hours ($p=0.888$).

In terms of safety: one patient experienced a mild transfusion reaction, most likely attributable to an in-hospital dose of fresh frozen plasma (FFP). No additional treatment was necessary.

Patient characteristics and outcomes	Prehospital URBC (n=50)	Controls (n=50)	p Value
Sex, male, n (%)	45 (90%)	45 (90%)	
Age, years	33 (18-70)	33 (18-63)	.981
Mechanism, n (%)			
MVA	35 (70%)	34 (68%)	
Penetrating	7 (12%)	3 (6%)	
Fall from height	5 (10%)	6 (12%)	
Other	3 (6%)	7 (14%)	
Prehospital shock class	4 (2-4); n=49	4 (2-4); n=50	.695
ISS	34 (9-75); n=45	35 (18-75); n=40	.242
Time until hospital arrival, min	84 (12-154); n=27	71 (24-90); n=50	.118
HEMS RBC, mL	750 (250-5000)	-	-
HEMS crystalloids, mL	1500 (0-9250)	1750 (250-5000)	.065
Survival, n (%)			
24-hour	31 (70%)	34 (68%)	.531
30-day	27 (55%); n=49	30 (60%)	.547
HB			
Hb, mmol/L	8 (3.4-10.4); n=39	6.5 (3.0-8.9); n=47	**.001**
BE, mEq/L	-9.9 (-25.0-0.7); n=37	-6.6 (-23.2- -0.6); n=45	.628
Lactate, mmol/L	3.6 (0.8-21); n=35	3.2 (1.1-14.2); n=33	.142
Shock on admission, n (%)	26 (70%); n=37	26 (58%); n=45	.243
INR	1.3 (1-10); n=35	1.3 (1-3.1); n=39	.529
TIC, n (%)	14 (40%); n=35	10 (26%); n=39	.188
In-hospital 24h RBC requirement, mL	1443 (0-19315); n=42	2240 (0-15120)	**.004**
Cumulative 24h RBC requirement, mL	1958 (270-20580); n=42	2240 (0-15120)	.888

Table 1: Patient characteristics and outcomes in the prehospital URBC patients and control cohort, data presented in median with range.

DISCUSSION

Crystalloid fluids became available in the 1960's and thereafter their use became widespread, replacing whole blood transfusion. [17] In contrast, recent research has focused on the prehospital administration of blood plasma, coagulation factors and erythrocytes. Smaller studies with limited power demonstrated the feasibility of the prehospital use of plasma, which led to the funding of three, already announced, civilian randomized clinical trials by the American Department of Defense. [18-20] Recombinant factor VIIa (RFVIIa) appeared most promising, however its use decreased drastically after no survival benefits could be demonstrated in clinical settings. [17, 21] Transfusion of red blood cells has gained the most attention after physicians recognized the necessity of early recovery of oxygen supply to vital organs. Numerous studies examined the safety of uncrossmatched O negative RBC. [6, 7, 10, 12] Some studies report conclusions on the effects of prehospital transfusion of URBC in civilian settings. [22-24]

The cohort study presented here examines the effects of prehospital transfusion of URBC, administered by two physician-staffed European HEMS. Patients gained no significant benefit in terms of 24-hour or 30-day survival when compared to prehospital controls who received only crystalloid fluids. This is in contrast to the findings of Brown et al. and Holcomb et al. who found improved short term survival.[23, 24] Our findings confirm those found by Miller et al. in a recent large study showing no beneficial effect on survival.[14] The lack in beneficial effect that we found could be due to the relative small number of patients presented here.

One possible explanation for the lack of a beneficial effect in this cohort might be the relative delay in prehospital administration of URBC. In the current situation URBC must be obtained from local blood banks when ordered on-scene, however to obtain an effect in bleeding control and hypoperfusion prevention expedited administration of erythrocytes might be essential.

This will be further studied in a test in which the HEMS helicopter will be equipped with two units of URBC as to accommodate immediate application. Stored blood is cooled, which is not optimal for the bleeding trauma patient. Since hypothermia prevention is crucial to prevent patient deterioration, a fluid heater will be used to optimize the temperature of the refrigerated erythrocytes.

At presentation at the ED the first blood samples showed a significantly higher Hb concentration in the URBC group. This can be explained by the fact that erythrocytes have been given to these patients. However, there are also patients in the treatment cohort who presented elevated HB levels on initial presentation at the ED. These patients probably received URBC without the necessity for this treatment. Identifying those patients that actually suffer from a life threatening hemorrhagic shock can be challenging in the field when only clinical parameters are available.

For instance, a cervical spine injury with neurogenic shock can also present with comparable vitals, but lack the need for blood transfusion. This differentiation might be facilitated by the implementation of ultrasound and point of care hemoglobin concentration measuring devices in prehospital setting.

Analysis showed no difference in the incidence of TIC. This may be explained by the fact that the URBC are administered relatively late. In addition, no coagulation factors are administered in a prehospital setting. In ongoing bleeding TIC may be limited by quick URBC suppletion in combination with (freeze-dried) plasma. Unfortunately, the latter is not yet available in the Duct civilian prehospital setting.[25, 26]
Sumida et al. showed that patients, admitted after prehospital URBC transfusion, were more often in shock than the control group. [22] While in our study, no significant differences in shock on presentation were observed. Total RBC requirement was comparable between both groups, in contrast to the results of other studies.[22, 24] This might indicate a mere transition of the moment RBC were given, not a beneficial effect in itself.

In terms of safety, one mild transfusion reaction was observed. The reaction was presumed to be the result of the in-hospital administration of fresh frozen plasma and therefore unrelated to prehospital URBC transfusion. The observed results confirm the previously reported safety of prehospital treatment with URBC. [6, 7, 10, 12]

Previously Sumida et al. concluded that their study was severely limited by the differences in flight times between their cohorts. No significant differences in the time until admission to a hospital are observed in this study. [22] It can be hypothesized that hypovolemic, bleeding trauma patients with a prolonged time until admission suffer from higher mortality rates than when prehospital time is limited. Future data collection with sufficient power to perform a subgroup analysis on prehospital time may provide additional information regarding patient survival.

STUDY LIMITATIONS

Although a relative large study including two physician staffed HEMS operations, this studies retrospective nature has its limitations. Due to incomplete registration, patients with prehospital blood transfusions had to be excluded from the cohort. This is because a verified outcome regarding hospital survival was needed to include the patients in our dataset. In 5 patients information regarding outcome was available, but not thorough enough to calculate an ISS. These patients were included in the group for analysis on primary and secondary outcome measures. Because of selection of control patients on among others ISS, this may have influenced the selection of control group patients and therefore the outcome of the study.

CONCLUSION

No survival benefits, lowered TIC or decreased incidence of shock on admission were found after prehospital HEMS URBC transfusions in this cohort study. This study showed no out of hospital transfusion reactions and therefore URBC transfusions by physician staffed HEMS was deemed to be safe. A prospective randomized study is warranted to evaluate the effect of early administered and preheated URBC on survival of patients with severe prehospital hemorrhagic shock.

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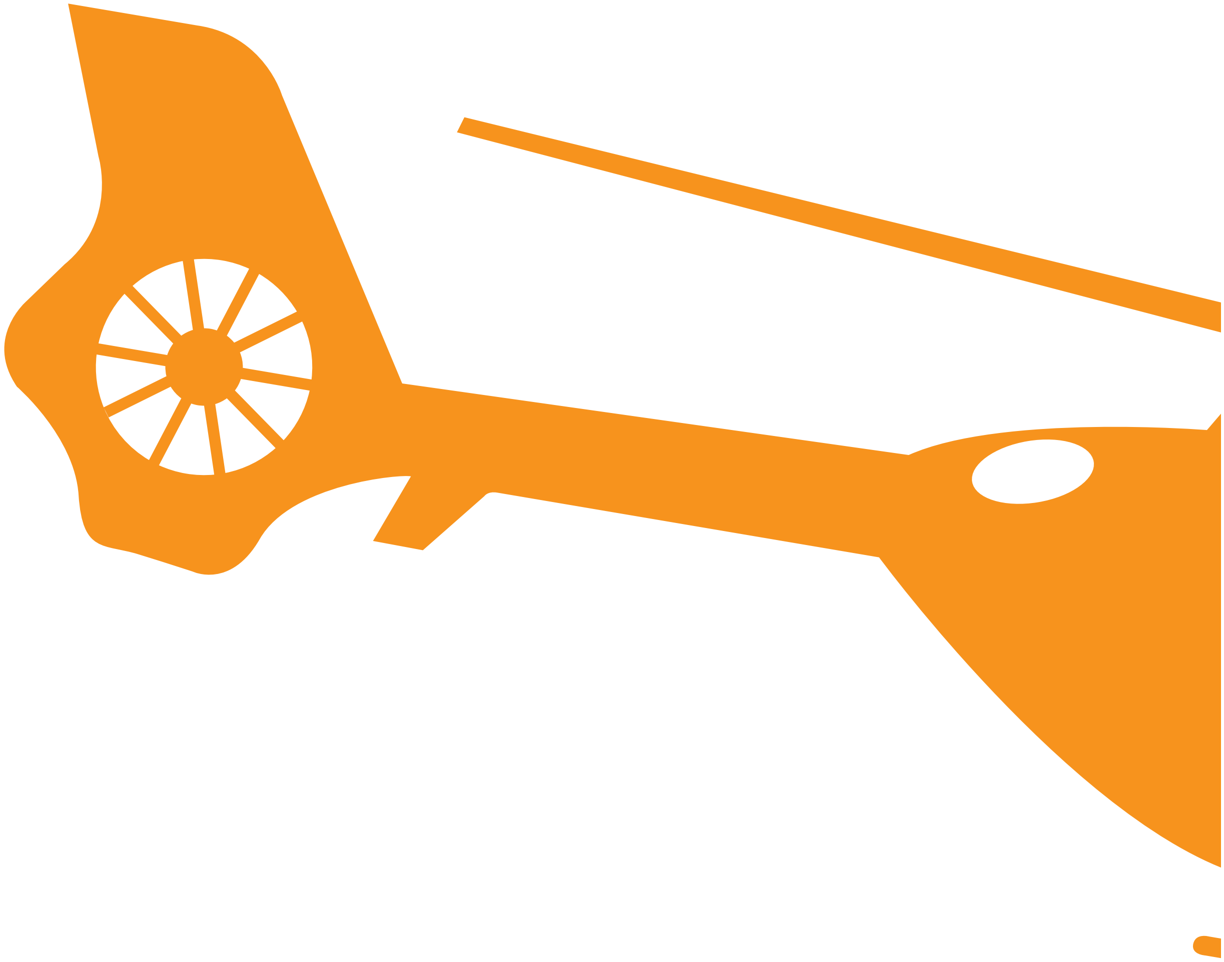

Van Vledder MG, Van Waes OJF, Kooij FO, Peters JH, Van Lieshout EMM, Verhofstad MHJ.

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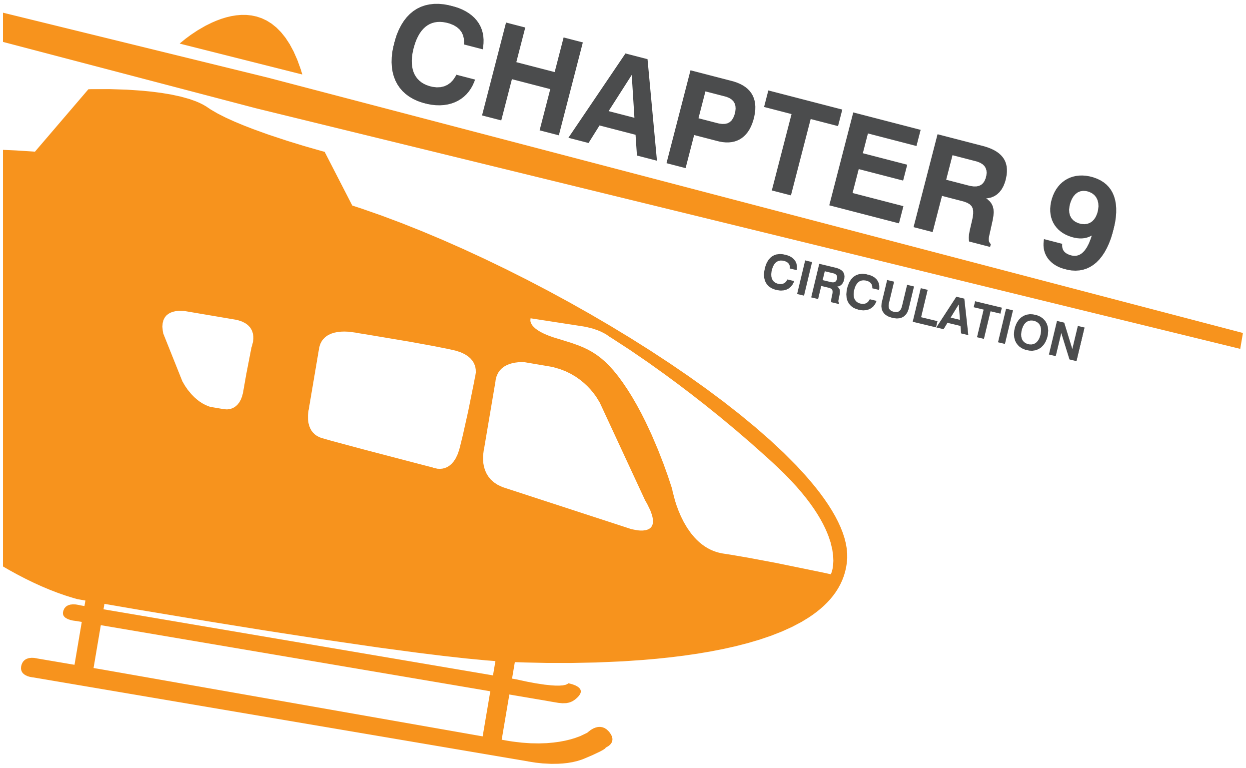
CHAPTER 9

CIRCULATION



Out of hospital thoracotomy for cardiac arrest after penetrating thoracic trauma. Implementation and outcomes in a physician staffed HEMS operation

ABSTRACT

Introduction:

Emergency department thoracotomy is an established procedure for cardiac arrest in patients suffering from penetrating thoracic trauma and yields relatively high survival rates (up to 21%) in patients with cardiac tamponade. To minimize the delay between arrest and thoracotomy, some have advocated thoracotomy on the accident scene. The aim of this study was to determine the proportion of patients with return of spontaneous circulation and subsequent survival after out of hospital thoracotomy in the Netherlands.

Methods:

A retrospective analysis of data collected on all out of hospital thoracotomies performed in the Netherlands after penetrating trauma between April 1st, 2011 and September 30th, 2016 was performed. Data on patient characteristics, trauma mechanism and outcome were collected and analyzed. Primary outcome measure was return of spontaneous circulation after the intervention. Survival to hospital discharge was the secondary outcome variable.

Results:

Thirty-three prehospital emergency thoracotomies were performed. Ten patients (30%) had gunshot wounds and 23 patients (70%) had stab wounds. Nine patients (27%) had return of spontaneous circulation and were presented to the hospital. Of these, one patient survived until discharge without neurological damage. Five died in the emergency department or operating room and three died in ICU.

Conclusion:

Return of spontaneous circulation after out of hospital thoracotomy for cardiac arrest due to penetrating thoracic injury is achievable, but a substantial number of patients die during the in hospital resuscitation phase. However, neurologic intact survival can be achieved.

INTRODUCTION

Traditional cardiopulmonary resuscitation for out of hospital traumatic cardiac arrest is associated with poor survival [1]. For patients with cardiac arrest resulting from cardiac tamponade after penetrating thoracic injury, emergency thoracotomy with decompression of the pericardial sac may offer a significant chance of survival. Emergency department series have reported survival rates up to 21% [1].

Emergency department thoracotomy has been included in the guidelines of the European resuscitation council as a resuscitative procedure for patients suspected of having circulatory arrest and cardiac tamponade [2]. Emergency room thoracotomy has been an established procedure in Dutch trauma centers for many years with favorable results [3]. Longer transportation times to the hospital may be associated with poor outcome in these patients; Ideally thoracotomy should be performed within 10 minutes after circulatory arrest, which is very hard to achieve when arrest occurs in an out of hospital setting[1]. Davies *et al*. reported on prehospital thoracotomies performed by the physician-led London Helicopter Emergency Medical Service (HEMS) in patients suffering from cardiac arrest after sustaining a stab wound to the chest. Thirteen out of 71 patients survived to hospital discharge after out of hospital emergency thoracotomy [4]. Therefore, it was hypothesized that adding this procedure to the armamentarium of Dutch HEMS personnel may lead to increased odds of survival in selected patients.

The aim of this retrospective case-series was to determine the proportion of patients with return of spontaneous circulation and subsequent survival after out of hospital thoracotomy. Furthermore, we describe the introduction and implementation of this procedure in the Dutch physician staffed Helicopter Emergency Medical Service (HEMS)

METHODS

Dutch HEMS operation

The Netherlands covers approximately 41,000 square kilometers and holds about 17 million inhabitants. Prehospital emergency medical services are mostly provided by ground ambulance crews staffed with paramedics, trained in prehospital trauma life support (PHTLS) and a background in intensive care or emergency medicine. Ground emergency medical services (EMS) are supplemented by four physician-led HEMS operations across the country. A HEMS team consists of a board-certified anesthesiologist or trauma surgeon, a specialized nurse, and a helicopter pilot. The primary purpose of the Dutch HEMS operation is to provide specialized medical care on scene, including advanced airway management and specific procedures such as thoracostomy and chest tube drainage.

Three of four Dutch HEMS operations implemented prehospital thoracotomy and participated in this study. The fourth HEMS station is located in a largely rural environment in which penetrating thoracic injury due to gunshot or stab wounds is less frequently encountered and have not yet introduced this procedure into their practice.

Training for out of hospital thoracotomy

In order to familiarize HEMS crew members with the procedure of emergency thoracotomy, physicians and nurses received theoretical and practical training by board certified trauma surgeons with extensive experience in emergency department thoracotomy. First, the available protocols and literature with regard to indications and outcomes for resuscitative thoracotomy were discussed. Thereafter, the anatomy of the thoracic wall and mediastinum were reviewed thoroughly and the technique for anterolateral and clamshell thoracotomy was described. Finally, skills were extensively and repeatedly trained in the cadaver lab on fresh frozen cadavers (Figure 1).

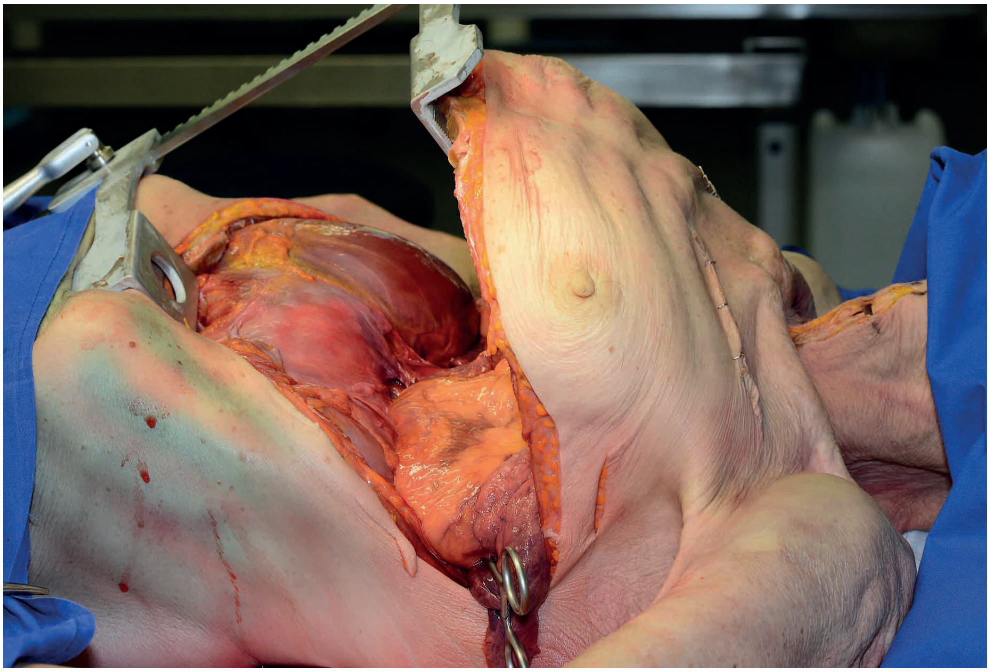


Figure 1: Thoracotomy training in the cadaver lab on fresh-frozen body
Photograph by Ruud Eijk

Indications, technique and equipment

During in-hospital resuscitation on a stretcher or operating table at near eye level, a left anterolateral thoracotomy provides sufficient access to the mediastinum to open the pericardium and decompress cardiac tamponade. In the prehospital setting, a clamshell thoracotomy is preferred as this provides optimal exposure for the supine patient on the ground. The procedure is relatively easy to perform and allows for treatment of various traumatic injuries, even for non-surgical personnel [5]. Indications and technique are strictly protocolled and modeled on the recommendations of Wise *et al.* [6]. In short, thoracotomy is performed in all patients with (1) penetrating thoracic injury or upper abdominal injury with suspected cardiac tamponade, (2) a delay shorter than 10 minutes between cardiac arrest and arrival of the HEMS crew or signs of life (pupil reflexes, gasping or ECG activity) at arrival of the HEMS crew, (3) no other non-survivable injuries and (4) the inability to transport the patient to an ER equipped for thoracotomy within 10 minutes of cardiorespiratory arrest.

After the HEMS crew and EMS personnel agree on the indication for out of hospital thoracotomy, the patient is placed in supine position, asepsis is applied and bilateral thoracostomies are created in the 5th intercostal space in the mid-axillary line to exclude a tension pneumothorax as a possible cause for arrest. If circulation does not recover, both thoracostomies are connected resulting in a clamshell thoracotomy. A Finochietto rib-spreader is used for permanent exposure. After opening the thorax and pericardium, fluids and clotted blood are removed and bleeding wounds in the heart are occluded with a finger, a balloon catheter or sutures (Figure 2). If the heart does not start beating spontaneously, internal massage is attempted with additional procedures such as leg raise, prehospital blood transfusion or transthoracic defibrillation (if ventricular fibrillation occurs) at the discretion of the treating physician. When exsanguination from a source outside of the heart is encountered (lung, great vessels or below the diaphragm), hemostatic measures including lung twist or cross-clamping the aorta may be attempted. In case of return of spontaneous circulation (ROSC), standard post ROSC care is initiated and the patient is transferred to the nearest trauma center. If no ROSC is noted 15 min after opening of the pericardium further resuscitation is withheld.

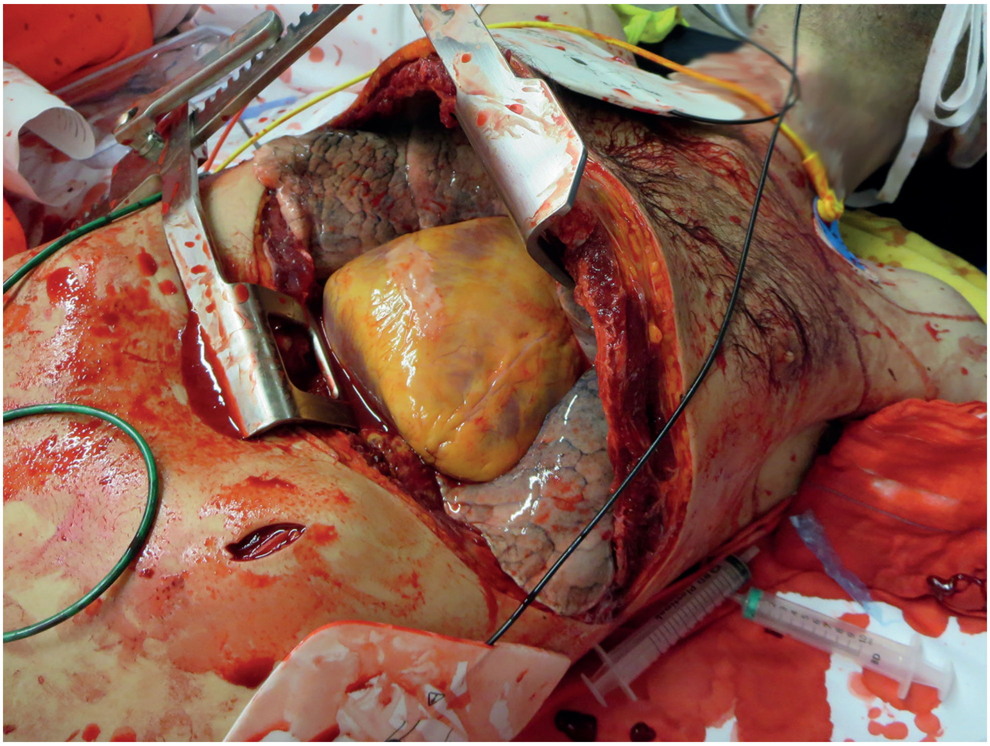


Figure 2: On-scene clamshell thoracotomy

Our thoracotomy kit contains the following instruments; 2 pair of protective goggles, 2 pair of surgical gloves, anti-septic solution, gauzes, five abdominal packs, two disposable scalpels (size 20), one pair of heavy scissors, two hemostatic clamps, two forceps, one pair of Metzenbaum scissors, a Gigli-saw, a Finocietto ribspreader, a needle holder, one double armed polypropylene 3-0 suture, a 6 Fr Foley Catheter and a skin stapler.

DATA COLLECTION AND STATISTICAL ANALYSIS

This study is a retrospective analysis of data collected between April 1st, 2011 and September 30th, 2016. Patients were identified by searching a prospective database of patients undergoing out of hospital emergency thoracotomy. This was cross checked and supplemented by data from a computer database in which all Dutch HEMS dispatches are registered using the Dutch terms for “thoracotomy” and relevant synonyms. Missing data as well as data on in-hospital treatment and outcome were retrospectively acquired from the electronic patient files. The following variables were collected; age, gender, trauma mechanism, peri-arrest ECG rhythm,

	Stab wound N=23	Gunshot wound N=10
Age		
Median (SD)	38(18)	31 (9)
Unknown	5	1
Delay between arrest and thoracotomy		
Witnessed	5 (22%)	2 (20%)
< 10 minutes	11 (48%)	3 (30%)
> 10 minutes	5 (22%)	2 (20%)
Unknown	2 (8%)	3 (30%)
Peri-arrest rhythm		
EMD	16 (70%)	3 (30%)
Asystole	6 (26%)	5 (50%)
Unknown	1 (4%)	2 (20%)
Other penetrating injuries		
None	19 (84%)	7 (70%)
Abdomen	1 (4%)	0
Head	0	2 (20%)
Abdomen and neck	1 (4%)	1 (10%)
Extremity	2 (8%)	0
Technique		
Anterolateral	4 (17%)	0
Clamshell	19 (83%)	1 (100%)
Cardiac Tamponade		
Yes	14 (61%)	1 (10%)
No	9 (39%)	7 (70%)
Unknown	0	2 (30%)
Outcome		
Dead at the scene	14 (61%)	10 (100%)
Dead in ER	2 (9%)	0
Dead in OR	3 (13%)	0
Dead in ICU	3 (13%)	0
Survival to discharge	1 (4%)	0

Table 1: Comparison of characteristics and outcome of patients undergoing pre-hospital thoracotomy for cardiac arrest following penetrating chest injury due to gunshot wounds and stab wounds.

C

delay between cardiac arrest and thoracotomy, technique used to enter the thorax, injuries found after thoracotomy and outcome. Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 23.0 (SPSS, Chicago, Ill., USA). Missing values were not imputed. For continuous parametric data (*e.g.*, age) the mean and standard deviation, and for continuous non-parametric data the median and percentiles are reported. For categorical data (e.g., gender) numbers and frequencies are reported. The study protocol was approved by the Medical Research Ethics Committee of the coordinating center.

RESULTS

A total of 33 out of hospital thoracotomies were performed. Fourteen thoracotomies (42%) were performed by five trauma surgeons and 19 thoracotomies (58%) were performed by eleven anesthesiologists. Patient characteristics and outcome are presented in table one, stratified by trauma-mechanism.

Zero out of ten patients with gunshot wounds had return of spontaneous circulation. Nine out of 23 patients with stab wounds (39%) had return of spontaneous circulation after thoracotomy on-scene and were presented to the hospital with spontaneous circulation (Figure 3). Of these, one patient (4%) survived neurologically intact to hospital discharge. Three patients died in the ICU (13%) among whom was one patient that died as a result of ongoing hemorrhage from a stab wound to the neck combined with severe coagulopathy. Two patients were found to have severe post-anoxic brain damage once in ICU and further treatment was withheld. Two patients (9%) succumbed in the ER due to ongoing hemorrhage from other penetrating injuries to superior vena cava injury and aorta respectively. Three patients (13%) died in the OR: One died due to exsanguination from a large right ventricle tear, another patient died due to cardiac failure resulting from right ventricle ischemia following traumatic transection of the right main coronary artery and the third patient died due to refractory cardiogenic shock after prolonged open chest cardiac massage.

The one surviving patient in this series was a 35-year-old man that sustained a stab wound just below the left nipple. On arrival of the ground EMS and HEMS crew within 10 minutes of the initial call, the patient was still conscious and had spontaneous circulation. The patient was urgently loaded into the ambulance. An ultrasound performed during transportation to the nearest trauma center confirmed cardiac tamponade. Seconds after the diagnosis, the patient went into circulatory arrest. After tracheal intubation a left anterolateral thoracotomy was performed by the HEMS physician in the ambulance. The pericardial sac was opened and blood clots evacuated. The patient regained spontaneous circulation and there was profuse bleeding from a penetrating wound in the anterior side of the right ventricle which was successfully occluded with gentle finger pressure. Once in the hospital, the patient was urgently transferred to the OR where the perforation was sutured with minimal further blood loss. Apart from a slightly prolonged period of ICU admission due to pneumonia, the further course was uneventful. Nine days after hospital admission the patient was discharged home without any neurological impairment.

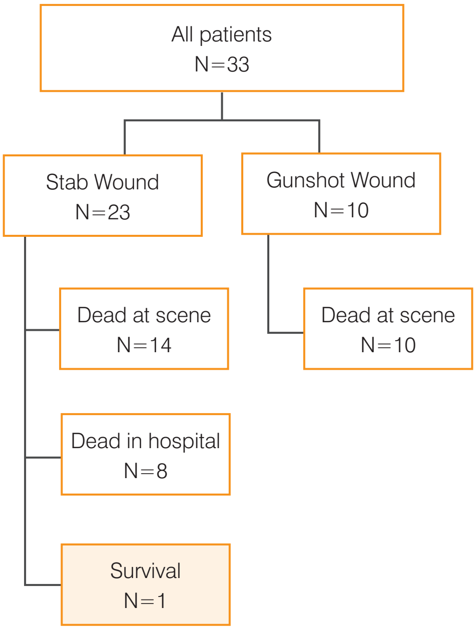


Figure 3: Flowchart with patient outcomes

PROVIDER SAFETY

Multiple glove tears with subsequent skin exposure to the patient's blood were reported (no complete data). Two HEMS physicians reported a superficial skin cut following scalpel injury during the prehospital surgery. In both cases, the patients' blood was found to be free of pathogens

DISCUSSION

This paper describes the introduction of prehospital emergency thoracotomy in the Dutch HEMS operation. A total of 33 prehospital emergency thoracotomies were performed in patients suffering cardiac arrest after sustaining penetrating thoracic injury. Nine patients had ROSC and one patient survived to hospital discharge. Since 59% of thoracotomies were performed by anesthesiologists (among which the only surviving patient in this series), we believe this procedure can be successfully taught to and safely performed by all Dutch HEMS physicians [7].

Outcomes in the current series are relatively poor when compared to the scarce data that is available on the subject. However, we believe this large consecutive case series to be an important addition to the existing literature, as it may provide important lessons for other pre-hospital services with regard to expected outcomes and potential pitfalls.

In 2001, Coats *et al.* reported on 34 patients in cardiac arrest after sustaining penetrating thoracic injury (gunshot or stab wound) undergoing out of hospital emergency thoracotomy of whom four patients survived (10%) [8]. Four years later, after excluding all patients that did not meet the very stringent inclusion criteria for their study, Davies *et al.* reported on 71 patients with a single stab wound to the chest and a delay of less than 10 minutes between arrest and thoracotomy. Thirteen patients survived (18%) [4]. From both series it is clear that patients with cardiac arrest due to a single stab wound to the chest and a short delay to thoracotomy have the best odds of survival. This notion is further supported by the fact that all available case series and case reports that document survival after out of hospital emergency thoracotomy pertain to patients with a single stab wound to the chest or epigastrium, a short delay to thoracotomy and cardiac tamponade upon opening the chest [6, 9, 10]. Indeed, when we limit the current analysis to this group of patients with a single stab wound, short delay and cardiac tamponade, the survival rate in this series is one out of seven (14%).

Conversely, it is clear from the current series as well as other available data that patients going into cardiorespiratory arrest after sustaining gunshot wounds to the heart, patients with multiple gunshot or stab wounds, patients without signs of life after sustaining their injury and patients who arrest as a result of exsanguination do uniformly succumb when going into cardiac arrest in an out of hospital setting, even when on-scene emergency thoracotomy is performed. Withholding resuscitative thoracotomy in these patients remains a point of debate. Experience from ER thoracotomy has shown that even in these patients there is an –albeit small- chance of neurologically intact survival [3 1 11]. Since the available data on out of hospital emergency thoracotomy for pulseless patients with gunshot wounds to the chest is extremely limited, the first survivor may as well be expected.

Whether out of hospital thoracotomy should be performed in patients with cardiopulmonary arrest after blunt force trauma has not been addressed in the current study. Although some Dutch HEMS physicians have achieved return of spontaneous circulation in patients with a witnessed arrest after blunt trauma (but no survivors), we decided not to include these patients in the current study. A Japanese series reporting on 34 prehospital thoracotomies for blunt trauma did not identify any survivors in their cohort either[12].

Patient selection is probably the largest contributor to the poor overall results in this series. More stringent criteria will certainly lead to less futile thoracotomies, but may refute some patients a last chance of survival. Perhaps ultrasound may aid a better identification of potential survivors, as a recent study showed that the absence of both cardiac motility and pericardial effusion on transthoracic ultrasound is associated with zero survivors [13]. On the other side, precious time may be lost while performing ultrasound which may even affect neurological outcome. Two other factors should be considered when evaluating the poor survival-rate in this study. First, as this is a novel procedure for most of Dutch HEMS physicians, many may not have reached the top of their learning curve for out of hospital emergency thoracotomy yet. Second, of the nine patients who had ROSC and made it to the hospital, eight succumbed in the ED, OR, or ICU. As these nine patients were admitted to seven different hospitals across the country, experience with patients presented after prehospital emergency thoracotomy is severely limited in most emergency departments. Better education and selection of receiving hospitals and the development of specific protocols for these patients may contribute to a higher rate of survivors in the near future.

Of the eight patients that made it to the hospital but did not survive until discharge, uncontrollable hemorrhage was the cause of death in four patients. Two patients died due to severe post-anoxic brain damage and two patients due to cardiac failure. Unfortunately, the exact cause of death in patients that did not make it to the hospital is unknown in the current series. Likely, the majority of these patients will have suffered from massive cardiac or intrapericardial great vessel injury, extrapericardial great vessel injuries, parenchymal lung injuries or mixed injuries with concomitant exsanguination. Indeed, a series from South Africa identified these injuries to be responsible for 50%, 22%, 15% and 13% of prehospital deaths resulting from penetrating thoracic trauma respectively [14].

One of the major concerns we had regarding the introduction of this procedure is provider safety. As a significant proportion of trauma victims may be carrier of blood borne pathogens, this is a main concern[15]. Indeed, some have reported glove tears and two incidents were reported in which the HEMS physician sustained a penetrating finger injury. Luckily, no blood borne pathogens were detected in the trauma victims blood. Wearing double gloves and protective eye gear and incorporating the risk of incidents due to sharp needles, knives or fractured ribs in the team briefing should be standard of care.

Another concern is the psychological burden laid upon non-medical emergency providers personnel at the scene, since being confronted with an opened chest may be a traumatic experience. We recommend rapid pre-briefing and post-procedural debriefing. Additional support should be offered if needed.

In summary, out of hospital emergency thoracotomy for pulseless patients with penetrating thoracic injury was successfully implemented in the Dutch HEMS operation leading to return of spontaneous circulation after thoracotomy in 27% of patients and a first survivor. We therefore believe prehospital emergency thoracotomy is a feasible and justified resuscitative procedure in the trauma care system of the Netherlands. However, since out of hospital thoracotomy exerts certain risks for the healthcare providers and may be a traumatic experience for bystanders, exact indications and contra-indications should be an area of constant evaluation.

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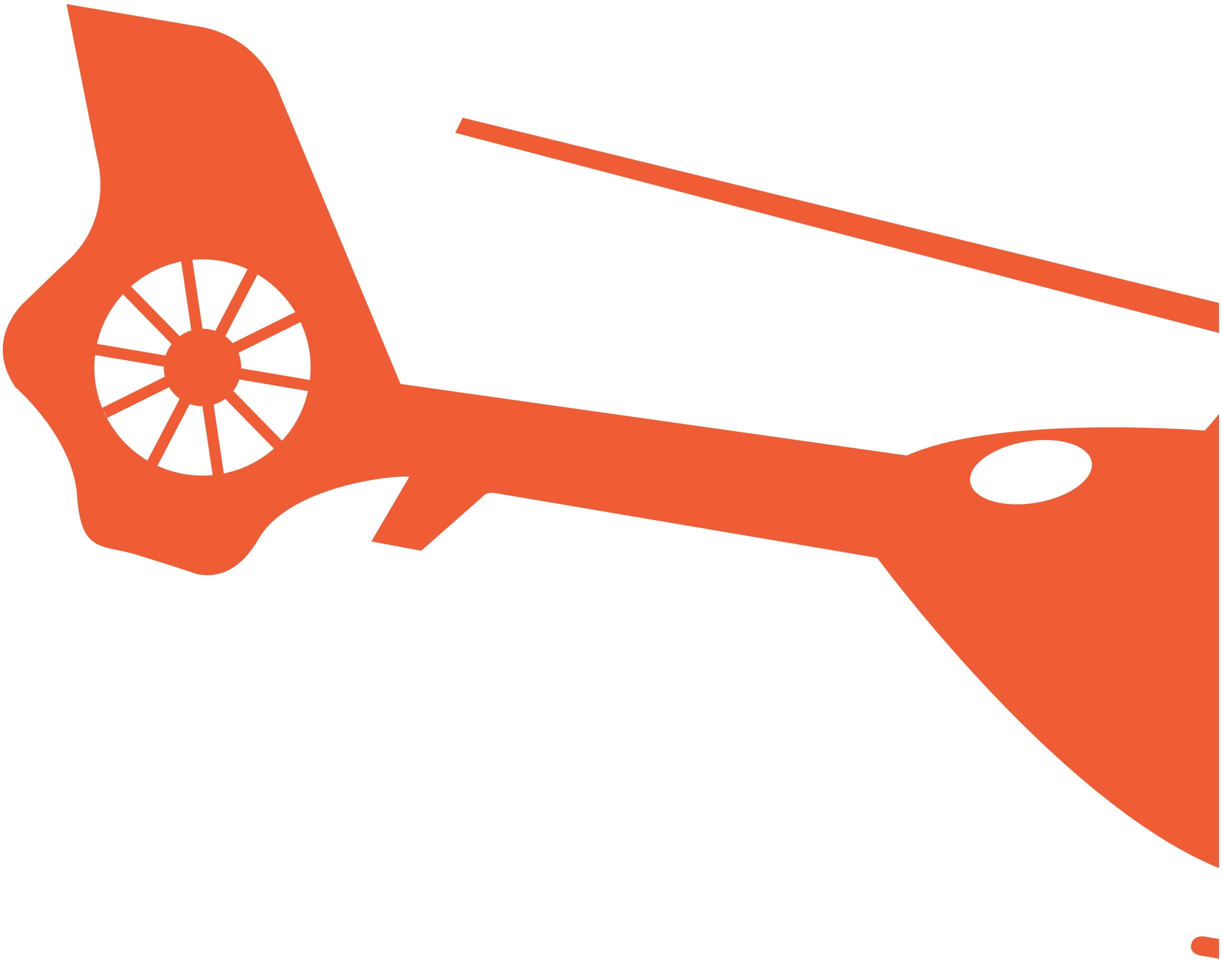

Peters JH, van Wageningen B, Hoogerwerf N, Tan ECTH.

Prehospital and Disaster Medicine 2017; 32(4): 1-5

CHAPTER 10

DISABILITY

A new promising technique to quantify Traumatic Brain Injury in prehospital setting

ABSTRACT

Introduction:

Early identification of traumatic brain injury (TBI) is essential. Near-infrared spectroscopy (NIRS) can be used in prehospital settings for noninvasive monitoring and the diagnosis of patients who may require surgical intervention.

Methods:

The handheld NIRS Infrascanner uses eight symmetrical scan points to detect intracranial bleeding. We tested the scanner in our physician-staffed helicopter emergency medical service. The results were compared with those obtained using in-hospital computed tomography (CT) scans. Scan time, ease of use and change in treatment were scored.

Results:

A total of 25 patients were included. Complete scans were performed in 60% of patients. In 15 patients, the scan was abnormal, and in one patient, the scan resulted in a treatment change. Compared with the results of CT scanning, the Infrascanner obtained a sensitivity of 85.7%% and a specificity of 72.7%.

Discussion:

In our setting, most patients had severe TBIs with an indication for transport to a trauma centre prior to scanning. In one patient, the scan resulted in a treatment change. Evaluation of patients with less severe TBI is needed to support the usefulness of the Infrascanner as a prehospital triage tool.

Conclusion:

We obtained promising results using the Infrascan NIRS device in prehospital screenings for intracranial haematomas in TBI patients and found high sensitivity and good specificity. Further research in necessary to determine the beneficial effects of enhanced prehospital screening on triage, survival and quality of life in TBI patients.

INTRODUCTION

Worldwide, trauma is one of the leading causes of death, disability and healthcare costs [1 2]. In particular, trauma resulting in traumatic brain injury (TBI) is a major burden for society [1]. Early identification of TBI is essential. In addition to optimizing treatment strategies, immediate transport to an appropriate-level trauma centre with neurosurgical intervention options improves the outcome for TBI patients [3-5].

In patients with low Glasgow Coma Scores (GCS), the decision to transport to a level 1 trauma centre is evident. However, this decision is less clear when patients have a temporarily lower GCS, post-traumatic amnesia or are intoxicated. Adequate patient selection is important but difficult when using only clinical parameters. For instance, a patient with an expanding epidural haematoma may initially present with mild complaints, but this condition can change rapidly. Prehospital on-site cerebral scanning for a haematoma could optimize patient triage, allow the initiation of brain-preserving resuscitation and potentially improve the outcome for TBI patients.

Near-infrared spectroscopy (NIRS) is a technique that uses the reflection of light to detect fluid/haemoglobin presence near the brain. NIRS has been described as a promising “work in progress” when used for noninvasive cerebral tissue monitoring [6]. Near-infrared is the term used to define light with a wavelength of approximately 600 to 1,000 nm. In this range, tissues are relatively translucent because of the low absorption of the waves. The amount of absorption of this energy is used to determine the tissue or fluid type because these light waves are able to penetrate several centimetres into tissues, including bone. Using this measurement, NIRS can be used for noninvasive monitoring and diagnosing. When comparing the reflection patterns on both sides of the patient’s skull, an asymmetrical reading can indicate a subdural, epidural or extra-cranial haematoma [7].

The purpose of this methodological clinical study was to evaluate the practical use of the NIRS Infrascanner device in the prehospital on-site screening of patients suspected of having a TBI. This screening was conducted by members of our physician-staffed helicopter emergency medical service (HEMS).

PATIENTS AND METHODS

The Infrascanner Model 2000 (InfraScan Inc. Philadelphia USA) is a handheld NIRS apparatus (Picture 1). A precursor of this device was developed with the support of the United States Navy's Office of Naval Research and the US Marine Corpsand has FDA clearance [8 9], which was obtained after clinical testing and validation in a large, double-blinded, multicentre trial [10]. The Infrascanner was used in TBI patients prior to computed tomography (CT) scans of the brain, which represent the gold standard for detecting intracerebral haematomas. In 365 patients, a sensitivity of 88% and a specificity of 91% were demonstrated for haematomas larger than 3.5 cc in volume and less than 2.5 cm from the surface [10]. Other studies of smaller patient groups and of children confirmed the usefulness of the Infrascanner in detecting TBIs [11-14].

Picture 1: The Infrascanner Model 2000

To perform an Infrascanner examination, eight symmetrical points (bilateral frontal, temporal, parietal and occipital) on the patient's head must be scanned (Picture 2). The measured data are presented on a screen, and an abnormal reading in comparison with the contralateral side is presented in red.

Picture 2: Use of the Infrascanner

After approval of the local ethical committee, we started a feasibility study with an Infrascanner 2000 in our HEMS. In the Netherlands, 4 HEMS function as an adjunct to paramedic ambulance services. Our regional HEMS is located in the south-eastern part of the Netherlands; this service targets approximately 1/5 of the Netherlands and approximately 4 million inhabitants and is available according to dispatch guidelines. The Nijmegen HEMS operates 24/7 using night vision goggles and receives more than 2,000 dispatches annually.

Dutch paramedic ambulance services (with registered EMS nurses) work according to national EMS guidelines. These guidelines state that registered EMS nurses are not allowed to perform advanced prehospital treatment, such as rapid sequence induction using muscle relaxants, nor are they trained to perform thoracostomies for penetrating thoracic trauma. For these interventions in severely injured patients, the physician-staffed HEMS provides additional on-site knowledge and treatment options.

HEMS physicians (n=8) were adequately trained and familiarized with the scanner prior to its operational use, by a salesman in cooperation with an author of the manuscript (ET). We scanned patients with suspected neurocranial traumas, including patients with normal and diminished GCS. Hospital CT scan results were available and were compared with the Infrascan results.

Data were collected using our dispatch database combined with a questionnaire regarding ease of use and satisfaction with the scanner. In this questionnaire, the HEMS physician scored the scan time, scan results and ease of use on a 0-10 scale. It was recorded if the scan results led to a change in treatment or hospital choice.
Data were collected and analysed using Microsoft Office Excel 2007. Data are presented as medians with ranges.

RESULTS

A total of 25 patients were included in the study, most of whom were male (n=15) (60%). The median age was 54 years (range 7-79 years). Three children, aged 7, 10 and 11 years were scanned. The reasons for dispatch included road traffic accidents, n=9 (36%), lowered consciousness from other causes, n=9 (36%), falls from heights, n=6 (24%) and blunt trauma to the head, n=1 (4%). The average GCS at the time of the scan was 6.9 (median 3).

In six cases, the scanner was used prior to transporting the patient to the hospital. The other patients (n=19) were scanned during transport to the hospital. The median scan time was 4 minutes (range 1.5-10 minutes).

HEMS physicians scored a median ease-of-use of 7 (range 3-8). Comments from the users were often related to the difficulty in scanning the dorsal side of the head with the patient in the supine position and to the screen not being visible while scanning. In addition, the Infrascanner produces a sound when the scanning is complete; in a noisy environment, it can be difficult to obtain auditory feedback from the device.

A complete scan, containing all eight scan locations, was conducted in 15 patients (60%). In the other 10 patients, complete scanning of the dorsal occipital site was not possible because of accessibility. These patients were immobilized on a long spine board with head blocks, and because of a suspected cervical spine injury, head manipulation was not conducted.

The Infrascan results were normal in 10 patients. In 15 patients, the device displayed abnormal results. In one patient, the abnormal scan resulted in an addition to the initial treatment: hypertonic saline (10%) for brain preservation. No patients were transported to a hospital other than the location initially planned because of the Infrascan results.

In the accepting hospitals, a CT scan was performed on all patients, and 11 showed no intracranial bleeding. In 14 patients, the CT scan of the brain showed intracranial bleeding. In five cases, the Infrascan results did not match those of the CT scan. There were three false positive results and two false negative results of the Infrascan.

In the patients younger than 16 years of age (n=3), one false positive result occurred; the other two measurements were adequate. (Table1)

Patient Number	Sex	Age	GCS	Complete Infrascan	Infrascan abnormal	CT scan abnormal	Infrascan matches CT
1	M	59	3	1	0	0	1
2	M	79	3	0	1	1	1
3	F	54	3	0	1	1	1
4	M	38	14	0	0	0	1
5	V	10	10	1	1	0	0
6	M	7	3	1	0	0	1
7	M	65	15	0	0	0	1
8	M	37	15	0	0	0	1
9	V	53	3	1	1	1	1
10	V	55	3	0	1	0	0
11	M	66	11	0	0	1	0
12	M	11	3	0	1	1	1
13	V	34	3	0	0	0	1
14	V	65	3	1	1	1	1
15	V	65	3	1	1	1	1
16	M	73	3	1	0	1	0
17	F	44	15	1	0	0	1
18	M	55	10	1	1	1	1
19	M	74	15	1	1	1	1
20	M	44	3	1	1	0	0
21	M	51	3	1	1	1	1
22	F	67	12	0	1	1	1
23	M	52	3	1	1	1	1
24	M	65	3	1	1	1	1
25	F	44	11	1	0	0	1

Table 1: Patient characteristics and results. (Data for patients <16 years of age are highlighted)

The sensitivity of the Infrascanner in our cohort was 85.7%, with a specificity of 72.7%. When the children were excluded the sensitivity was 84.6% and the specificity increased to 77.8%.

D

DISCUSSION

Early detection and quick, appropriate treatment are essential to prevent secondary damage and optimize initial treatment in patients with TBI. This approach includes patient triage and transport to a trauma centre with adequate neurosurgical intervention options. However, such triage can be challenging, and early detection of intracerebral bleeding may be facilitated with new NIRS devices such as the Infrascanner. Because this device is relatively new in Europe, we present the results of an initial cohort of 25 patients scanned on-site in prehospital settings by our physician-staffed HEMS.

Study Limitations

During this research period, many more TBI patients were treated, although the attending HEMS physician had to take the time to perform the investigation. Often, this time was not available or was needed for other vital treatments. If the patient already had an indication to be transported to a level 1 trauma centre, the added value of NIRS scanning for triage was limited in the opinion of the physicians. The decision against performing an Infrascan examination in these cases was not investigated in this study.

In this study, we have a selection bias because of under-screening for the most severely injured patients, and not all consecutive TBI patients were scanned. In further research, all patients who are eligible for scanning and can be included for study must be evaluated.

No patient follow-up is presented in this study. In this pilot study, we aimed to test the Infrascan in a prehospital setting and compare the data to the first hospital CT scan to assess its practical use.

Feasibility / usability

There is a learning curve for using the Infrascanner properly, especially in how to scan in the prehospital setting. Scanning a patient takes time, and this is sometimes not available because of other vital priorities. The median scan time was 4 minutes (range 1.5-10 minutes). Using this time is defendable when it does not delay vital interventions (such as during transport). Most of the patients (76%) were scanned after initial treatment and stabilization while being transported to the hospital. In these cases, the decision had already been made to transfer the patient to a level 1 trauma centre because of a low GCS, trauma mechanism or associated injuries. The average GCS at scanning was 3. The high incidence of severe TBI in this cohort makes is difficult to draw conclusions regarding the use of the NIRS device as a triage tool in suspected TBI patients. More and less severely injured patients are needed to evaluate this topic and to determine the value of this tool in triage.

Our study also scored the ease of use of the Infrascanner; the median score was 7. The observations regarding auditory device feedback and screen/button location will be shared with the manufacturer. If possible, customizing the Infrascanner for noisy prehospital environments may enhance future user satisfaction.

Because many of our patients had possible cervical spine injuries that limited access to the dorsal scan zones, we only obtained a complete scan of the brain in 60% of patients. Even with this high number of incomplete scans, we were able to achieve a sensitivity for intracerebral haematomas of 85.7%% in the entire cohort.

One patient had a normal Infrascan result but had a small subarachnoid haemorrhage with a volume that was likely below the detection level of the Infrascanner. As indicated previously, a minimal amount of blood must be present to be detectable, which we assumed to be more than 3.5 ml and in the first 2.5 cm from the surface of the brain [10]. The larger the area of bleeding is, the more clinically significant it will be. The goal of prehospital scanning is not to detect all minimal haematomas, but to triage patients who eventually need to be transported to a hospital with neurosurgical facilities. Further research is needed to evaluate the detection threshold in relation to clinical intervention.

The obtained sensitivity of 85.7% is comparable with the data published by Robertson et al. (88%). Our specificity, at 72.7%, was lower than that previously described in the hospital setting (91%) [10]. This result may have been because we encountered more extensive bleeding, well exceeding the detection threshold mark, which may have increased the number of detections. The relatively large number of false positive results might have been caused by the scanning circumstances. An abnormal NIRS scan result should be verified with a second scan to confirm the reading. In our cohort, this was not performed due to the lack of time. Adding a second NIRS scan could further improve the specificity.

In 76% of the cases, patients were scanned while driving at high speeds in ambulances or during helicopter flight. As mentioned before, the back/dorsal side of the patients was frequently not accessible because of the necessity for cervical spine immobilization, which led to a high number of patients with incomplete scans (40%). This limitation distorted the measurements and may have led to a higher number of false-positive scanning results.

In our opinion, HEMS patients with severe TBI are not the patients who will benefit most from prehospital screening with the Infrascanner. These patients need to go to a centre with the highest level of care available, regardless of the scan results. Ambulance services could benefit even more from the NIRS. Further research must focus on the less severely injured patients, who do have an obligatory reason for referral to a Level 1 trauma centre, to optimize patient triage and prevent transport delay.

In hospitals, the CT scan is and will remain the gold standard in haematoma screening in TBI patients for the foreseeable future. However, CT scans use potentially harmful radiation and must therefore be used with caution and only with valid indications, especially in children [15-17]. Thus, alternative algorithms and a step-up approach in cranial screening of TBIs, possibly using NIRS, may be preferable [12].

Further research regarding cost, time management, triage, patient survival and quality of life is required to determine the prehospital role of NIRS.

CONCLUSION

This study obtained promising results using the Infrascan NIRS device in the prehospital screening for intracranial haematomas in TBI patients and found high sensitivity and good specificity. However, further research in necessary to determine the beneficial effects of enhanced prehospital screening on triage, survival and quality of life in TBI patients.

CONTRIBUTORSHIP STATEMENT

ET and JP designed the study, and wrote the draft of the article. JP, BvW, NH and ET conducted the scans and collected the data used in this article. BvW and NH supported by commenting to article draft and helped with data interpretation. All listed authors made critical contributions to this article regarding its structure and conclusions and provided advice for revising the manuscript. JP submitted the article.

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COMPETING INTERESTS

None of the authors had competing interests in relation to this study.

DISCLAIMER

A portion of this article was previously published in Dutch [18]. Permission to publish these data was granted by the publisher.

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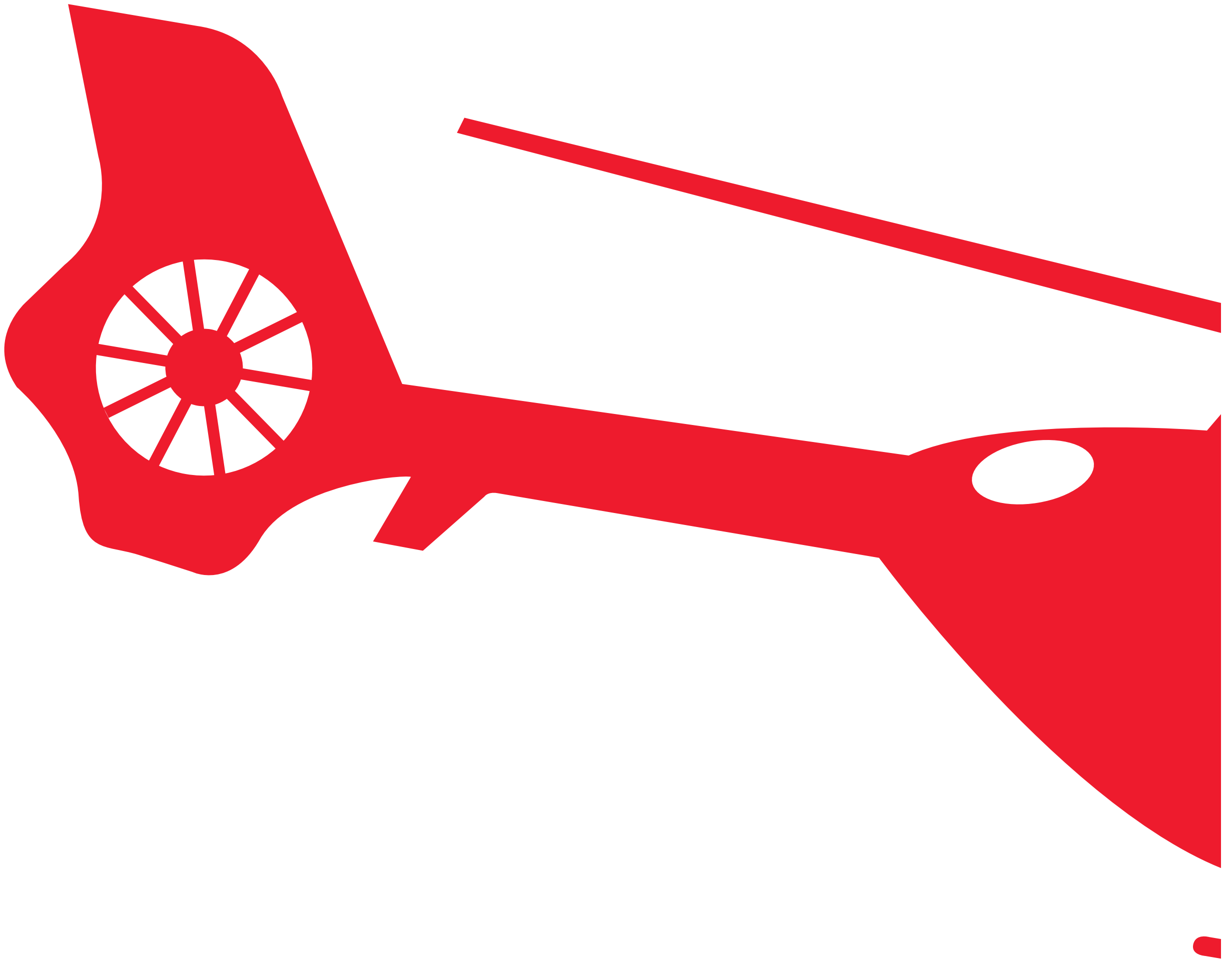

Peters JH, Beekers C, Eijk R, Edwards MJR, Hoogerwerf N.

Air Medical Journal 2014 May-Jun; 33(3): 112-114

CHAPTER 11

EXPOSURE/ENVIRONMENT

Evaluation of Dutch HEMS in transporting children

ABSTRACT

Background:
In the Netherlands Helicopter Emergency Medical Services (HEMS) function as adjunct to paramedic ambulance service delivering hospital-level medical care to a prehospital location. The main goal of Dutch HEMS is to provide on scene medical expertise not primarily to serve as transport. Transportation of patients to specialized hospitals is sometimes mandatory especially in cases of critically ill or wounded children. In literature no support can be found to support the safety of transportation by helicopter.
We retrospectively evaluated the safety of this type of transportation and if any problems were encountered transporting children by helicopter.

Methods:
We reviewed our local HEMS database for all children (<16 years) transported by helicopter to a level 1 trauma center between January 2007 and December 2012.

Results:
A total number of 430 patients were transported by helicopter to a hospital (0-87 years, mean 31.6). Of these patients 83 (19%) were younger than 16 years (0-15.7 years, mean 6.6). Causes for HEMS transport in children varied but main groups were road traffic accidents (40%), cardiopulmonary arrests (15%), falls from height (12%) and horse riding accidents (7%). In the children group one accidental extubation of the orotracheal tube was noted while lifting the patient (10 years old) into the helicopter. This was immediately noticed and the patient was reintubated without complications. No further adverse events were encountered during transportation time.

Discussion:
The accidental extubation is not a specific complication of helicopter transportation but is inextricably linked with moving severely injured and intubated patients/children.

Conclusion:
We conclude that transporting children by helicopter is a safe method of transportation for critically ill children to adequately equipped medical centers.

BACKGROUND

In the Netherlands Helicopter Emergency Medical Services (HEMS) function as adjunct to paramedic ambulance services. Dutch HEMS consists of an experienced flight nurse and physician capable of delivering hospital level medical care at a prehospital location. This includes advanced airway management, rapid sequence induction (RSI), chest tube placement and fracture stabilization. HEMS is available at a 24/7 base for both trauma and non-trauma cases according to dispatch guidelines. The main goal of Dutch HEMS is to provide rapid medical treatment, not primarily patient transportation. [1, 2] Transportation of patients to specialized hospitals is sometimes mandatory especially in cases of critically ill or wounded children. [3, 4] The care for children in the prehospital setting is difficult and demanding because of a relative low incidence, limited physiological reserves and the need for specialized therapeutic interventions. [5, 6] Most hospitals in The Netherlands lack this experience as it is only available in few of the level 1 trauma centers. In the Dutch setting, helicopter transportation from an accident scene to a hospital is twice as fast as compared to ground transportation, independent of trauma mechanism, distance to the hospital or weather conditions. [7]

Transportation of critically ill children can be conducted more safely with a specialized transport team trained in pediatric transport medicine.[8] However, due to the restricted space inside the helicopter medical treatment during a helicopter flight is limited. According to flight regulations safety belts must be used during all phases of the flight. This restricts the possibility for the HEMS physician to perform medical interventions. The HEMS nurse has to perform technical flight tasks and is therefore unable to provide medical support during the flight.

We hypothesize that helicopter transportation is safe and useful in transporting children to hospitals. To our knowledge there is no report in the literature to confirm or reject our hypotheses. Therefore we conducted an evaluation of this form of transport in the Dutch HEMS setting.

METHODS

We studied the HEMS database, from the Radboud University Nijmegen Medical Center in the Netherlands. The Nijmegen HEMS is a 24/7 operation ready to be dispatched covering 10,088 square kilometers in the eastern part of the Netherlands with a population of 4.5 million inhabitants. Approximately 19.5 % of the population in this area is under 16 years of age. HEMS is called by Emergency Medical Services (EMS) dispatch centre (primary call) or by EMS at accident locations (secondary call). In primary calls Dutch HEMS is called on specific injury mechanisms or suspected injuries including compromised vital signs. HEMS is also deployed in non-trauma cases. [6] If weather or technical factors do not permit helicopter deployment a rapid response vehicle is available to transport the team. These transports were excluded.

HEMS physicians (either an anesthesiologist or a trauma surgeon) have received extensive additional training in adult and pediatric emergency care, pain, airway management and extrications techniques. HEMS physicians are authorized to perform medical interventions that EMS paramedics are not allowed to perform by Dutch law. HEMS nurses are experienced EMS paramedics receiving additional training in navigation and form the helicopter flight crew together with the pilot.

All essential data derived from all dispatches were collected prospectively in a cohort study. Parameters collected were an indication for dispatch, demographic data and vital parameters prior to and after transportation. Adverse events or changes in vital parameters were also noted in this dispatch database.

RESULTS

From January 1, 2007 - December 31, 2012 a total of 430 patients were transported by HEMS helicopter to a level 1 trauma center. Eighty three (19%) of these were younger than 16 years of age at time of transportation (mean 6.6 years, range 0-15.7). No patients receiving cardiopulmonary resuscitation (CPR) were transported to a hospital by HEMS helicopter. All children were endotracheal intubated prior to air transportation.
The main group of children that needed HEMS treatment and transport were involved in motor vehicle accidents (40%). Twelve children had a cardiopulmonary arrest prior to helicopter transportation (15%) all with return of spontaneous circulation before the flight to the hospital. The third group (12%) were children treated because of falls from height. All causes of HEMS deployment and following transportation are listed in table 1.

Reasons for HEMS deployment/transport	Number of patients	Percent
Motor vehicle accidents (incl. pedestrians)	33	39.8
Cardiopulmonary arrest	12	14.5
Fall from height	10	12.0
Horse related accidents	6	7.2
Submersion	4	4.8
Transportation between hospitals	4	4.8
Trapped/mangled extremities	4	4.8
Extensive burns	3	3.6
Seizures/convulsions	2	2.4
Septic	2	2.4
Critically ill newborns	2	2.4
Object on head	1	1.2
Total	83	100%

Table 1: Reasons for HEMS deployment and helicopter transports.

During HEMS transports no cardiac arrest or pulmonary problems were encountered. In one case an accidental extubation was noted while lifting the patient (10 years old) into the helicopter. This was immediately corrected by reintubation. No clinical deterioration was noted during this event. No tension pneumothorax arised during flight due to mechanical ventilation.

DISCUSSION

Transporting critically ill children may cause specific problems and requires special training and skills in order to increase quality and lower the possibility of transportation related problems. [3, 4] In our setting we transported children with spontaneous circulation only. When in need for CPR ground transportation was chosen. Because of an increased working space, more manpower, and the opportunity to intervene.

Our HEMS only transported children after sedation and endotracheal intubation. This reduces the risk of in-flight problems such as loss of a patent airway, nausea, vomiting, anxiety and fear. Obtaining an endotracheal airway while flying in the HEMS helicopter is difficult to perform due to suboptimal conditions. Therefore a preflight selection on scene is performed to triage which patient may benefit from helicopter transportation. This considering the risks associated with this type of transportation. Time and distance to a specialized hospital capable of delivering adequate care for this patient group must also be taken into account. No strict protocols or guidelines exist for our HEMS crew to decide when to fly or when to drive. [7] Factors as previously mentioned must be taken in consideration before transporting critically ill patients especially in the vulnerable group of children.

One unpredicted and unwanted event was reported during the 83 pediatric transports. The accidental extubation did not cause any significant clinical problems and was quickly corrected by reintubation. The potential for extubation remains a point of extreme caution while transporting children. The extubation happened while lifting a ten year old patient in the helicopter. This procedure equals the movement of a mechanically ventilated patient inside an ambulance. We therefore concluded that this is not a complication related to helicopter transportation but to the general transport process.

CONCLUSIONS

After reviewing all children transported by Nijmegen HEMS we conclude that transporting children by helicopter to adequately equipped medical centers is safe. Furthermore we would like to stress the importance of transport related problems such as the possibility of extubation. Especially in children.

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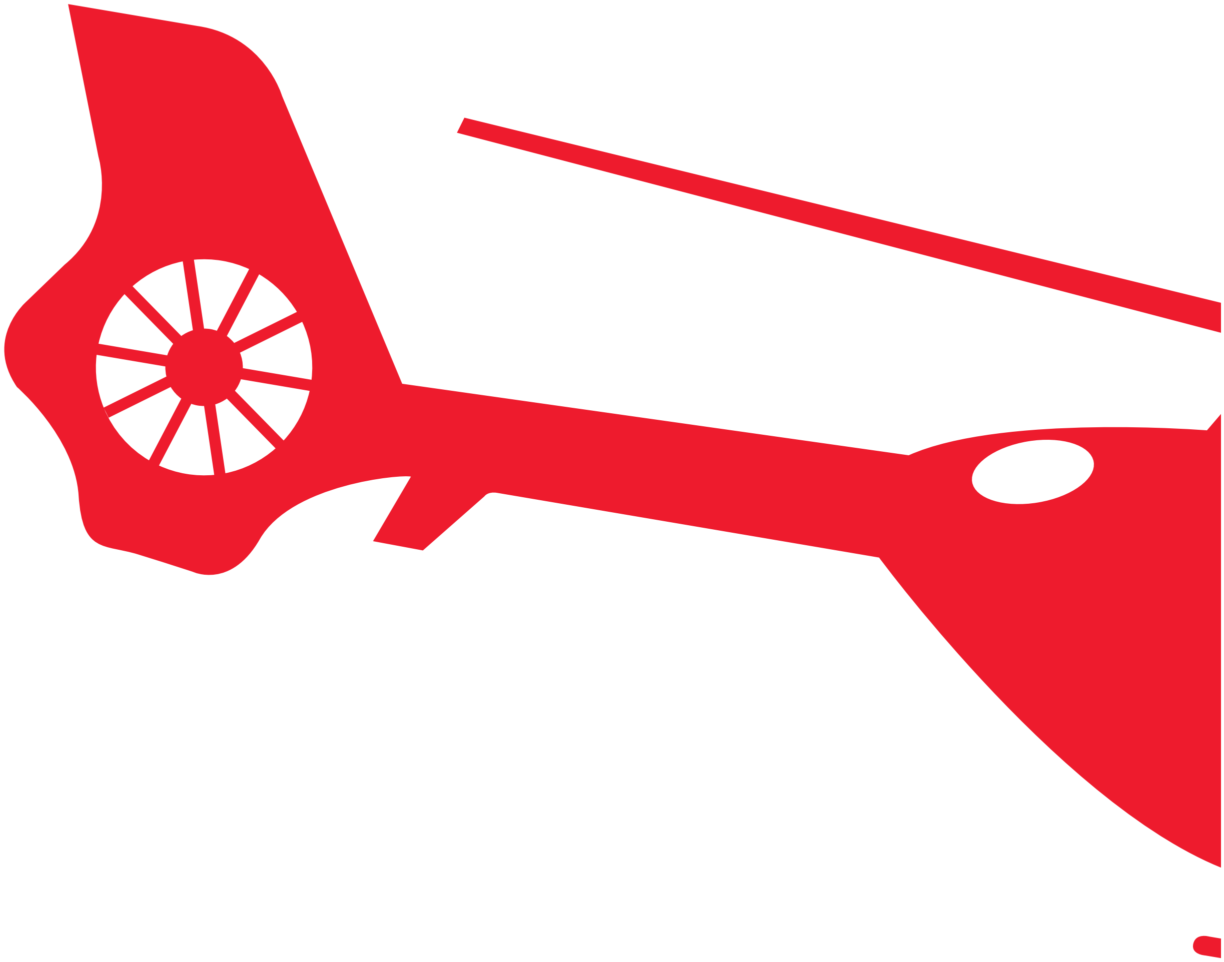

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CHAPTER 12

EXPOSURE/ENVIRONMENT

Helicopter Emergency Medical Service patient transport at night – safe and useful?

ABSTRACT

Introduction:

Dutch helicopter emergency medical services (HEMS) are available 24/7, so also during night times. Working without daylight brings additional challenges; both in patient care and in flight operation. We retrospectively evaluated the safety of this nighttime helicopter transportation of patients.

Methods:

Our HEMS database was reviewed for all patients transported by helicopter during nighttime. Both inter-hospital transports and patients transported from accident location to a hospital were included. The time travelled by helicopter was compared with time that road transportation of these patient would have taken.

Results:

In total 513 patients were transported by helicopter. Of these patients 72 were transported during nighttime (14%), median age 25.3 years (range 1.1-73.9). Median flight time to the hospital was 16 minutes (range 5-42). To travel by road this would have taken a median of approximately 44 minutes (range 23 – 100 minutes). When comparing these travel times a significant faster transport by helicopter during night times was seen ($p<0.001$). Three non flight specific incidents were noted.

Conclusion:

We conclude that helicopter transportation of patients without daylight is safe and fast in Dutch setting.

INTRODUCTION

In the Netherlands four helicopter emergency medical services (HEMS) function as an adjunct to paramedic ambulance services. Dutch HEMS are physician staffed and available according to dispatch guidelines for both trauma and nontrauma cases. The main goal of Dutch HEMS is to provide medical treatment on scene.[1, 2] Transportation times are usually short by ground transport but the transportation of patients to specialized hospitals that are at further distance is sometimes mandatory, for instance in critically ill or wounded children or in patients with severe burns.[3-5]

Since 2006 Nijmegen HEMS, operating in the eastern part of the Netherlands, has expanded its helicopter-based work from a daytime operation to a full 24/7 service. Medical treatment in night operation matched daytime, but night flight distances and time were slightly prolonged.[1]

Apart from hardware changes required in the helicopter itself, the character of the work changed as well. Obviously, working at night and transporting patients by helicopter in the dark brings additional challenges like working with limited visibility. For instance finding the needed gear, read the amount of oxygen left in the cylinder and prepare medication for administration.

Aviation rules and regulations are more strict after sunset regarding landing zones and for HEMS crew skills. For instance the HEMS nurse, who is also the navigator as part of the flight crew, is not allowed to perform additional medical tasks while flying at night under HEMS conditions. If a patients is transported by helicopter at night the HEMS physician has to perform all medical tasks without support from the nurse. This in contrast to road transport by ambulance in which there are always two persons available to perform medical procedures.

The lack of visibility may also lead to more difficult interpretation of physical signs and symptoms during transport in a helicopter.

For night flights night vision goggles (NVG) are used by both crew members to enhance vision. On the other hand the use of NVG may lead to disorientation, physical complaints and hardware interaction problems which may cause safety issues. [6-8]

Since 2006 Dutch HEMS operations are conducted 24/7. We hypothesized that helicopter transportation is safe and useful during night, but to our knowledge no literature is available to support our hypothesis. We therefore conducted an evaluation of night transportation in Dutch HEMS by reviewing all patients transported by air.

PATIENTS AND METHODS

We reviewed the HEMS database from the Radboud University medical Center in the Netherlands. This database contains essential information from all HEMS dispatches. We selected all patients transported by helicopter to a hospital. Both inter-hospital transports and patients transported from accident location to a hospital were included. We selected the following data from the database: patient characteristics, vital parameters, time of deployment, reason for deployment, flight characteristics, treatment and flight related adjuncts, designated hospital, and complications during transport. Night transport was defined as the transportation of a patients by helicopter when at least part of the transport was performed after sunset according to a daylight calendar for our location.[9]

Road travel times for the distance from accident location to hospital were calculated using accident and hospital postal codes in an online version of Google maps.[10]

Data were analyzed using SPSS (IBM, SPSS version 20) using the Wilcoxon signed-rank test for related samples.

RESULTS

From January 2007 till December 2013 a total of 513 patients were transported by helicopter (49 females, 464 males; median age 33.3 years, range 0-87.1). Of these patients 72 were transported during nighttime (14%). This were 16 females and 56 males, median age 25.3 years (range 1.1-73.9). Ten of the night transported patients were under the age of 16 at time of transport (14%, median age 5.1 years).

Three patients (4%) were transported without tracheal intubation. These patients all had maximal Glasgow coma scores (GCS). In two patients there was a suspected spinal injury, one had a lower leg fracture . Two of these patients were transported by helicopter because of the remote accident location not reachable for road vehicles. All other patients were sedated and mechanical ventilated prior to helicopter transport (n=69).

All the transported patients had spontaneous circulation during the flight to the hospital. Three patients sustained a cardiopulmonary arrest prior to flight and were successfully treated with cardiac advanced life support.

Three patients were transported at night by helicopter from a hospital with lower level of care to a level 1 trauma center, after initial stabilization. One patient was transported from an intensive care to a higher level intensive care. In the Netherlands these sort of transports are done by a ground mobile intensive care unit (MICU). In this case this no MICU was available within acceptable amount of time.

Median flight time to the hospital was 16 minutes (range 5-42). One accident location was not clearly defined in the database. This particular flight was excluded from analysis. Comparative road travel distances for the night transport flights were between 22 and 147 kilometers (n=71, median 59). To travel by road this would have taken a median of 44 minutes (range 23 – 100 minutes). When comparing these travel times a significant faster transport by helicopter during night times was seen ($p<0.001$).

During night flight three incidents were noted. Two were related to the on board mechanical ventilator. In one case there was a problem with the amount of oxygen in the ventilation mixture. In the other case there was a ventilator pressure related problem. Both problems did not lead to oxygenation/ventilation problems in these patients. They were classified as a ventilator hardware related problems and not linked to the HEMS procedure.

Another incident occurred in a patients who had a tachyarrhythmia in-flight. This relapsed spontaneously, without the need for intervention or medication. The incident was also interpreted as not related to the helicopter transportation.

There were no reports of flight related safety issues regarding the NVG or the helicopter operation.

DISCUSSION

After starting a 24/7 HEMS operation the possibility to transport a patients at night by helicopter to a well equipped hospital seemed possible and feasible. Safe HEMS operation depends on continuous training, skill improvement and quality monitoring.[11]

We reviewed the patients transported at night by our HEMS. Patient characteristics, demographics and reasons for nightly HEMS procedures were equal to daylight operation.[1] All but three patients transported at night had tracheal intubation to secure the airway. This reduces the risk of in-flight problems such as the loss of a patent airway, nausea, vomiting, anxiety and fear. While flying in our type HEMS helicopter, obtaining a tracheal airway is difficult because of limited working space. To transport a patient without tracheal intubation, especially with limited light as in night operations, asks for a thorough preflight patients selection. The benefits of helicopter night transport for those patients must outweigh the additional risks of a possible loss of a secured airway. Only one patient was intubated to prevent in-flight problems with the airway and ventilation. This patient needed neurosurgical intervention. If this patient could have been transported by ambulance as fast as in the helicopter to a level 1 trauma center probably intubation was not yet performed. In this case tracheal intubation was performed to prevent further in-flight problems.

In our reviewed patients transported at night all patients had spontaneous circulation prior to take off. Although it may be possible to perform cardiopulmonary resuscitation while flying, the increased working space, manpower and intervention options make ground transportation more favorable in those cases. Triage of patients with a high probability of sustaining a circulatory arrest is necessary to prevent unwanted in-flight problems with loss of circulation. In those cases, for instance in patients with return of spontaneous circulation after a cardiopulmonary arrest, the risks of transport with possible suboptimal medical support must be considered.

Helicopter flight times at night to the hospital were significantly reduced compared to the calculated time needed to travel by ambulance. These times were calculated using software that calculates distances and travel times using postal codes. The times calculated with this tool were the driving times under normal conditions, and are not corrected for the increased speeds as result of using the emergency vehicle's *warning lights* and s*irens*. On the other hand these calculations doe not correct for delaying factors such as traffic lights, roadblocks and so on. So the actual time difference between helicopter and ambulance transport may be slightly different than in our calculation the exact amount of time needed is difficult to calculated and varies with numerous factors. Travel times presented here are the times from accident location to the hospital. The time that is necessary to install a patient in an ambulance or helicopter was not available. Although the HEMS team is skilled and efficient in loading and unloading a patient from the helicopter this takes some additional time in comparison with road ambulance transport.

There were three incidents during night flight, two were ventilator related and one with a tachyarrhythmia. In our opinion those incidents are not helicopter flight specific. In an ambulance the hardware or software of a ventilator device may also cause problems. The cardiac rhythm disturbance is also an event not linkable to the helicopter flight in an intubated and sedated patient.

CONCLUSION

After reviewing all patients transported by Nijmegen HEMS at night we conclude that this is a safe way of transportation. Good patients selection is essential and to minimize in-flight problems. The travel times are significantly reduced compared to road transportation by ambulance. This makes the helicopter useful for night transportation of patients.

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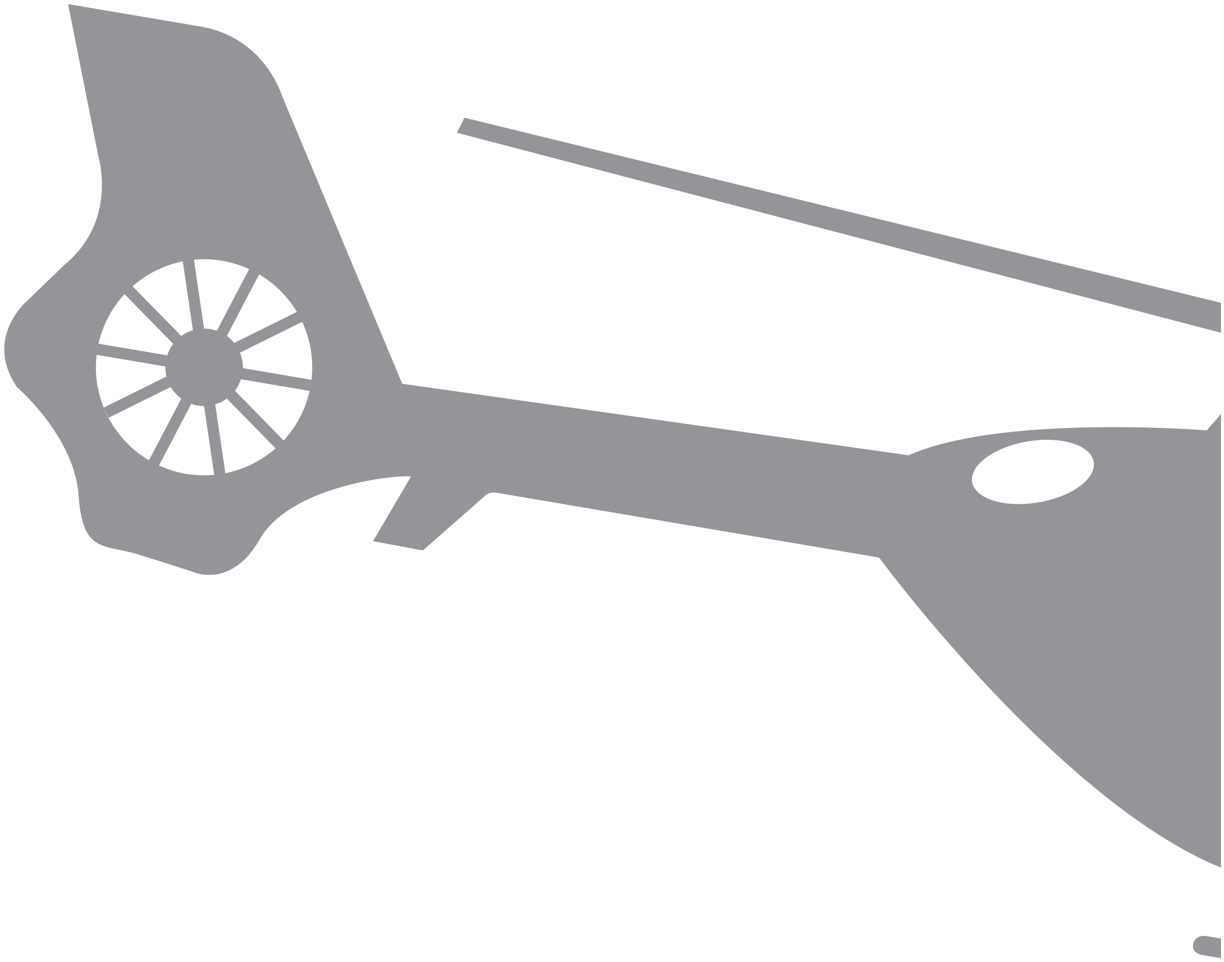

CHAPTER 13

Summary and general discussion

An optimal treatment of a vulnerable prehospital patient is essential to maximize the survival chance. Such vulnerable patients patients need the best care and expertise available. To improve knowledge and skills in the field, mobile medical teams were introduced in the Netherlands in the late 1980s of the last century. Initially, these teams used ground transportation. Later, in 1995 a helicopter was introduced to transport the teams to the dispatch location and the Dutch helicopter emergency medical services (HEMS) was a fact. Since 2001, Nijmegen HEMS supports ambulance services in providing care to the patients with compromised vital parameters.

In this summary the overview and conclusions of the different chapters of this thesis are described, arranged according to the “ABCDE” from the Advanced Trauma Life Support (ATLS) course.

A

One of the vital systems that most frequently needs intervention is a threatened airway. These patients most often require a secured airway using a endotracheal tube placed through the vocal cords, with an insufflated cuff distally. The prehospital patient is more difficult to intubate than a patient in the hospital environment, who has an empty stomach and therefore has a limited chance of aspiration. Hospital patients are supine on an (OR) table at a comfortable height and with sufficient light. This in contrast to the non-sober, trapped patient sitting half upright in a deformed car with bleeding facial lacerations etcetera. Limiting the number of attempts needed to secure the airway is essential to minimize the risks of aspiration and prevent a rise in intracranial pressure.[1, 2] Muscle relaxants are administered to facilitate intubation, prevent laryngeal spasms and reduce the risk of aspiration. Anesthetics are administered to prevent an increase in intracranial pressure and stress during this procedure. Dutch ambulance nurses are legally not allowed to administer pharmaceuticals with the intention to facilitate intubation, such as muscle relaxant drugs. In **chapter 2** results are presented evaluating the difference in first-pass intubation success rates, comparing the HEMS physician, the HEMS nurse and the ambulance nurses under comparable RSI circumstances. The number of intubation attempts until a secured airway is established is significantly lower in the HEMS physician cohort, reducing the risks, as described previously, in this vulnerable patient group. We can assume that the HEMS physician selected the patients that had a low risk of encountering a difficult airway for the ambulance nurse to intubate first. Therefore, the actual difference in first-pass intubation success rates could be even more pronounced when comparing physicians and ambulance nurses. The intubation skills of ambulance nurses vary and so does their exposure and training. It is difficult to draw a general conclusion for the whole group, but it is tempting to question the safety of endotracheal intubation by ambulance nurses using conventional laryngoscopes in the challenging prehospital setting. Video laryngoscopes have been introduced in some of the ambulance regions recently. The effect of these tools on first-pass and eventual intubation success rates needs to be determined. The use of these devices also needs adequate training and exposure. The introduction of "blind" (supraglottic) airway devices, such as laryngeal masks and laryngeal tubes, may be helpful as secondary option when endotracheal intubation fails. When experience is limited with endotracheal intubation, the laryngeal masks may be preferred as the primary airway device, limiting the risk of unsuccessful intubations. However, these devices may also cause additional tissue damage and swelling, especially when used by inexperienced healthcare providers, and do not prevent the risk of aspiration.

The eligibility of ambulance endotracheal intubation, in a setting with physician-staffed HEMS operations nationwide available on a 24/7 basis, needs to be determined. A nationwide registry of all airway interventions by all prehospital healthcare professionals could provide information that can be used to improve prehospital care.

When intubation fails and a patient cannot be ventilated and oxygenated adequately, an emergency surgical airway (ESA) may be necessary. In **chapter 3,** the results of this procedure, executed by a physician-staffed HEMS, are presented. The surgical airway is an infrequently performed but potentially lifesaving procedure. In a physician-based HEMS system, relatively low incidences of ESAs were reported in literature, compared with data from non-physician-based emergency services. Advanced airway management training and experience in both technical and non-technical skills possibly prevent the necessity of ESA. When an ESA was performed, in this cohort the success rate was high, indicating acceptable training and adequate technical skills.

When an endotracheal tube is placed, either through the oropharynx or through the cricoid membrane, the distal cuff provides the seal that secures the airway. It prevents the passage of saliva, vomit, blood or debris into the lower airways. It is essential, as described in detail in **chapter 4**, that the pressure inside the cuff is checked and adjusted if necessary. High cuff pressure may lead to mucosal ischemia and eventually tracheal stenosis or a tracheo-oesophageal fistula. In this chapter, data were presented from both HEMS and ambulance tubes. Initial pressures were almost all above what is considered safe, and were adjusted (lowered) after measuring. Cuff pressure measuring is an uncomplicated and expeditiously performed procedure. All healthcare professionals that perform endotracheal intubation must complete cuff pressure measurements. Therefore cuff pressure manometers should be available in every HEMS helicopter, all emergency departments, operation rooms and in every ambulance.

Patients can suffer traumatic cardiac arrest (tCA) as the result of a reversible cause. The basic algorithms used in non-trauma cardiac arrest, as taught in advanced cardiac life-support courses, do not focus on the specific causes of arrest in trauma patients. More targeted approaches in tCA have been recently suggested using the acronym HOTT. The potentially reversible causes of the traumatic cardiac arrest were evaluated and, if necessary, treated according to HOTT: Hypovolemia, Oxygenation, Tension pneumothorax and Tamponade.[3] In **chapter 5,** the focus is on TP as a possible cause of tCA. TP can be excluded as a cause of tCA when a resuscitative bilateral thoracostomy is performed. The patient cohort presented had poor outcomes despite decompression of the thorax, with a 10% incidence of TP. Further research is needed to determine the role of resuscitative thoracostomies in comparison with less invasive procedures such as needle thoracocentesis. In recent years, new devices have been introduced for the treatment of TP such as the ARS™ needle and the ThoraQuick Chest Decompression Device. A comparative study using these tools in tCA is required to determine the role for these devices in the optimal treatment strategy. In the treatment of patients with tCA, prompt, focused action is necessary. The implementation of an algorithm for the treatment of tCA patients, including TP treatment with thoracic drainage, may prevent thoracostomies being the last-resort therapy. This algorithm could thereby possibly increase the chance of a return of spontaneous circulation (ROSC) and survival.

C

Blood loss leads to hypothermia, acidosis, coagulopathy and an increased risk of mortality. One of the easiest method of bleeding control is the application of external pressure, for instance by using fingers or bandages. Conventional bandages are not always sufficient, particularly concerning major arterial bleeding. New bandages have recently been developed and implemented in prehospital trauma care. Chitosan-based hemostatic bandages were successful in obtaining bleeding control in a cohort of 24 patients, as described in **chapter 6.** This promising result needs to be evaluated in a comparative study using conventional bandages as a control group. The additional costs of the hemostatic bandages must be compared with the effect of this treatment in relation to the costs of possible prevented blood suppletion, interventions, morbidity and survival. Other types of haemostatic bandages, for instance using kaolin or topical thrombin, can also be used in a future prehospital comparative study.

Innovations are mandatory in limit the amount of patients that die from exsanguination. Lacerations, in particular scalp wounds, are a major source of blood loss and need urgent attention. A hemostatic device called the iTClamp is presented in **chapter 7**. With the use of this clamp, wounds can be approximated within seconds in order to limit ongoing bleeding. The first results of the iTClamp in HEMS operations were promising, with 90% bleeding control and positive user satisfaction. The role of the iTClamp in (pre)hospital blood-loss control needs to be subject to further investigation. This may indicate which patient group benefits most from the clamp and provide answers regarding the costs, necessity and efficiency of this new hemostatic device.

In specific cases of severe blood loss, the application of bandages or clamps is not sufficient to obtain hemostasis; for instance, when the bleeding focus is located inside the patient as in multiple fractures, pelvic ring disruptions or in patients with solid organ ruptures. Techniques such as traction splinting, the use of tourniquets and pelvic binding can be helpful in these cases.[4] However, if the amount of blood loss is too severe and time must be gained for the extraction and transportation of the patient, blood can be administered on scene. In **chapter 8,** a multicenter cohort of patients was presented, that received *uncross matched packed* red blood cells (URBC) in a prehospital setting. These transfusions were based on clinical decisions made by the HEMS physician, according to guidelines. Two Dutch HEMS teams provided their data for analysis. By matching these patients to a historic cohort with comparable vital parameters and shock classes, the effect of these transfusions on resuscitation was evaluated. No effect on short- or long-term survival could be demonstrated in this cohort. The prehospital administration of red blood cells was proven to be safe in this cohort.

Patients with a cardiac arrest after a penetrating thoracic trauma can potentially be saved by a prompt on-scene thoracotomy to obtain bleeding control. The majority of Dutch HEMS physicians are trained to perform this procedure. The first results of this intervention, in a prehospital setting, were presented in **chapter 9**. One long-term survivor was reported in this cohort (n=33). ROSC was achieved in 27%. The presented cohort was heterogeneous, including both gunshot injuries and knife wounds. The cohort of knife wounds had a higher incidence of ROSC (39%). Further research is needed to determine the patient group that is most likely to benefit from this procedure. This may also prevent futile medical interventions and potential risks for healthcare professionals.

D

The early identification of TBI is essential. Near-infrared spectroscopy (NIRS) can be used in prehospital settings for noninvasive monitoring and diagnosing patients who may require surgical intervention. A NIRS scanner was introduced by the Nijmegen HEMS team, a novelty in Europe. Data showed high sensitivity and positive specificity for TBI in prehospital patients. Results were presented in **chapter 10**. Due to the immobilization of the cervical spine it was difficult to perform a complete scan of the head in 40% of the patients, as the dorsal aspect of the head was often inaccessible. Despite this, satisfactory sensitivity and specificity were obtained for intracerebral traumatic abnormalities. In this setting, all patients had an indication to be transferred to a level 1 trauma center prior to the NIRS scanning. Therefore, treatment changes as a result of the scan were limited. A cohort of less severely injured TBI patients could possibly benefit more from this manner of prehospital diagnostics, facilitating triage and optimal hospital referral.

E

Trauma patients require optimal treatment in a hospital with adequate resources and skills. This is particularly necessary in a vulnerable group of trauma patients: children. Hospitals with specialized pediatric ICUs are limited, but severely injured children often need these facilities to receive optimal care. Usually a helicopter is the fastest method of transportation to these hospitals. **Chapter 11** presented a cohort of children who were transported to a level 1 pediatric trauma center by helicopter. Regarding these 86 children, only one unwanted event was encountered during helicopter transport: an accidental extubation. Although unwanted and unfortunate, this event is not specific to helicopter transportation and can occur also while lifting a patient in a (ground) ambulance. After reviewing all children transported by Nijmegen HEMS, it was concluded that transporting children by helicopter to adequately equipped medical centers is safe. Nevertheless, care must be taken to prevent transport-related problems such as accidental extubation, particularly in children.

Since 2006, Nijmegen HEMS extended its operations, becoming a 24/7 helicopter service using night vision equipment and crew training. During night conditions, patients are transported by helicopter as well. **Chapter 12** described a cohort of 72 patients that were transported during night conditions. No flight-specific adverse events were experienced during these transports. The observed time of transportation was significantly shorter in the helicopter group compared to the time it would have taken by ground transport. In conclusion, it can be stated that the helicopter transportation of patients during the night is rapid and safe in the Dutch setting.

Since the introduction, more than two decades ago, Dutch HEMS kept evolving into a professional organization. In the first year, less than one dispatch a day was performed, nowadays Nijmegen HEMS conducts over a 7-fold, approaching 3000 dispatches a year. This transition asks for committed professionals with extensive training, knowledge and experience. There are various 'life-support courses' available nationwide that must be attended prior to starting to work in a Dutch HEMS organization. Unfortunately, none of these courses prepares a person for the actual prehospital job. As a matter of fact, most of these courses focus on the in-hospital situation or have a basic level. The HEMS profession is learned on the job; in the field. Coached by colleagues and by extensive debriefing with the team and in team review sessions. Every dispatch incorporates decisions moments, considerations and actions leading to reactions that are valuable to evaluate. Only by reflection, training of necessary skills with frequent feedback the HEMS operation may continue to improve. Training of technical and non-technical skills is needed and ideally must be performed with all the involved professionals. Frequent, combined training with ambulance teams can be the next step in increasing the team performance. Obtaining multi-rater feedback on individual and the team performance can be helpful to identify focus points for supplementary training and coaching.

The organization of trauma care in the Netherlands is subject to changes and will inevitably lead to increased concentration of complex trauma care in large, level 1 trauma centers. [5] Further centralization of Dutch trauma care into five trauma centers or even in one center has been proposed.[6,7] As a result, the trauma landscape will most likely change in the years to come. The role of Dutch HEMS in this changing environment in relation to travel distances, availability and interhospital transportation needs to be determined.

In this thesis a various number of prehospital themes are described and evaluated. Conclusions, recommendations and the future perspective of this thesis are summarized in **chapter 14**.

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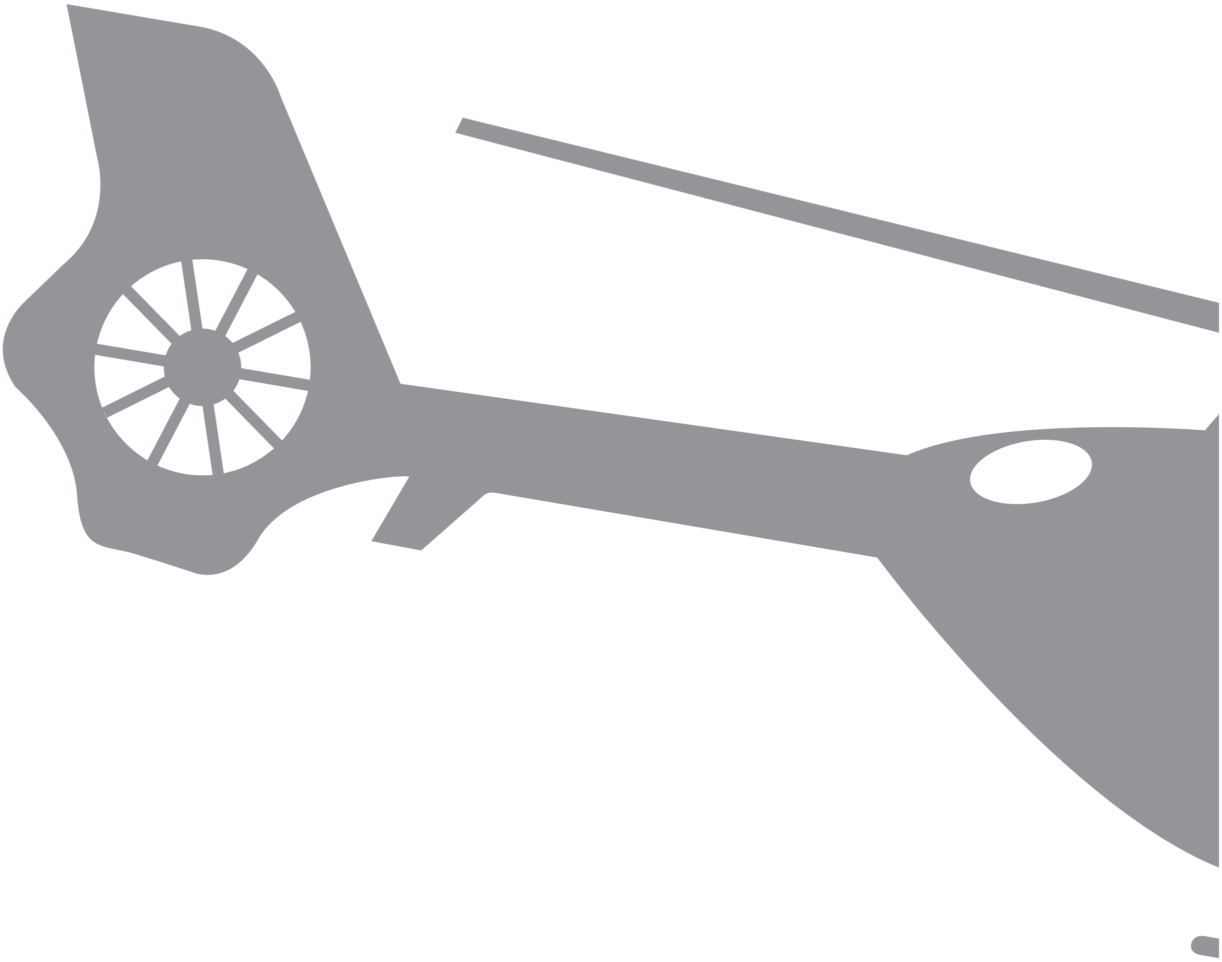


CHAPTER 14

Recommendations

A

- Evaluation of intubation skills of all healthcare professionals working in the prehospital field.
- A nationwide registry of all prehospital airway interventions, with emphasis on the number of attempts, the vital parameters during procedure and adverse events.
- An emergency surgical airway (ESA) is the ultimate intervention to secure a compromised airway. All professionals that perform intubations must be adequately trained to perform an ESA.
- Cuff pressure manometers must be available on all intubation sites, including ambulances.

B

- The role of thoracostomies in comparison with less invasive procedures as needle thoracocentesis needs to be determined.
- Novel devices for decompression of a tension pneumothorax, such as the ARS™ needle and the ThoraQuick Chest Decompression Device must be evaluated in a prospective study.
- The implementation of traumatic cardiac arrest treatment algorithms, including thoracic drainage, may increase the chance of return of spontaneous circulation.

C

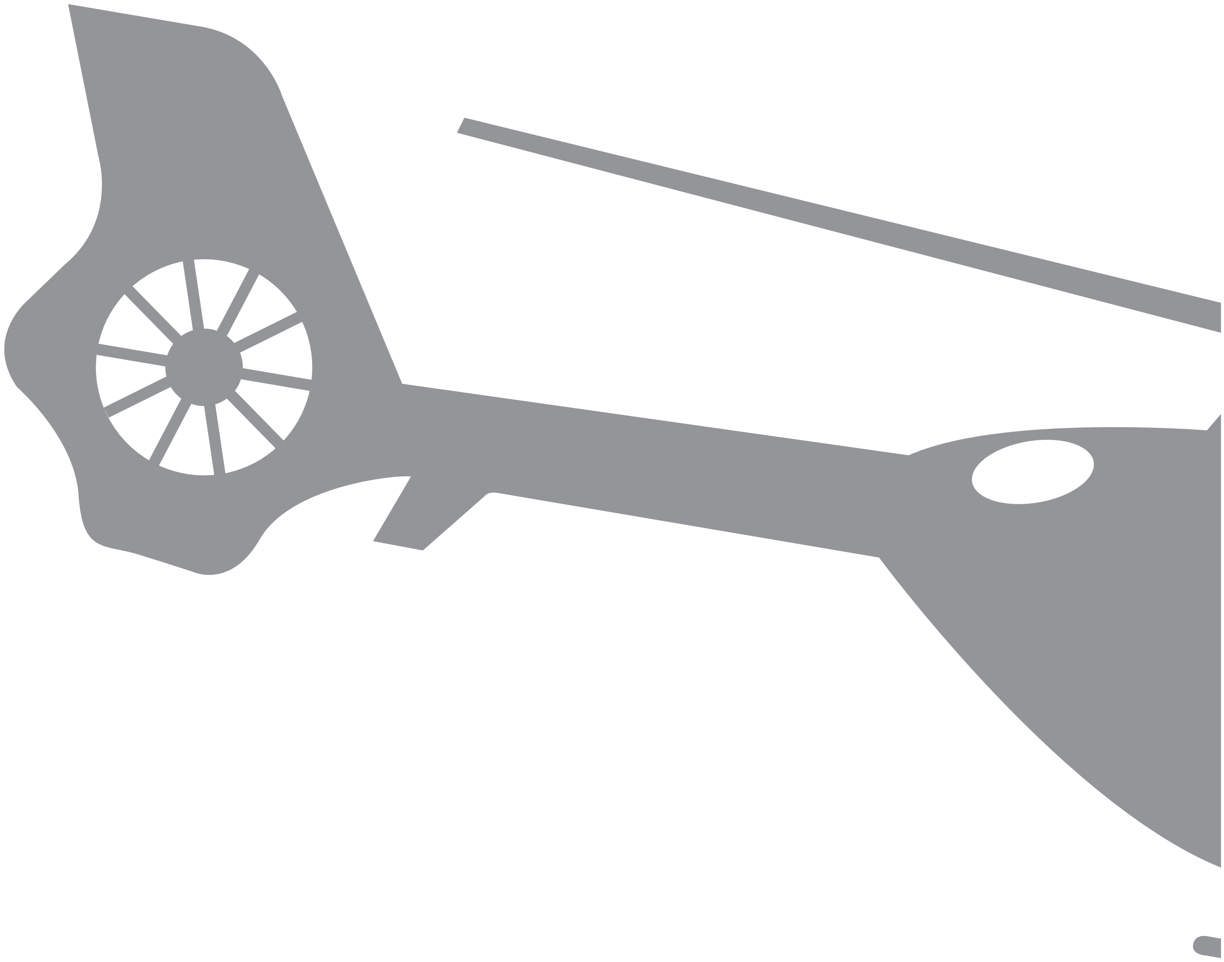
- A randomized control study using hemostatics (chitosan, kaolin or topical thombin) versus conventional bandages can provide information regarding the cost efficiency of this treatment option.
- More research must be performed to define the role of hemostatic clamps in the (pre)hospital treatment of superficial external blood loss.
- A prospective randomized study is warranted to evaluate the effect of early administered and warmed *uncross matched packed* red blood cells on the survival of patients with severe prehospital hemorrhagic shock. Patients that benefit the most from this intervention need to be identified and algorithms need to be adjusted accordingly, to prevent unnecessary use and costs.
- Prehospital thoracotomy in cardiac arrest in penetrating thoracic trauma needs accurate patient selection and frequent team training.

D

- An NIRS handheld scanner can be useful in the prehospital triage of TBI patients. A pilot study in an ambulance setting can provide additional data regarding optimization in the triage of TBI patients and their initial presentation in an adequately equipped neurosurgical trauma center.

E

- The ongoing evaluation of safety and adverse events during the (helicopter) transportation of patients is necessary to maintain adequate safety awareness and quality of care, particularly in a vulnerable pediatric patient group or during challenging conditions such as at night.



CHAPTER 15

Nederlandse Samenvatting

In dit proefschrift komen twee concepten van medische spoedzorg samen. De principes van de *Advanced Trauma Life Support* (ATLS) worden gebruikt om structuur en overzicht aan te brengen in onderzoek naar handelen van prehospitale mobiel medische teams in Nederland.

De ATLS doctrine is ontstaan nadat eind jaren 70 in de Verenigde Staten een orthopedisch chirurg, James Styner, neerstortte met zijn privé vliegtuig. Zijn vrouw overleed ter plekke, hijzelf en vier kinderen raakten ernstig gewond. De zorg in het lokale ziekenhuis was niet ingesteld op meerdere ernstige gewonde patiënten en er was geen structurele aanpak in de behandeling. Dit gaf Styner motivatie om een structuur te ontwikkelen waarmee er in een dergelijke hectische situatie, overzicht gehouden kan worden. Uitgangspunt is dat het meest levensbedreigend letsel primaire aandacht en behandeling krijgt. Hierbij gebruikt men de eerste letters van het alfabet: ABCDE. Wereldwijd hebben meer dan een miljoen artsen een ATLS certificaat gehaald. Hierdoor is de zorg voor de acute patiënt verbeterd en spreken alle betrokken hulpverleners “dezelfde taal”.

Om medische specialistische zorg naar de locatie te brengen zijn in de jaren 90 van vorige eeuw mobiele medische teams (MMT) opgericht. Omdat er in dergelijk teams een medisch specialist aanwezig is, heeft dit team meer mogelijkheden qua medicamenten en interventies. Initieel verplaatsten deze teams zich per voertuig, later per helikopter. In Amsterdam was dit vanaf 1995, MMT Nijmegen maakt vanaf 2001 gebruik van helikopter transport.

Trauma is in Nederland de belangrijkste doodsoorzaak in de leeftijdscategorie tot 40 jaar. In 2015 stierven in ons land 7241 mensen op een niet natuurlijke wijze. Het overlijden was in 3475 gevallen als gevolg van een val, 1871 zelfmoorden en 630 verkeersongevalslachtoffers.

Veel patiënten die het MMT behandelt hebben een bedreigde luchtweg, waarvoor endotracheale intubatie noodzakelijk is. Technisch kan dit lastig zijn en de omstandigheden zijn vaak complexer dan in het ziekenhuis. De patiënten zijn niet nuchter, liggen niet op een comfortabele hoogte op een operatietafel, maar zitten (half) in een beschadigde auto. Expertise is in dergelijke gevallen noodzakelijk. Het aantal pogingen dat noodzakelijk is een patiënt te intuberen moet zo laag mogelijk zijn in verband met aspiratie risico, verhoogde hersendruk en suboptimale gasuitwisseling. Ambulance verpleegkundigen mogen in Nederland geen spierverslappers en geen andere medicatie geven in doseringen die intubatie mogelijk maakt. Dat is een voorbehouden medische handeling. In **hoofdstuk 2** wordt een studie beschreven waarin het slagen van intubatie in de eerste poging tussen MMT artsen en ambulance (en MMT) verpleegkundigen wordt vergeleken. De studie geeft uitlag over intubatie slagingspercentages onder vergelijkbare omstandigheden. In beide groepen is gebruik gemaakt van hetzelfde medicatie regime, toegepast door de MMT arts. Het aantal primair geslaagde intubaties is significant hoger in de groep die geïntubeerd is door de MMT artsen. Omdat het geen gerandomiseerd onderzoek is, kan het zelfs zo zijn dat het werkelijke verschil nog groter is. De MMT arts zou de moeilijk ingeschatte gevallen mogelijk het liefst zelf willen behandelen. Het nadenken over ervaring, training en resultaten van alle hulpverleners die patiënten intuberen is nodig om optimale zorg te kunnen bieden aan deze kwetsbare patiëntengroep.

Als endotracheaal intuberen niet lukt en men er niet in slaagt de patiënt adequaat te ventileren, dan is het creëren van een chirurgische luchtweg een noodzakelijke optie. In **hoofdstuk 3** wordt een serie beschreven van chirurgische luchtweg interventies die prehospitaal door het MMT zijn uitgevoerd. De incidentie hiervan is relatief laag en het slagingspercentage hoog. Dit is conform verwachting gezien de expertise en training van de teams.

Na het plaatsen van een beademingsbuis dient het ballonnetje (cuff) aan het einde hiervan te worden opgeblazen. Hierdoor voorkomt men dat er slijm en/of bloed de longen in komt en kan met overdruk worden beademd. De druk in de cuff moet afdoende zijn, maar mag niet hoger zijn dan de doorbloedingsdruk aan de binnenkant van de luchtpijp. Te lang een te hoge druk kan leiden tot doorbloedingsstoornissen, vernauwingen en fistels naar bijvoorbeeld de slokdarm. In **hoofdstuk 4** wordt een studie beschreven waarin na intubatie de druk in de cuff wordt gecontroleerd en wordt vergeleken tussen de verschillende hulpverleners. Bijna alle gemeten drukken waren te hoog en werden bijgesteld naar een veilige waarde. Hieruit kan men concluderen dat na elke intubatie de druk dient te worden gemeten in de ballon. De hiervoor noodzakelijke meetapparatuur moeten dan ook beschikbaar zijn op elke spoedeisende hulp en in elke ambulance.

Een patiënt die gereanimeerd moet worden na een trauma kan dit overleven als er gezocht wordt naar behandelbare oorzaken van het circulatie arrest. Een van die oorzaken is een spanningspneumothorax. Dit kan worden behandeld door een opening in de borstkasholte te maken en de druk uit de longholte te laten ontsnappen: het creëren van een thoracostomie. In **hoofdstuk 5** wordt een cohort beschreven van thoracostomieën die gedaan zijn door het MMT, bij patiënten in een traumatische reanimatie. In 1 op de 10 patiënten was er sprake van een spanningspneumothorax. De algehele uitkomst in deze groep was, ondanks de thoracostomieën, slecht. De rol van thoracostomieën versus simpele naaldpuncties van de thorax, bij verdenking van een spanningspneumothorax, moet nog nader worden onderzocht. Wellicht dat een meer protocollaire en systematischere aanpak van patiënten met een traumatische reanimatie ook tot een betere overleving kan leiden.

Het stoppen van persisterend bloedverlies is essentieel bij traumapatiënten. Bloedverlies leidt tot afkoeling, verhoogde zuurgraad in het bloed en stollingsstoornissen. Deze vicieuze cirkel moet worden doorbroken om te voorkomen dat een patiënt komt te overlijden. Bloedstelpen kan op een simpele manier, door bijvoorbeeld met een vinger op een wond te drukken, of door het aanleggen van een conventioneel verband. Tegenwoordig zijn er moderne hulpmiddelen verkrijgbaar die effectief kunnen werken bij het verkrijgen van bloedingscontrole. Hierbij kan men denken aan verbanden die middelen bevatten die de bloedstolling activeren. Hieronder vallen verbanden die chitosan bevatten, gemaakt van het exoskelet van schaaldieren. Een succesvolle en veilige toepassing van dit soort verbanden in het prehospitale werkveld wordt beschreven in **hoofdstuk 6**.

Een andere methode om bloedverlies te stoppen kan bestaan uit het plaatsen van speciaal hiervoor beschikbare klemmen, zoals de iTClamp. Een studie met de iTClamp wordt gepresenteerd in **hoofdstuk 7**. Veelbelovende resultaten worden gezien met 90% bloedingscontrole en goede gebruikerstevredenheid. Een vergelijkend onderzoek met het gebruik van conventionele verbanden als controlegroep kan antwoord geven op de vragen over kostenefficiëntie en meerwaarde van dergelijke producten.

Inwendige bloedingen zijn vaak lastiger te behandelen, te denken valt aan bekkenringletsels, meerdere (been)breuken of bloedingen in buik en/of borstkast. Naast het eventueel plaatsen van een tourniquet of bekkenband, kan het nodig zijn om een patiënt een bloedtransfusie te geven. In het ziekenhuis is iets dergelijks vaak snel te effectueren. Buiten het ziekenhuis is het overgaan tot een bloedtransfusie meer uitdagend. Tot voor kort beschikten de traumahelikopters niet zelf over eenheden ongekruisd bloed. Bij de wens tot het geven van een transfusie moest dit bloed worden opgehaald uit een in de buurt (van het ongeval) gelegen ziekenhuis/bloedbank. Data aangaande prehospitale bloedtransfusies bij volwassenen van twee traumahelikopter organisaties werden samengevoegd. Deze gegevens werden vergeleken met een controlegroep van patiënten met dezelfde soort letsels en mate van bloedverlies, om te kijken wat de meerwaarde is van prehospitale bloedtransfusies. De resultaten van dit onderzoek zijn terug te vinden in **hoofdstuk 8**. Ten aanzien van overleving kon geen verschil worden aangetoond in dit onderzoek. Er werden geen prehospitale transfusiereacties beschreven, waaruit men mag concluderen dat een dergelijke interventie veilig kan worden uitgevoerd. Recent is gestart met het meenemen van twee eenheden ongekruisd bloed in de helikopter. Hierdoor kan er nog sneller worden overgegaan tot het geven van transfusies. Of dit wel evidente overlevingswinst zal opleveren zal moeten worden bezien.

Een hartsstilstand na een scherpe verwonding van de borstkast kan worden behandeld door het openmaken van de borstkast en het stelpen van de bloeding. Als dit circulatie arrest plaats heeft buiten het ziekenhuis, dan is in de tijd die het duurt om op een adequaat uitgeruste spoedeisende hulp of operatiekamer te komen te lang om de patiënt te laten overleven. De meeste mobiele medische teams in Nederland zijn getraind om op straat een thoracotomie uit te voeren. De eerste resultaten van deze prehospitale thoracotomieën in Nederland, met data van drie traumahelikopters, worden beschreven in **hoofdstuk 9**. In dit cohort van 33 patiënten wordt 1 overlevende gezien, met goede neurologische uitkomst na een prehospitale thoracotomie. Veel vaker lukte het om circulatie herstel te verkrijgen. Dit lukte in 27% van de cases. De gepresenteerde patiënten groep was samengesteld uit steek- en schotwonden. Subgroep analyse van alleen de steekwond patiënten laat een circulatie terugkeer zien van 39%. Nadere analyse en onderzoek moet de rol van een dergelijke ingreep binnen het Nederlandse prehospitale werkveld bepalen en een uitsluitsel geven over de patiënt die het meeste kans heeft geholpen te worden met een dergelijke interventie. Dit om, voor de hulpverlener potentieel risicovolle, medisch zinloze interventies te voorkomen.

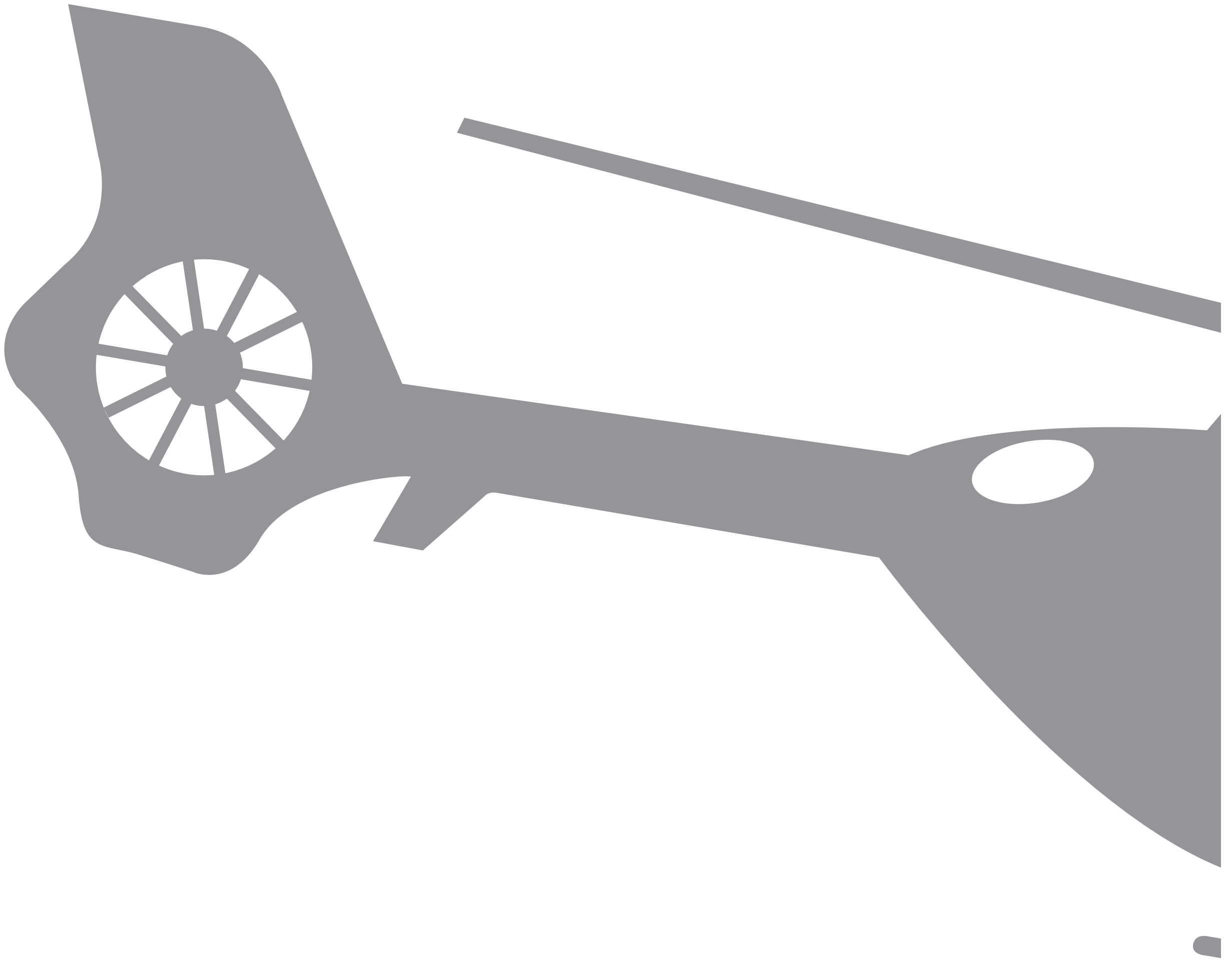
Het vroegtijdig herkennen van patiënten met traumatisch schedelhersenletsel is essentieel. Hierdoor kan een patiënt primair naar het juiste centrum worden gebracht en daarmee kan tijd tot eventuele interventie worden gewonnen. Een infrarood spectroscopie scanner kan helpen om op een niet-invasieve manier te bepalen of er een indicatie zou kunnen bestaan voor neurochirurgisch ingrijpen. Met een dergelijke scanner is het mogelijk om bloedingen in het brein te detecteren, al buiten het ziekenhuis. In **hoofdstuk 10** wordt een cohort MMT-patiënten gepresenteerd die gescreend zijn met een degelijk scanner. Er is sprake van een hoge sensitiviteit en een goede specificiteit voor traumatisch schedelhersenletsel bij deze patiënten. Dit ondanks de vaak niet volledige scans, in verband met rugligging en immobilisatie van de cervicale wervelkolom. Omdat alle patiënten in verband met de ernst van het letsel reeds een indicatie hadden om naar een level 1 traumacentrum gebracht te worden, zijn in dit onderzoek de behandelconsequenties beperkt. Een nader onderzoek van dergelijke apparatuur bij minder ernstig gewonde patiënten, zoals bij een reguliere ambulancedienst, zou uitsluitsel kunnen geven over de toegevoegde waarde van deze nieuwe diagnostische mogelijkheden.

Patiënten moeten zorg krijgen in een adequaat hiertoe uitgerust ziekenhuis. Er moet afdoende ervaring en faciliteiten zijn om de patiënt optimaal te kunnen behandelen. Lang niet altijd is dit aanwezig in het ziekenhuis dat het dichtste bij een ongevallocatie ligt. Met name bij kinderen is dit het geval, omdat slechts de academische level 1 traumacentra beschikken over een specifieke pediatrische intensive care. Deze reisafstand kan het snelste worden overbrugd door het kind in de helikoper mee te nemen naar het traumacentrum. Om de veiligheid van deze transporten te beoordelen worden in **hoofdstuk 11** de gegevens van een cohort van 86 kinderen beschreven, die met een helikopter naar het ziekenhuis gebracht werden. Hieruit is te concluderen dat kinderen op een veilige manier per helikopter van de prehospitale locatie naar een ziekenhuis kunnen worden getransporteerd.

Sedert 2006 wordt in Nijmegen ook gedurende de nacht gevlogen voor spoedinzetten. Hierbij wordt, na specifieke training, gebruik gemaakt van onder andere restlichtversterkers. Onder deze nachtelijke condities worden eveneens patiënten per helikoper getransporteerd naar een ziekenhuis. In **hoofdstuk 12** wordt de veiligheid van deze bijzondere transporten behandeld.

Hieruit blijk het veilig te zijn om gedurende de nacht patiënten per helikopter te vervoeren in Nederland.

Verschillende thema's die de acute prehospitale zorg betreffen zijn behandeld in dit proefschrift. De conclusies en aanbeveling die volgen uit dit onderzoek worden puntsgewijs beschreven in **hoofdstuk 14**.



APPENDICES

LIST OF ABBREVIATIONS

ABC	Acronym; Airway - Breathing - Circulation
ALS	Advanced Life Support
ANWB	Algemene Nederlandse Wielrijders Bond (The Royal Dutch Touring Club)
ATLS	Advanced Trauma Life Support
BMV	Bag-Mask-Valve (ventilation)
CICO	Can't Intubate, Can't Oxygenate
CPR	CardioPulmonary Resuscitation
CT	Computed Tomography
DFI	Drug Facilitated Intubation
ED	Emergency Department
EMS	Emergency Medical Service
ESA	Emergency Surgical Airway
ETI	Emergency Tracheal Intubation
FFP	Fresh Frozen Plasma
GCS	Glasgow Coma Score
HOTT	Hypovolemia, Oxygenation, Tension pneumothorax and Tamponade
HEMS	Helicopter Emergency Medical Service
ICU	Intensive Care Unit
INR	International Normalized Ratio
ISS	The Injury Severity Score
LMA	Laryngeal Mask Airway
MAA	Medical Air Assistance
MICU	Mobile Intensive Care Unit
NIRS	Near Infrared Spectroscopy
NVG	Night Vision Goggles
pHEMS	Physician staffed Helicopter Emergency Medical Service
PHTLS	PreHospital Trauma Life Support
RFVIIa	Recombinant factor VIIa
ROSC	Return Of Spontaneous Circulation
RSI	Rapid Sequence Intubation/Induction
SAD	Supraglottic Airway Device
TBI	Traumatic Brain Injury
tCA	Traumatic Cardiac Arrest
TIC	Trauma-Induced Coagulopathy
TP	Tension Pneumothorax
URBC	Uncrossmatched (type O Rhesus negative packed) Red Blood Cells

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OK assistenten, en dan met name de traumazusters. Wat zullen jullie soms gek van ons worden als er weer een andere set moet komen en worden geopend. Meestal dan een die we niet echt nodig hebben omdat het intussen al gelukt is. Bijzonder dat jullie het vol weten te houden om naar het “Foute uur” te blijven luisteren tussen 9 en 10.

Staf Heelkunde. We hebben een mooi team met goede en bijzondere mensen. Ambities genoeg en steeds meer ook gerealiseerd. Als je ziet wat er zich allemaal voltrekt binnen onze staf dan moeten we concluderen dat we goed bezig zijn!

Heren van de Cross-servicing. Dank voor de gastvrijheid en het feit dat jullie ons al jaren tolereren in jullie gebouw.

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Vliegers Lifeliner 3, piloten voor buitenstaanders. Het is een voorrecht om met jullie de dagen in het Volkelse door te brengen. De verschillende achtergronden die jullie hebben is bijzonder en leerzaam. Net als jullie wagenpark en nevenactiviteiten.

HCM-ers MMT Nijmegen, met een klein team gaan we op pad en moeten we het zien te doen. Fijn dat ik altijd weet dat jullie letterlijk en figuurlijk naast ons staan. Niet alleen om (meestal) op de juiste plek aan te komen, maar ook tijdens een hulpverlening. Alleen jullie weten hoe het echt was, welke verhalen er achter welke patiënten schuilgaan. Dank voor alle ondersteuning, samenwerking en vooral de gezelligheid!

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Vrienden, de “Nijmeegse” club en Bas in den vreemde. Levens veranderen en de frequentie van zien is minder. Maar als het dan weer zo ver is dan is het een enorm fijn gevoel dat er niet echt dingen anders geworden zijn. Laten we weer snel een mooi uitje plannen, liefst naar een stad met > 1.000.000 inwoners.

Paranimfen, Bas en Gerben. Het is een genoegen dat jullie me terzijde willen staan. Bas, zie uit naar nog veel samen plannen, regelen, poppen doorzagen en opereren. Gerben, getuige zijn op jullie huwelijk was een eer!

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Zussen Pauline, Lies en Tinus. En uiteraard Roland, Thomas en Laurens. Al wisten jullie waarschijnlijk niet of nauwelijks dat dit speelde, toch enorm bedankt voor alle gezellige uitjes, etentjes en veel te drukke weekends.

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Lucas en Anna, jullie snappen hier denk ik nog niets van. Al zal Anna intussen het begrip poppenkast wel snappen, ze kan dit in ieder geval nog niet lezen. Het is leuk om jullie wel te noemen omdat ik erg trots en blij met jullie ben!!!

Sharonneke, je weet wat je voor me betekent! Als soort van secretaresse moet je bij je drukke baan ook nog zorgen dat ik niet op drie plekken tegelijk dienst moet doen. Je bent een goede dokter, tekst corrigeerder en een super moeder, en zo kan ik nog lang doorgaan. Dank, dank en dank. Hou van je!

CURRICULUM VITAE

Joost Peters was born on the 14th of November 1976 and grew up in Losser, in the eastern part of The Netherlands. In 1995 he graduated from the Twents Carmellyceum in Oldenzaal.

During Medical School he spend most of his time on a bike, training and competing. The medical degree was received in 2001. During his study it was clear that he wanted to become a (trauma) surgeon. After Medical School his first job was in the Saint Raboud Hospital (nowadays called Radboud University Medical Center), Nijmegen (Prof. dr. R.P.J. Bleichrodt). Surgical training was started in the Canisius Wilhelmina Hospital, Nijmegen (dr. W. Barendregt) in 2004. Surgical training was continued at the Radboud University Medical Center in 2008 (Prof. dr. C.J.H.M. van Laarhoven) focusing on trauma surgery (dr. J. Biert).

During the last episode of surgical training the opportunity of participating in the helicopter emergency medical service emerged. Since 2010 he is part of the team of the Nijmegen Helicopter Emergency Medical Service , called Lifeliner 3. After completing his training to become a trauma surgeon (CHIVO, dr. J. Biert) he worked one year as trauma fellow with focus on prehospital healthcare. It was in this period that the first research on prehospital care was conducted.

Since 2012 Joost is a staff member in trauma surgery at the Radboud University Medical Center, in combination with an appointment as physician on the Lifeliner 3 helicopter. As instructor he participates in various life support courses such as the Advanced Paediatric Life Support (APLS®), Advanced Trauma Life Support (ATLS®) and Definitive Surgical and Anaesthetic Trauma Care (DSATC®). He is member of the Dutch Trauma Society (Nederlandse Vereniging voor Traumachirurgie) and the European Society for Trauma and Emergency Surgery (ESTES).

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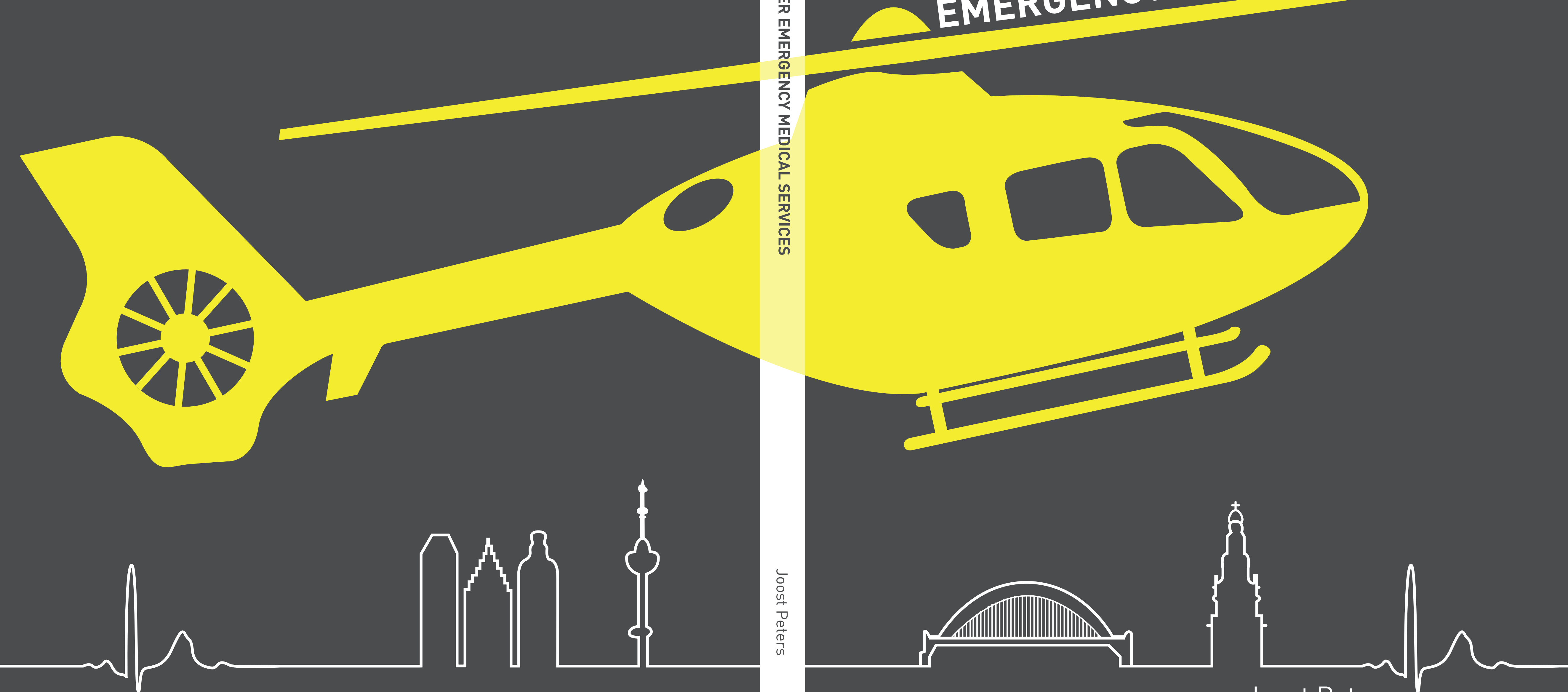

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