PREHOSPITAL CARE IN PEDIATRIC PATIENTS TREATED BY DUTCH HELICOPTER EMERGENCY MEDICAL SERVICES

Xavier R.J. Moors

De tekeningen op de voorkant zijn afkomstig van leerlingen van het Sint-Maartenscollege in Voorburg. Eind 2020 heeft het MMT medische bijstand verleend aan een van de leerlingen. Deze is daarna met helikopter transport naar het Sophia Kinderziekenhuis gebracht. Om het een en ander te verwerken werden er kaarten gemaakt en deze zijn bij de verschillende hulpdiensten afgegeven. Zo ook bij het MMT. Zoiets had ik nog niet eerder meegemaakt, zoveel kaarten en zo veel lieve woorden. Het heeft mij (diep) geraakt en opeens wist ik het, dit wordt de kaft!

Met dank aan de leerlingen van het Sint-Maartenscollege te Voorburg.

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Prehospital Care in Pediatric Patients Treated by Dutch Helicopter Emergency Medical Services

Prehospitale zorg aan kinderen die behandeld zijn door het Mobiel Medisch Team in Nederland

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Erasmus Universiteit Rotterdam
op gezag van de
rector magnificus

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For Evi, Dex, Cas

and all other children

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CHAPTER 1

General Introduction

The Netherlands has a population of over 17 million people and covers an area of 41,543 km^2. Primary pre-hospital care is provided throughout the country by a system of regional Emergency Medical Services (EMS) which are staffed by paramedics. The EMS adhere to a national protocol that provides clear and precise procedures[1] that need to be followed. Ambulances (normal road vehicles) are used to transport medical care to the point of incident and transporting the patients to the appropriate hospitals. For vitally compromised children however, the established protocols and level of expertise of the EMS are limited[1,2].

EMERGENCY MEDICAL SERVICE (EMS)

Most, in excess of 95%, of the paramedics are Ambulance Nurses having had a background in either intensive care, emergency care or anesthetics. In 2014 the course, Bachelor Medische Hulpverlener (BMH), was introduced and in 2019 additional training, namely Lange Tranche Verpleegkundige for nurses without a background in intensive care, emergency or anesthetics was provided which enabled successful candidates to become paramedics as well. In order to qualify as an Ambulance Nurse candidates have to complete a seven month training at the Academie voor Ambulancezorg. The course is structured into nine modules – twenty-three days of instruction of which one day for pediatrics in general and emergencies (this day is divided into a half day instruction and a half day practical training).[3]

According to Ambulancezorg Nederland[4], there are a total of 813 ambulances complimented by a staff 6174 employees. The total number of dispatches by the EMS in 2018 was 1.322.844. The number of dispatches that concerned children, patients under the age of 16, was 70.110 (5.3%). The number of dispatches concerning children under the age of 1 year, however, was 14.551 (1.1%). These figures indicate that, on average, every EMS employee sees 11 to 12 patients under the age of 16 every year, roughly one a month. Included in these figures are transfers between hospitals, transfers to home addresses, non-urgent medical care and pediatric intensive care transfers (These transfers include in addition to EMS staff a doctor and a regular nurse). The relatively few incidents per month is why exposure and expertise in acute care to vitally compromised children is so limited.

Practicing as an Ambulance Nurse requires competency in some complex procedural skills. Skills that may rarely be used in normal daily duties. One of the most complex procedures is that of airway management, these include correct Bag-Mask Ventilation (BMV) and Endotracheal Intubation (ETI). Several studies have been made with regard to the training and subsequent maintenance of these skills[5-7.] One particular study, which focused on airway training for paramedics, demonstrated that there was a correlation between having experience dealing with live patients and performance success[8]. Opportunities for obtaining operating room experience, however, are extremely limited. Ongoing experience with ETI in the field is similarly low with an annual median frequency of less than one per Ambulance Nurse in some areas. This is even lower for opportunities involving pediatric cases. In a review of intubations of the adult population a requirement of having experience with a minimum of 50 ETI cases was necessary in order to achieve a 90% success rate of successful intubations within two attempts[9]. The incidents of performing complex airway procedure in the non-elective situation is twenty times higher than in the elective situation, it is therefore necessary for pre-hospital health care providers to perform at least 50 ETI cases during training. In the case of pediatric patients, the number of intubations is even greater.

In order to maintain the required skill competency levels the Netherlands Inspectorate of Health and Youth Care (Inspectie Gezondheidszorg en Jeugd), based on the recommendations of the Netherlands Society of Anesthesiologists, requires that a minimum of 50 ETI are performed annually. In an attempt to achieve these levels of competence Ambulance Nurses were assigned to various Anesthesia Departments of hospitals for periods of between one to five days in order to gain experience performing ETI and BMV procedures on adults. This practice has been hampered in recent times by the fact that ETI’s are less frequently used since the introduction of Laryngeal Mask Airway (LMA), consequently little or no opportunity for experience has been provided. The resulting effect of this has been that there is a loss on interest in live training. The combination of ETI’s in pediatric patients being less frequent and of greater complexity than in the case of adults has resulted in lower success and higher complication rates in the Netherlands.

In addition, frequent training is needed to maintain adequate airway management, because these skills rapidly diminish after training [5]. This makes it challenging for EMS given limited resources and competing needs for training on other topics. There are some reports of pre-hospital ETI success rates comparable to the in-hospital rates, especially if performed by highly skilled physicians [12-14]. Many EMS regions in The Netherlands still consider ETI the gold standard for pediatric airway management; while others have abandoned ETI due to safety concerns, highlighting the controversy among experts in out-of-hospital care [6,7,15]. This has resulted in the EMS regions to abandon pediatric intubations and have adjusted the national protocol accordingly.

To counteract the decline of post training skill levels frequent re-training is needed to maintain airway management competence[5]. With the required training, reports of pre-hospital ETI success rates comparable to in hospital rates as performed by physicians have been made. This training, combined with the competing demand for training in other competences in other procedures are a challenge on the limited resources of the EMS.

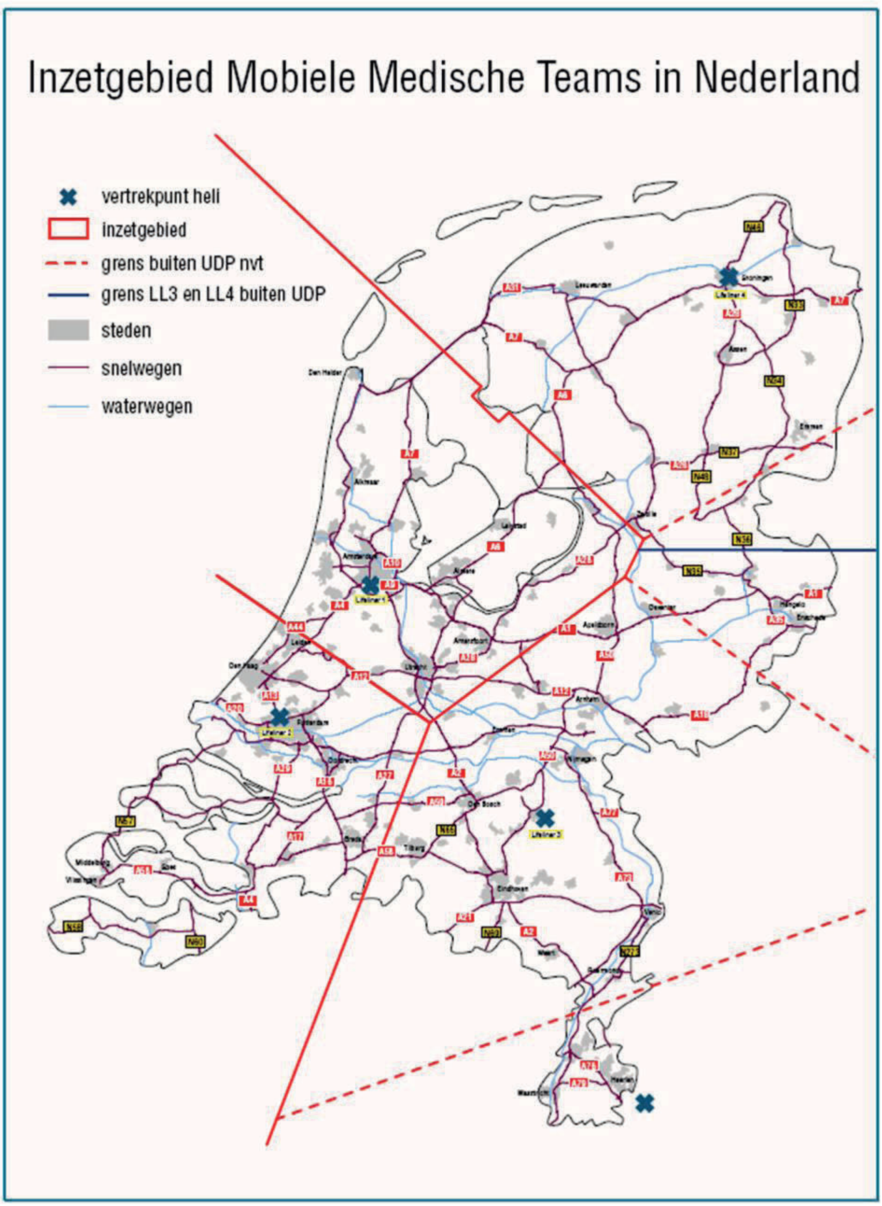
HELICOPTER EMERGENCY MEDICAL SERVICE (HEMS)

Complementing the Regional Emergency Services there are four Helicopter Emergency Services (HEMS) which provide their services throughout the Netherlands. In addition to the inclusion of the helicopter service, as the primary transport mode, the HEMS included in its basic compliment a specialist medical physician.

Initially, HEMS was introduced in Amsterdam in 1995, this unit included a specialist medical team which is either a Board-Certified Anesthesiologist or a Trauma Surgeon and a specialist Nurse (either an EMS paramedic or from the hospital's Emergency Department). In addition to the two medical personnel there is also the helicopter pilot who operates the helicopter. Initially the HEMS operational hours were from 07h00 to 19h00 or daylight hours (depending on time of year) only. In 2009 the service was extended to include 24-hour cover where the after hour and hours of darkness periods were covered using motor vehicles instead of airborne helicopter transportation.

Since February 2011 HEMS availability has been provided twenty-four hours 'a day seven days a week, in the event of adverse weather conditions instead if deployment by helicopter specially equipped motor vehicles are used.

Figure 1. Location of Dutch HEMS



Source: Trauma Center South West Netherlands(www.traumacentrumzwn.nl)

Of the eleven Level 1 trauma hospitals in the Netherlands only four deploy HEMS teams.

In the Rotterdam HEMS, in order to become eligible, the surgeons receive a two-month training in anesthesia, which includes a two-week pediatric anesthesia course. If the physician is an anesthesiologist, then training is undertaken in surgical procedures as well as a two-week pediatric anesthesia course. All HEMS physicians are trained in Advanced Pediatric Life Support and Neonatal Life Support. To maintain standards all physicians are required to perform a minimum annual rate of 50 ETI.

There is close collaboration between HEMS and EMS. Both entities use, where applicable, the same protocols. Depending on the information regarding the incident and based on nationwide criteria HEMS teams are primarily dispatched by the respective EMS Dispatch centres. In the event that the EMS paramedics attending to an incident, and having assessed the conditions of the patient, the EMS paramedic can also request directly for the HEMS to be dispatched. In February 2020 the Netherlands HEMS received their 100,000th dispatch. Currently the Rotterdam HEMS receives 4,000 dispatches annually.

Nationally there are 80 HEMS physicians and nurses. Initially, when the HEMS became operational, the EMS that were on the scene of the incident requested HEMS assistance in stabilizing vitally compromised or seriously injured children. In, latest data available, 2018 the HEMS received 12,000 calls. 22% of the patients were below the age of 18, the result of this is that HEMS teams are receiving far greater exposure to pediatric cases than their EMS counterparts.

This has resulted in the HEMS now being the primary dispatch team in the cases involving vitally compromised or seriously injured children, The Netherlands model of HEMS is not universal, and the inclusion of a physician as part of the medical crew is not always the case. In the United Kingdom the use of helicopters is more a choice for mode of transport than specialized medical assistance due to long distances and congested traffic delays when transporting patients by road. The primary role of the Netherlands HEMS is to deliver the specialized medical team to the incident site as quickly as possible. The certified physician is trained and has high exposure to performing critical medical interventions such as rapid sequence inductions, thoracostomy, blood transfusion, administration of inotropic or vasopressor medication as well as decision making. In most pediatric cases the physician will accompany the patient with the EMS ambulance to the hospital.

Transport of patients by helicopter is very limited, with improved connections between the helicopter landing platform to the Emergency Department in 2014, patient transport occurs in about 3% of all cases.

When HEMS became operational, EMS on scene frequently asked for assistance in stabilizing vitally compromised or seriously injured children. Currently the HEMS is activated primarily when vitally compromised or seriously injured children are concerned. Currently, in the Netherlands, around 22% of the patients treated by HEMS are children. This is unique for a European-based HEMS. For instance, Rotterdam HEMS treat around 40 pediatric cardiopulmonary resuscitation (CPR) each year, which means that every doctor performs on average one pediatric CPR every three to four months.

The pre-hospital data on the outcomes concerning pediatric EMS and HEMS in the Netherlands as well as in other countries is lacking and is one of the reasons for undertaking research for this thesis. It is difficult to measure the experience and adequacy of the health care provider when stabilizing vitally compromised or seriously injured children, with the increased number of pediatric cases dealt with by the HEMS does this provide the service with this required experience? In order to address this question a data base has been drawn up. Data from 1 January 2012 through to 1 January 2018 has been extracted from the main data base of the Erasmus MC. From this data 1902 dispatched to treat pediatric patients have been collated. Not all of these cases are unique there are cases where the same patient has been the focus of several dispatches, there is one instance of a patient being attended to by the HEMS ten times.

AIMS AND OUTLINE OF THE THESIS

Aims

The primary aim of this thesis is to analyze the incidents of pediatric patients being treated by the Netherlands HEMS and their outcomes. In addition, a comparison is made of the impact of treating children by HEMS in combination with EMS services as to children being treated by EMS services only. The emphasis of the research is the quality of:

- Intubation
- Cardiopulmonary resuscitation
- Pre-hospital blood transfusion
- Perinatal care

In addition to the analysis of this data a review of the degree of added value achieved when the services of the HEMS and EMS operating in combination is made.

Outline

This thesis describes the results of studies conducted to investigate the benefit of HEMS in treating severely injured or critically ill children.

The Rotterdam HEMS provides care for patients of all ages and includes pediatric patients, which currently constitute 22% of all patients. The reason for calls to the HEMS are for a variety of critical situations which include sepsis, cardiopulmonary resuscitation, respiratory failure, and trauma.

The purpose of airway management is to provide adequate tissue oxygenation and ventilation while avoiding aspiration, this is achieved by performing the standard method of securing the airway - endotracheal intubation (ETI)[19,26,27]. The out-of-hospital environment often creates unique challenges, such as difficult visibility situations or patients in difficult positions, making ETI potentially a risky procedure[20-23]. The rate of success of performing ETI vary and depend on the patient group being investigated and the qualifications and experience of the ETI health care provider[24,25,28,29]. The success rate of the

Rotterdam HEMS, how this compares with other HEMS services globally and whether these success rates are comparable to the in-hospital situation are presented in **Chapter 2**.

It is not obligatory in the Netherlands to report the numbers or outcomes of pediatric resuscitation, consequently little is known about incidences and outcomes of pre-hospital cardiopulmonary resuscitation (CPR). In order to better understand the incidences and outcomes a database search has been performed of all pediatric CPR cases performed by the Rotterdam HEMS over a six-year period. **Chapter 3** records the incidents, outcomes, interventions and added value achieved of pediatric pre-hospital CPR's performed by the Rotterdam HEMS.

Chapter 4 describes the national experiences of the Netherlands by all four HEMS services, this is the first time that a national report has been compiled of the numbers of incidents and their outcomes for pre-hospital pediatric CPR has been made.

The aim of providing a physician staffed HEMS service is to have specialist medical care at the incident scene and improve survival rates of severely injured or critically ill patients. Previous studies have had insufficient data or backup details to be able to provide conclusive evidence of the efficacy of the HEMS in saving lives. Den Hartog et al. has investigated this subject for injured adult patients and indicates that an additional 5.33 lives saved per 100 dispatches when physician staffed HEMS teams were used compared to EMS teams. **Chapter 5** investigates this same subject but in pediatric patients.

Massive hemorrhage is recognized as a leading cause of preventable deaths. In some instances bleeding can be easily stopped by simple application of pressure to the wound or using a tourniquet, this however cannot be achieved with internal bleeding in the abdomen or thorax for instance. For situations where the simple measures cannot be used the HEMS teams bring certain blood products when dispatched. If there are patient entrapments or where the patient cannot be delivered timeously to a Level 1 trauma centre to receive necessary blood products, unmatched Type O negative red cell transfusions can be administered to patients, including pediatric patients, by the HEMS teams. A study of the use of blood products by the HEMS has been made using in particular the patients treated by the Nijmegen and Rotterdam teams, this is summarized in **Chapter 6**.

According to international literature pre-hospital deliveries constitute between 0.0006 and 1.99% of all deliveries[30-32]. This figure in Norway is 0.2% and in Flanders, Belgium it is 1%. In the Netherlands, where approximately 13% women opt to give birth at home the pre-hospital deliveries are much higher. In the Netherlands not all women are eligible for having a home delivery – this is only for women who are without risk factors during their pregnancy may opt for this[37]. Notwithstanding these limitations in cases where (suspected) complications during labour arise or requests for (epidural) pain relief are requested the patients are transferred to a nearby hospital. Currently there is little record of neonates receiving urgent medical care by either EMS or HEMS services in the Netherlands. A study of neonates by the HEMS has been made, this is summarized in **Chapter 7**.

When there is a cardiac arrest during pregnancy a perimortem caesarean delivery is an essential part of the resuscitation of both mother and fetus. The recommendation is that this procedure is started after the initial four minutes of CPR application and performed within the next minute. While perimortem caesarean deliveries are not per se complex procedures the cognitive, emotional and operational circumstances surrounding the delivery can make the procedure complicated especially in the pre-hospital environment. A study of all perimortem caesarean deliveries performed by all HEMS services in the Netherlands has been done to examine procedures, outcomes, complications and adherence to recommended guidelines with the aim of formulating and providing recommendations for future application. These results are presented in **Chapter 8**.

Chapter 9 consists of a summary and general discussion, reflecting on the data presented.

Chapter 10 provides a summary of the conclusions, discussion and recommendations in Dutch.

Recommendations resulting from this thesis are presented in **chapter 11**.

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CHAPTER 2

Retrospective Analysis of Out-of-Hospital Paediatric Intubation by a Dutch Helicopter Emergency Medical Service

Moors Xavier RJ, Oude Alink Michelle B, Bouman Stef JM,
Den Hartog Dennis, Houmes Robert Jan and Stolker Robert Jan

Clin Pediatr Res 2019, 3(1):56-62

ABSTRACT

Background

Endotracheal intubation (ETI) is frequently performed in critically ill or severely injured paediatric patients and remains the gold standard to secure the airway.

Objective

The objective of this retrospective study was to examine the first attempt and overall success rate of out-of-hospital emergency paediatric intubation by a physician-staffed Helicopter Emergency Medicine Service (HEMS).

Methods

This was a retrospective database analysis of all paediatric (< 18-years) intubations performed by HEMS physicians during a six-year period (2012-2017). The recorded findings included patient demographics, operator background, airway interventions (including intubation attempts), video-assisted intubation, and complications.

Results

Three hundred and sixty-one paediatric patients required the airway to be secured. In 280 of these cases, a HEMS physician performed the intubation. The first attempt success rate was 227 (81%) and the overall ETI success rate was 276 (98.5%) after one or more intubation attempts. Surgery was necessary to clear the airway in only one case.

Conclusion

Prehospital ETI of critically injured or ill paediatric patients had a high success rate when performed by HEMS physicians in The Netherlands. In paediatric cases with a potentially compromised airway, the threshold for HEMS deployment should be low.

INTRODUCTION

Little is known about the success rate and complications of paediatric endotracheal intubation (ETI) in a prehospital setting by a Helicopter Emergency Medical Service (HEMS). The Rotterdam HEMS provides care for patients of all ages, including paediatric patients. Currently, paediatric patients are involved in 22% of all calls, which makes it a unique service. These calls are for a wide variety for critical illnesses including sepsis, cardiopulmonary resuscitation, respiratory failure, and trauma. The purpose of airway management is to achieve adequate tissue oxygenation and ventilation, while limiting aspiration. One of the key goals of resuscitation and critical care is to establish and maintain a patent airway by endotracheal intubation [1,2] and remains the standard method to secure the airway [3]. Unique challenges can be seen when intubating a paediatric patient in an out-of-hospital environment [4-7], making it a potentially risky procedure. Rates of successful ETI vary depending on the investigated patient group and the qualifications of the intubating health care provider [8-11]. The ETI success rate for pre-hospital paediatric patients is between 55 and 100%, with a high complication rate varying from unrecognized oesophageal intubation to potentially “lethal” ventilator settings for less experienced emergency medical service (EMS) health care providers [12]. There is evidence in the Netherlands that intubations performed by paramedics are less safe and successful than other, less invasive techniques such as bag-valve-mask ventilation or even laryngeal mask airway placement [3,13-15]. Even intubations performed by physicians are prone to critical errors and failure if they have insufficient training and equipment, and intubation success may depend on physician’s speciality [4,16-18]. For out-of-hospital paediatric ETI, success rates are generally lower than for the adult population [4,19]. Due to a lack of frequent exposure to paediatric patients and paediatric intubations, poor performances are seen for all providers of emergency medical care [14,15,20]. In addition, frequent training is needed to maintain adequate airway management, because these skills rapidly deteriorate after training, making it challenging given limited resources and competing needs for training on other topics [21]. There are some reports of pre-hospital ETI success rates comparable to the in-hospital rates, especially if performed by highly skilled physicians [22,23]. Successful airway management requires training, skills, and ongoing experience to consistently perform these procedures in an effective, timely, and safe manner [12]. Many EMS regions in The Netherlands consider ETI the gold standard for paediatric airway management; while, others have abandoned ETI due to safety concerns, highlighting the controversy among experts in out-of-hospital care [13-15]. Analyses of such findings have led authors to suggest restricting (paediatric) intubation to physicians alone [15,24].

The primary endpoints of this study were the first attempt and overall success rates for out-of-hospital, at the scene paediatric ETI by physician-led HEMS. Secondary endpoints were the type of intubation (direct laryngoscopy or video-assisted intubation using the McGrath video laryngoscope); complications of airway management, including failure of intubation; success by operator type; patient's age, and medication-assisted intubation.

MATERIALS AND METHODS

Study design

We performed a retrospective analysis during a six-year period (2012-2017) of a custom-made TRIN database that included all consecutive deployments by the Rotterdam HEMS. This database also contained findings about paediatric ETI, the number of ETI attempts, success rate, medication given prior to intubation, and by whom the intubation was performed (trauma surgeon versus anaesthesiologist). A Microsoft access Query was performed on this TRIN database including patients less than 18-years of age and intubation. Only two physicians abstracted the data from the original HEMS database. The definition of an intubation attempt was the preparation for intubation, with or without medication, and trying to visualize the vocal cords using direct or video assisted laryngoscopy for an ETI. If tube placement was not successful and the (video assisted) laryngoscope was withdrawn from the oropharynx, this was marked as end of the intubation attempt.

Positioning of the tracheal tube into the oesophagus and alternative airway access manoeuvers were scored. Tube position was verified by fogging of the tube during expiration, symmetrical thoracic movements, auscultation of breath sounds bilaterally, depth of tube placement and capnography. In some cases, ultrasound was used to verify movement of the pleura. All paediatric patients intubated in the presence of the HEMS were included. Paediatric patients intubated prior to arrival of the HEMS were excluded because of lack of proper documentation by EMS personnel. We considered $P < 0.05$ as statistical significant.

Study setting

The Netherlands has a population of over 17 million people and covers an area of 41,543 km^2. There are four HEMS teams in the Netherlands; hence, the country is divided into four areas. Only a small part of the East and Southeast is served by HEMS from centres in Germany just across the border. In the Netherlands HEMS was introduced in 1995, enabling additional care by a medical team to the regular ambulance crew. A HEMS team consists of a physician (board-certified trauma surgeon or anaesthesiologist), a specialized nurse (registered nurse from the Emergency Department [ED] or paramedic) and a helicopter pilot. Rotterdam HEMS has 11 physicians, nine anaesthesiologists and two trauma surgeons. The group of anaesthesiologists receive surgical skill training (chest drain, surgical airway, thoracotomy, etc.); while, the trauma surgeons receive extended anaesthesia training for two months. During this training, because of the high incidence of paediatric patients, they also receive training in paediatric anaesthesia by our Paediatric Anaesthesia Department for two weeks.

A specially designed emergency vehicle is used if the incident is close by or the weather prevails. According to national protocol by EMS Dispatch HEMS can be dispatched primarily or secondarily by the EMS crew at the incident location. On average it takes around 8 minutes to get to the scene. Sometimes HEMS is first on scene.

The HEMS follows the same medical protocols and acts in close collaboration with the EMS. After a few years it became protocol to activate HEMS for stabilizing vitally compromised or seriously injured children because EMS frequently asked HEMS for assisting these children.

Selection of participants

All children under the age of 18-years on the day of the emergency call were extracted for analysis. From 2012 to 2017, we selected all consecutive patients who required tracheal intubation. After identifying all intubations in paediatric patients, we analysed data regarding the first attempt success rate, intubation attempts, success by operator type, patient age, medication given prior to intubation, and type of intubation. Inclusion criteria were out-of-hospital paediatric ETI by the Rotterdam HEMS. For the purpose of this study, intubations were classified as with or without medication. The intubation medication includes at least an anaesthetic induction agent and a neuromuscular blockade, sometimes combined with an opioid. The intubations performed without medication occurred during cardiopulmonary arrest. The first-look laryngoscopy was defined as the first passage of the laryngoscope blade between the lips with intention to intubate the trachea, whether or not this led to passage of an endotracheal tube. Maximum efforts were made to complete the dataset. Data not found are reported as unknown in the results. Patients primarily treated in other hospitals and then transferred to our hospital were excluded.

Ethics approval

The Medical Ethical Committee of the Erasmus University Medical Center (MEC-2018-1376) approved this study.

RESULTS

In a six-year period (2012-2017), Rotterdam HEMS received 16674 calls in total, of which 7706 (46%) missions were cancelled by EMS before arriving at the scene. Of the 8968 patients treated, 1905 (21%) were paediatric patients. In this six-year period, 2609 patients underwent ETI in the prehospital setting, including 361 paediatric patients. Of these paediatric patients, 280 were intubated by a HEMS physician. Due to missing data, only 273 intubations could be analysed (Figure 1). The overall success rate was 276 (98.5%) and the first attempt success rate was 227 (81%) (Table 1). There is no significant different in the overall or first attempt success rates when the patient was intubated in a classic manner or a video-assisted device (McGrath video laryngoscope) was used

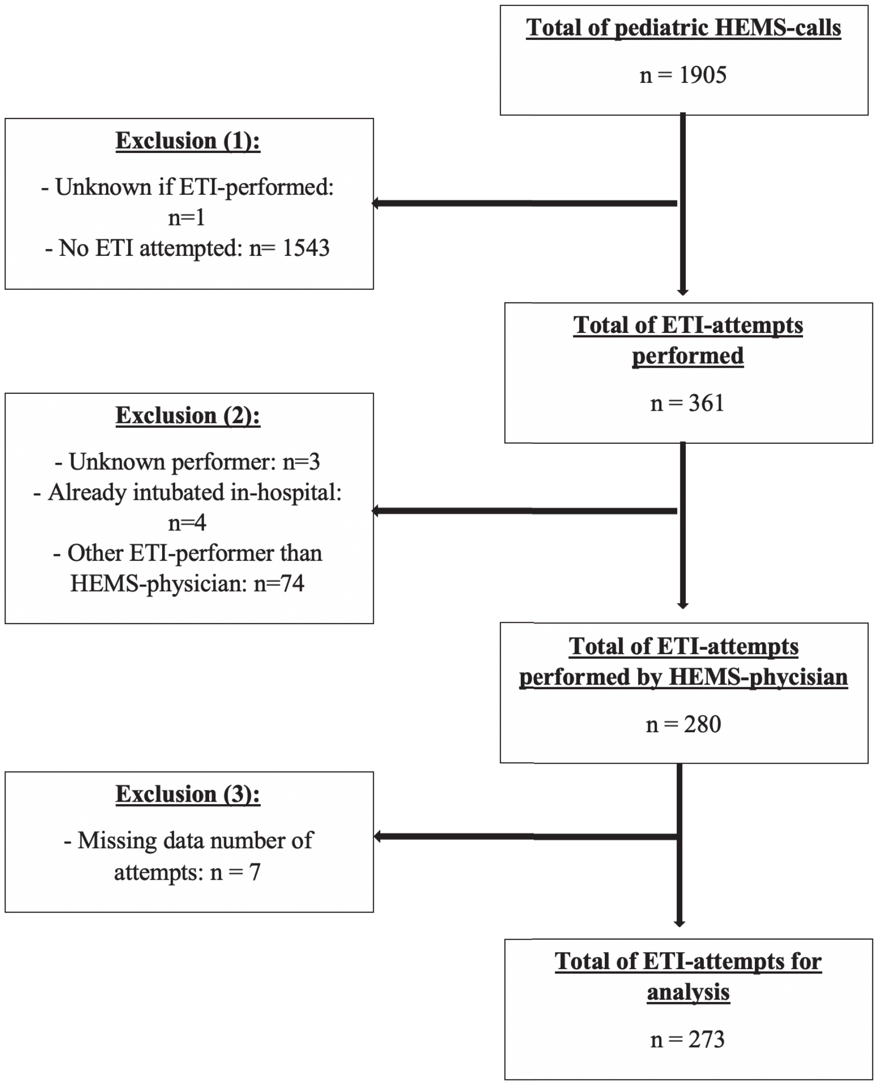

Figure 1: Total intubations with exclusions.

Table 1. Number of intubation attempts in relation to overall and first pass success rate.

	Number of intubation attempts	1st attemp	2nd attemp	3rd attemp	4th attemp	failed intubation
HEMS Physician	273	221	41	5	2	4
Overall success rate		81%	96%	97,8%	98,5%	
First pass succes rate		81%				

Table 2. Classic vs video assisted intubation.

	Classic laryngoscopy	Video assisted laryngoscopy	Unknown device
Number off attempts	174	76	23
Overall success rate	173 (99,4%)	76 (100%)	n.a.
First pass success rate	142 (81,6%)	61 (80,3%)	n.a.

Table 3. Intubation related to age. A: Attempt; O: Overall success; FP: First Pass; F: Failed intubation

Age In years	Number ETI attempts	Overall success rate	First pass	Anesthesiologist A/O/FP/F	Trauma Surgeon A/O/FP/F
0-1	54	51 (94,4%)	34 (63%)	48/45/30/3	6/6/3/-
1-2	30	30 (100%)	24 (80%)	28/28/23/-	2/2/1/-
2-3	22	22 (100%)	20 (90,9%)	21/21/20/-	1/1/0/-
3-4	18	18 (100%)	15 (83,3%)	18/18/15/0	0/0/0/0
4-5	8	8 (100%)	7 (87,5%)	7/7/6/-	1/1/1/-
5-6	10	10 (100%)	8 (80%)	7/7/6/-	3/3/2/-
6-7	9	9 (100%)	6 (66,7%)	6/6/5/-	3/3/1/-
7-8	4	4 (100%)	2 (50%)	2/2/1/-	2/2/1/-
8-9	9	9 (100%)	6 (66,7%)	9/9/6/-	0/0/0/0
9-18	92	91 (98,9%)	86 (93,5%)	79/78/78/1	14/14/13/-
Unknown	17	17 (100%)	12 (70,6%)	15/15/11/-	2/2/1/-

Table 4. Intubation with or without assistance of medication.

Intubations	Assisted by medication	non medication assisted
Number of attempts	174	99
Overall success rate	174 (100%)	95 (96%)
First pass success rate	154 (88,5%)	67 (67,7%)

Table 5. Overall and first pass success rate by intubator.

	Anesthesiologist	Trauma Surgeon
Number of attempts	238	35
Overall success rate	234 (98,9%)	35 (100%)
First pass success rate	197 (82,8%)	24 (68,6%)

(Table 2). Table 3 shows an overview of the patient's ages in this study population. Fifty-four (20%) children under the age of 1-year were intubated.

ETI assisted by medication (at least an induction with a hypnoticum (Etomidate, Propofol or Ketamine) in combination with a muscle relaxant (Rocuronium or Suxamethonium), sometimes an opioid was added (Fentanyl)) had a significantly higher first attempt rate than ETI without medication (during CPR) (88.5% vs. 67.7%, p = 0.0002) (Table 4). Anaesthesiologists intubated 238 paediatric patients; whereas, trauma surgeons intubated 35 paediatric patients. For the whole group together, there was no significant difference in success rates when intubated by an anaesthesiologist vs. a trauma surgeon (p = 0.09) (Table 5). When examining intubations with and without medicine, the anaesthesiologist had a significantly better success rate; medication-assisted first attempts: 95% CI (2.8485 to 39.2547) p = 0.0133.

In four (1.5%) paediatric patients, ETI failed. All four were performed by an anaesthesiologist. Two failed because the vocal cords could not be visualized. The other two cases had trismus of the jaw; one of these cases surgical airway was performed. The reasons why more than one attempt was needed were: Not been able to visualize vocal cords (18), view obscured by vomit (5) or blood (1), tube size too big (2) or too small (uncuffed tube) (1), laryngoscope blade malfunction (1), difficult intubation due to facial trauma (1), corpus alienum (1), or unknown (22). The overall success rate was 100%, except in the age groups: Zero to one year of age and 15 to 16-years of age. The first attempt success rate was lower in younger children (Table 3) and in paediatric patients in cardiopulmonary arrest (the non-medication group). No unrecognized oesophageal intubations were discovered at admission to the hospital.

DISCUSSION

Several studies have examined prehospital paediatric ETI performed by paramedics or emergency physicians from different clinical backgrounds, but little is known about children who undergo prehospital ETI by anaesthesiologists or anaesthesia-trained trauma surgeons [3-6,13-18,24]. Looking at the whole group, we could not find a significant difference when intubated by an anaesthesiologist or an anaesthesia-trained trauma surgeon. This is likely because the number of intubations was not large enough in the second group. Only two of a total of 11 physicians in the Rotterdam HEMS are trauma surgeons. The two trauma surgeons only intubated 35 paediatric patients, but if divided proportionally they should have intubated 50. This could be because they might have a higher threshold for performing paediatric intubations and may try to get to the hospital earlier to avoid intubating these patients in a prehospital setting. When taking a closer look at medication-assisted intubation, a significant difference was found in favour of the anaesthesiologist; medication assisted 1st pass: 95% CI (2.8485 to 39.2547) p = 0.0133.

Compared with the study by Hansen, et al. [12], our analysis showed a higher rate of successful first attempts (81% vs. 68.9%) and a higher rate of overall success (98.5% vs. 81.1%). Our study had a comparable overall success rate (98.5% vs. 98.6%) to Schmidt, et al. [22], who examined highly trained physicians who intubated paediatric patients. Our success rate is comparable to in-hospital paediatric emergency ETI [25]. Like in other studies, the group of paediatric patients under the age of one year and the group of paediatric patients intubated under cardiopulmonary arrest (non-medication group) had lower first attempt rates in our study. If the group of paediatric patients under the age of one year was removed, the first attempt success rate would be 85% which is in line with other studies on physician-performed paediatric intubations. If we removed the intubations done by trauma surgeons, the first attempt success rate would be 92%, which is in line with the study done by Schmidt, et al. [22], looking at highly trained physicians (92% vs. 95%). As stated earlier, we could not find a significant difference between the intubations performed by an anaesthesiologist vs. a trauma surgeon, but this may be due to limited numbers of patients.

In the prehospital setting, tracheal intubation is more difficult and can be challenging than when performed in hospital under controlled conditions [4-7]. This is why alternative airway devices, such as laryngeal tubes or laryngeal mask airways, have particular value for prehospital use because they require less training and have a high success rate with low incidence of complications. In the Netherlands, a previous study by Moors, et al. [15] showed that paediatric intubation by an EMS team has a high rate of failure and complications. It also showed that the overall success rate of ETI by EMS was 57%, which is in the lower range compared with other studies [12]. Thus, ETI should not be performed by EMS in The Netherlands. But tracheal (paediatric) intubation offers unparalleled advantages such as uninterrupted chest compressions during cardiopulmonary resuscitation, facilitation of invasive ventilation with monitoring of end tidal CO2, high inspiratory airway pressures with or without positive end expiratory pressure (PEEP) [26] indicating that the threshold for deployment of a physician-staffed HEMS in The Netherlands should be low for paediatric patients with a compromised airway.

Of all 1905 paediatric calls, 361 (19%) paediatric patients were intubated. This large number of paediatric intubation means that HEMS are frequently called to critically ill or severely injured children who require securing of their airway. As stated earlier, success rates are generally lower for out-of-hospital and even in-hospital paediatric intubation due to lack of training or experience with paediatric patients and paediatric intubations [14,15,20]. Successful airway management requires training, skills, and ongoing experience to consistently perform these procedures in an effective, timely, and safe manner [12/a>]. Our results from the Rotterdam HEMS indicate their success rate is high, and rates were similar for the adult population and in-hospital emergency paediatric ETI [25], indicating that this is a critical but safe procedure when performed by the HEMS physician. This could be due to their frequent training and exposure to critically ill and severely injured paediatric patients.

LIMITATIONS

This was a single centre retrospective study which is a major limitation. Furthermore, essential parts of our evaluation relied on self-assessment. Therefore, we could not rule out potential bias associated with under-or-over-rating as well as under-or-over-reporting of events. However, only seven patients were excluded due to missing data.

CONCLUSION

Prehospital intubation of critical injured or ill paediatric patients has a high success rate when performed by HEMS physicians in The Netherlands. This emphasizes the additional value of the physician-staffed HEMS and that the threshold for deployment of HEMS should be low in cases of a potentially compromised airway in paediatric patients. The first attempt and overall success rates were significantly higher for Dutch HEMS physicians compared with ambulance paramedics in the Dutch prehospital setting. Thus, we advise that Dutch ambulance paramedics should be cautious about intubating paediatric patients without HEMS supervision.

Conflict of Interest Statement

The authors have no conflict of interest to disclose.

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No funding was received.

Article Summary

1. Why is this topic important?

Little is known about the success rate and complications of paediatric endotracheal intubation in a prehospital setting performed by a Helicopter Emergency Medical Service (HEMS) and poor performances are seen for all providers of emergency medical care due to a lack of frequent exposure to paediatric patients and paediatric intubations.

2. What does this study attempt to show?

The primary endpoints of this study were the first attempt and overall success rates for out-of-hospital, at the scene paediatric endotracheal intubation by physician-led HEMS. Secondary endpoints were the type of intubation (direct laryngoscopy or video-assisted intubation using the McGrath video laryngoscope); complications of airway management, including failure of intubation; success by operator type; patient's age, and medication-assisted intubation.

3. What are the key findings?

Prehospital intubation of critical injured or ill paediatric patients has a high success rate when performed by HEMS physicians in The Netherlands. The overall success rate was 98.5% and the first attempt success rate was 81%. ETI assisted by medication had a significantly higher first attempt rate than ETI without medication (88.5% vs. 67.7%, $p = 0.0002$). When examining intubations with and without medicine, the anaesthesiologist had a significantly better success rate; medication-assisted first attempts: 95% CI (2.8485 to 39.2547) $p = 0.0133$.

4. How is patient care impacted?

This emphasizes the additional value of the physician-staffed HEMS and that the threshold for deployment of HEMS should be low in cases of a potentially compromised airway in paediatric patients. The first attempt and overall success rates were significantly higher for Dutch HEMS physicians compared with ambulance paramedics in the Dutch prehospital setting. Thus, we advise that Dutch ambulance paramedics should be cautious about intubating paediatric patients without HEMS supervision.

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Bedankt!
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CHAPTER 3

Pediatric out-of-hospital cardiopulmonary resuscitation by helicopter emergency medical service, does it has added value compared to regular emergency medical service?

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ABSTRACT

Purpose

To determine the outcome of out-of-hospital (OOH) cardiopulmonary resuscitation (CPR) and the advanced life support (ALS) procedures provided in pediatrics by the Rotterdam Helicopter Emergency Medical Service (HEMS) METHODS: Retrospective evaluation of all pediatric (0-17 years) OOH cardiopulmonary arrests within a 6-year period and attended by the Rotterdam HEMS team.

Results

There were 201 OOH CPRs from October 2008 until October 2014. Endotracheal intubation was performed in 164 cases and done by HEMS in 104 patients (63%), intraosseous/intravenous cannulation 43/27 times, and additional medication given by HEMS in 70 patients (35%). The overall survival rate for OOH CPR was 15%, but in trauma was low. Twenty-seven of the 29 pediatric patients who survived until discharge are neurological well. Although the Dutch nationwide ambulance protocol states intubation, intravenous, or intraosseal excess and medication, in many patients, only HEMS provided additional ALS care.

Conclusion

The HEMS brings essential medical expertise in the field not provided by regular emergency medical service. HEMS provide a significant quantity of procedures, obviously needed by the OOH CPR of a pediatric patient.

INTRODUCTION

The Helicopter Emergency Medical Service (HEMS) was introduced in The Netherlands in 1995, enabling the delivery of a medical team to the scene in addition to the regular ambulance service. A HEMS team consists of a physician (board-certified anesthesiologist or trauma surgeon), a specialized nurse [Paramedic or Registered Nurse from the Emergency Department (ED)] and a helicopter pilot.

The Emergency Medical Service (EMS) protocol in The Netherlands is a nationwide protocol with precise description of procedures to follow, but the ambulance crew is limited in expertise and experience in vitally compromised children [1, 2]. When HEMS became operational, EMS frequently secondary asked for assistance in stabilizing vitally compromised children. After a few years, it became protocol to activate HEMS primarily in vitally compromised children. Prehospital data concerning pediatric EMS and / or pediatric HEMS in The Netherlands are lacking and it is difficult to extrapolate research done in other countries due to the differences in their HEMS and EMS organizations and HEMS dispatch criteria. Previous studies show a low survival rate in pediatric out-of hospital cardiopulmonary resuscitation (OOH CPR) [3–7]. This study was done to assess the survival rate and outcome in OOH CPR in pediatric patients treated by the Rotterdam HEMS. It is difficult to measure the expertise that leads to additional care provided by HEMS. To do so, we wanted to evaluate the medical interventions done either by the HEMS or by the EMS and to examine how often the HEMS provided this additional medical care, which was or could not be pro- vided by the EMS.

METHODS

We performed a retrospective analysis of a database in which every patient treated by Rotterdam HEMS is registered. Only patients under the age of 18 on the day of the emergency call were included in the period October first 2008 until October first 2014. We selected all consecutive patients who underwent OOH CPR.

We considered an OOH cardiopulmonary arrest when EMS and /or HEMS objectified the indication of OOH CPR by clinical assessment, because it is difficult for a non-professional to assess if an arterial pulse is present in a pediatric patient [8]. The Pediatric Basic Life Support (PBLS) guidelines also advise PBLS providers when in doubt to start CPR. This study included pediatric patients by PBLS providers (police or fire brigade) only when an automatic external defibrillator (AED) gave a shock, this to avoid pediatric patients with poor circulation but with cardiac output.

Patients primarily treated in other hospitals and then transferred to our hospital were excluded.

After identifying all pediatric OOH CPR cases, we analyzed all ALS procedures, done by EMS and /or HEMS and the outcome of every case. We divided the groups in trauma, drowning, CPR at birth and non-trauma. The non-trauma group includes patients who do not fit in one of the other groups, for example, septic patients or patients with cardiomyopathy, etc. The unknown group consists of patients, due to missing data, and we did not know which group they belonged to.

Our primary outcome parameters were survival and success rate of ALS procedures, such as intubation, venous access, and intraosseal access. Secondary predictors were cause of OOH CPR and first rhythm.

RESULTS

A total of 201 pediatric OOH CPRs were selected in the database (Table 1).

Nine patients (4%) were lost to follow up and we could not assess if they survived and were discharged from hos- pital. Out of the 192 subjects, 29 patients survived to discharge from hospital (15%). Two of them suffered from severe neurological disability. In eight patients, there was no registration of the indication of OOH CPR, due to missing data (one hospital refused to give data). Mean age is 5.0 years with a range 0–16.9 years. The first rhythm related to survival until discharge from hospital is shown in Table 2. In the survivor group, all pediatric patients showed return of spontaneous circulation (ROSC) before leaving the incident scene to hospital.

HEMS performed intubation in 104 patients, 79 intubations were done by EMS alone and eight by EMS under direct supervision by an HEMS physician. Unsuccessful primary intubations by EMS without supervision occurred in 40 of 79 intubations (51%). In 27 of the 40 unsuccessful intubations, EMS tried to intubate, but failed, another seven tubes were placed intraesophageally, four intrabronchially, and one neurotrauma pediatric patient was intubated after ROSC without additional medication. The overall success rate by EMS was 57 versus 99% for HEMS. Only one intubation done by HEMS failed, because the patient could not be intubated due to rigor mortis, and the team feels responsibility to the parents to carry on for psychosocial reasons.

Table 1 OOH CPR by cause and number of survivors

Cause of out-of-hospital arrest	Number of patients	Percentage of total OOH CPR	Survivors	Percentage survivors/ group
Trauma	45	22	2	4
Drowning	26	13	8	31
At Birth	7	3	4	57
Non-trauma	115	57	15	13
Unknown	8	4	0	0
Total	201		29	

Intravenous access was successfully achieved in 76 patients, 27 by HEMS versus 41 by EMS (8 unknown). Intraosseal access was achieved in 139 patients, 43 by HEMS versus 33 by EMS (63 Unknown). Intraosseal dislocation (first attempt successful in bone marrow then dislocated) was found in four patients and extraosseal placement in 14 patients (not in bone marrow), all done by EMS.

ALS procedures in the survivor group are shown in Table 3. HEMS did the majority of these procedures. Failures by EMS were extubation by accident (1), intra- bronchial intubation (1), leakage due to too small tube size (1), tube intraesophageal (2), and failed intubation [tried to intubate but not succeeded (3)]. In the survivor group, 15 pediatric patients received medication by HEMS not mentioned in the nationwide EMS protocol, such as sedation, relaxation, antibiotics, and medication to regulate blood pressure.

Table 2. First Rhythm with number of patients related to survival until discharge from hospital.

First rhythm	Number of patients	Number of patients who survived until discharge	Percentage (%)
Asystole	130	7	5
Bradycardia	26	6	23
Unknown	14	7	50
Ventricular fibrillation	9	7	78
Ventricular tachycardia without output	1	1	100
Pulseless electrical activity	12	1	8
Sinus tachycardia	9	0	0

Table 3. ALS procedures in survivor group by HEMS and/or EMS

ALS procedure	HEMS	EMS with HEMS supervision	EMS	EMS failure	
Intubation	23	2	10	8	2 not intubated
IO access	10		6	3	
IV access	8		3		
Medication not stated in APLS guidelines	15				

ALS: Advanced Life Support, APLS: Advanced Pediatric Life Support, EMS: Emergency Medical Service, HEMS: Helicopter Emergency Medical Service, IO Intra osseous, IV: intra veneous.

DISCUSSION

We found a 15% survival rate in OOH CPR of children. Studies in other countries [3–7] show lower survival rates (2.1–11%). A possible explanation is the group of low- risk OOH CPR at birth. The Netherlands has a high number of planned birth delivery at home. In the 90s, 35% of pregnant women had a planned delivery at home. In 2012, still, 20% of pregnant women had a planned delivery at home. Although delivery at home is decreasing, a significant number of pregnant women choose to deliver at home rather than a (planned) delivery in hospital. In other countries, the vast majority of women have planned birth in hospital rather than at home. To compare this study to others, taking out the OOH CPR at birth, the overall survival rate would be 13% instead of 15%. When HEMS became operational, EMS frequently secondary asked for assistance in stabilizing vitally compromised children. After a few years, it became protocol to activate HEMS primarily in vitally compromised children and over the years HEMS gained more and more experience. Nowadays, 21% of all calls are concerning pediatric patients. That could also be an explanation why the survival rate from the early years has gone up to 13%.

In our study, EMS performed less ALS procedures than HEMS. Maybe, EMS would have done more ALS procedures if HEMS took more time to get on scene or was not available. However, in a large number of cases, HEMS arrived later at the scene, but EMS only provided BLS care; in cases, they also should have performed ALS procedures.

HEMS did the majority (73%) of ALS procedures in the survivor group of 29 patients. Especially the patients who were intubated not correctly or had a non-working intraosseous access, HEMS could have altered the outcome by emergency correction of the endotracheal tube and /or intra- osseous cannulation (Table 3). In addition, intubation done by an HEMS physician was more successful than by an EMS paramedic. Members of HEMS have more training, experience and exposure. Successful intubation in children seems to be a difficult task for EMS paramedics [1, 9, 10]. Bag-mask ventilation is to be preferred to a failed intubation effort, even if bag-mask ventilation is suboptimal [9]. Pediatric airway skills decay quickly after training because of the low-call volume, and endotracheal intubation skills drop off more significantly than bag-mask ventilation skills [11]. HEMS had to perform an emergency correction of the tracheal tube in 11 patients (14%). In the opinion of the authors, this is an unacceptable rate. Because of the high rate of unsuccessful intubations, EMS in The Netherlands should not intubate children.

It is difficult to measure long-term neurological out- come in (very) young children. Only few of them had a prior admission to hospital, which make it difficult to objectively assess a small neurological deficit. Two pediatric patients were obviously severely neurological impaired and scored severe disability based on a modified Pediatric Cerebral Performance Category Scale [12]. After the incident, they remained in a wheelchair and are not able to perform normal activities of daily living. The other 27 survivors are scored in the category normal or no change from baseline or mild disability. There is no previous scoring so it is difficult to set a baseline, but most of the children in this group score conform other children of their age.

All survivors in our study had ROSC before transport to hospital. This could mean that there is time to set up a good BLS and ALS rather than “scoop and run” to hospital.

Prior to our study and prior to 1997 (the start of Rotterdam HEMS), there are no studies available with only EMS and OOH CPR in pediatric patients performed in The Netherlands with outcome known to the authors.

Another finding was that HEMS delivered additional medication, not stated in national EMS protocol to 70 patients. Most of the medication was given after ROSC, for instance, medication to regulate blood pressure (and thus cerebral blood perfusion), sedation, or antibiotics in sepsis.

The retrospective design of this study may be considered as a limitation. In addition, in nine (4%) patients, there were missing data and we could not assess if they lived up to discharge from hospital.

After reviewing all pediatric out-of-hospital cardio pulmonary resuscitations (OOH CPRs), 29 patients (15%) survived until discharge. The Helicopter Emergency Medical Service (HEMS), especially the younger the patients, performed the majority of the advanced life support (ALS) skills, such as intubation, intraosseous, and /or intravenous access, and had less failures than in procedures performed by Emergency Medical Service.

Therefore, we conclude that Helicopter Emergency Medical Service brings essential skills and expertise to the scene of out-of-hospital cardio pulmonary resuscitation in pediatric patients.

ACKNOWLEDGEMENTS

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COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest

None.

Funding

No external funding was received for this study.

Ethics approval

The Medical Ethical Committee of the Erasmus University Medical Center (MEC-2015-428) approved this study.

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CHAPTER 4

Nationwide retrospective analysis of Out-of-Hospital Pediatric Cardio Pulmonary Resuscitation treated by all four Dutch Helicopter Emergency Medical Service in the Netherlands.

Moors XRJ, Oude Alink MB, Bouman S, De Leeuw MA,
Hoogerwerf N, Weelink EE, Den Hartog D, Stolker RJ

Accepted in Air Medical Journal

ABSTRACT

Introduction:

There is generally limited but conflicting literature on incidence, causes and outcomes of pediatric out-of-hospital cardiac arrest. This study was done to determine the incidence and outcome of pediatric out-of-hospital cardiac arrest reported by all helicopter emergency medical services in the Netherlands, and a description of causes and treatments and in particular, a description of the specific interventions that can be performed by a physician-staffed helicopter emergency medical service.

Methods:

A retrospective analysis was performed of all documented pediatric (0<18 years of age) out-of-hospital cardiac arrest from July 2015 to July 2017, attended by all four Dutch helicopter emergency medical service teams.

Results:

202 Out-of-hospital cardiac arrests were identified. The overall incidence in the Netherlands is 3.5 out-of-hospital cardiac arrest in children per 100,000 pediatric inhabitants. The overall survival rate for out-of-hospital cardiac arrest was 11.4%. 11 (52%) of the survivors are in the drowning group and at the age between 12 to 96 months.

Conclusion:

The Helicopter Emergency Medical Service are frequently called to pediatric OHCA in the Netherlands. Survival rate is normal to high compared to other countries. The age group 12 to 96 months and drowning seem to have a relatively favorable outcome.

Keywords

HEMS; pediatric; prehospital; cardiopulmonary resuscitation; Survival

INTRODUCTION

Cardiorespiratory arrest is a rare event during childhood that needs immediate treatment in order to achieve the best chances of survival without neurological damage. There is a lack of studies on incidence, causes and outcome of pediatric out-of-hospital cardiac arrest (OHCA) as a result of a missing reporting system in the Netherlands. Internationally reported pediatric OHCA incidences range widely from 6.0 to 19.7 per 100,000 pediatric person-years [1-5], as do reported survival rates (from 0% to 19%) [1-8]. One study reported 233 pediatric OHCA cases with a survival rate of 9% during a study period of four years in a part of the Netherlands [9].

The paramedics in the Netherlands are all Registered Nurses (RN), of whom the vast majority has a background as Intensive Care Unit, Emergency Department or Anesthetic nurses. On top they receive an additional training of nine months followed by an exam before they are allowed to work individually within EMS. The EMS protocol in the Netherlands is a nationwide protocol with precise description of procedures to follow, but the ambulance crew is limited in expertise and experience in vitally compromised children [11,13]. Nevertheless EMS is authorized, as stated in the nationwide protocol, to perform ALS procedures on pediatric patients.

Helicopter Emergency Medical Service (HEMS) was introduced in order to deliver a trained medical specialist (physician), anesthesiologist or surgeon, to the scene in addition to a regular ambulance crew. There are four HEMS teams covering the entire area of the Netherlands. Pediatric OHCA is one of the primarily dispatch criteria for HEMS in the Netherlands [10,11]. There is limited data on the incidence and outcome of pediatric OHCA in the Netherlands and the benefit of HEMS deployment in this.

The primary aim of this study was to assess the incidence and outcome of pediatric OHCA reported by all HEMS services in the Netherlands. Additionally, causes and treatments of pediatric OHCA were analyzed, as well as specific interventions performed by HEMS. The aim of this study was to gain insight in the presumed added value of HEMS on pediatric OHCA in the Netherlands. Secondarily to identify which pediatric patients are more at risk and which are surviving in order to adjust training or create awareness.

METHODS

Study setting

The Netherlands has a population of over 17 million people covering an area of 41,543 km^2. In 2020 there were approximately 2.9 million people younger than 18 years of age living in the Netherlands [12]. HEMS is dispatched either primarily according to national protocol by Emergency Medical Service (EMS) Dispatch or secondarily by the EMS at the incident location. When HEMS became operational in 1995, EMS frequently secondary asked for assistance because of limited expertise and experience in vitally compromised children [11,13]. After a few years (well before the study period) it became standard protocol to activate HEMS primarily in vitally compromised children 10. Since February 2011 HEMS is 24/7 available by helicopter but if the weather conditions are below limitations or in case the incident is so nearby, a specially designed emergency vehicle is used to transport the HEMS team. Since the start of HEMS in 1995, all four HEMS stations have received over 80,000 calls, of which around 35,000 were canceled by EMS prior to arriving. Nowadays 22% of patients treated are under 18 years of age.

Study design

A retrospective analysis was performed on all 4 HEMS databases where all patients, treated by one of four HEMS, are registered. When needed, additional data was obtained from receiving hospitals. Patients were selected who had a documented OHCA and were under the age of 18 on the day of the emergency call between July 2015 and July 2017. One year follow up was performed to determine if patients were still alive. Survival status was obtained by inquiry of the civil registry from the government. The latest date of follow-up was considered June 18, 2018.

Data collection

Inclusion was based on documented OHCA, either confirmed by clinical assessment by EMS/HEMS personnel, or by a shockable rhythm on Automatic External Defibrillator analysis prior to EMS arrival. This to avoid the inclusion of pediatric patients with poor but spontaneous circulation [14].

Patients primarily treated in other hospitals and then transferred by HEMS were excluded.

All cases were divided into groups; medical, traumatic, drug overdose, drowning, electrocution, asphyxial and not recorded based on Utstein Resuscitation registry templates for out-of-hospital cardiac arrest [15]. Due to the high prevalence in the Netherlands of home delivery, a specific group of resuscitation at birth was made [16]. The following data were extracted from the registries: Age, initial rhythm, defibrillation, time to HEMS on scene, medical interventions, vascular access, administered medication, airway intervention, outcome and primary cause of cardiac arrest.

Statistical analyses

Categorical variables are presented as numbers and percentages. Complete case analyses were performed.

RESULTS

Patient characteristics and incidence of pediatric OHCA

During the study period, 202 pediatric OHCA cases were identified. 17 patients were excluded due to missing baseline data (figure 1).

In 19 patients no exact age was recorded (only age in years) and could not be determined afterwards. Baseline characteristics are presented in table 1. Table 2 gives an overview of cause of OHCA. Most cases were between 12 months and 96 months of age and this was also the group with the highest survival percentage. 58% patients were male, 42% were female. In the group of pediatric patients with a medical cause of OHCA, 45 (41%) had a previous medical history.

The overall incidence of OHCA in the Netherlands is 3.5 OHCA per 100,000 pediatric inhabitants (0<18 years of age) but varies by region between 0 and 17.2 per 100,000 pediatric inhabitants (Table 3).

Figure 1.

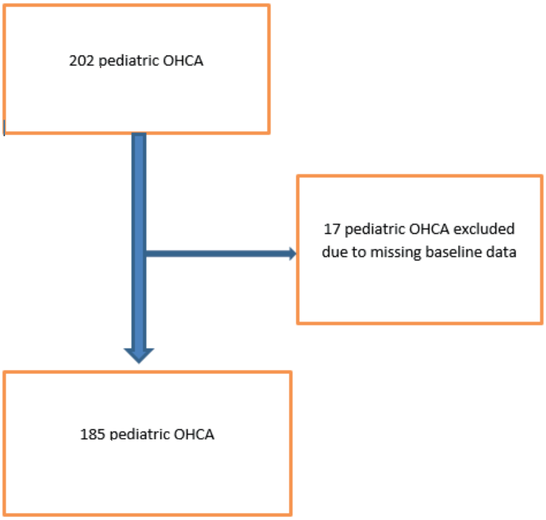

Table 1. One year survival and initial rhythm by age.

Age (Months)	Total	VF/VT	PEA	Asystoly	Unknown rhythm	Survival
0-1	27	0	6 (22%)	16 (59%)	5 (19%)	4 (15%)
1-12	41	2 (5%)	2 (5%)	31 (76%)	6 (15%)	0
12-96	59	4 (7%)	9 (15%)	39 (66%)	7 (12%)	12 (20%)
96-216	58	8 (14%)	11 (19%)	29 (50%)	10 (17%)	5 (9%)
Total	185	14 (8%)	28 (15%)	115 (62%)	28 (15%)	21 (11%)

VF; ventricular fibrillation, VT; Ventricular Tachycardia (without output), PEA; Pulseless electric activity.

Table 2. Cause of out-of-hospital cardiac arrest (OHCA) and survival.

Cause of OHCA		Survival
Medical	104 (56%)	4 (4%)
Traumatic	30 (16%)	1 (3%)
Drug overdose	1 (1%)	0
Drowning	26 (14%)	11 (42%)
Electrocution	0	0
Aphyxial	14 (8%)	3 (21%)
OHCA during birth	10 (5%)	2 (20%)
Not recorded	0	0
Total	185	21 (11%)

Table 3. Number of pediatric OHCA per 100.000 inhabitants (0<18 years of age). (OHCA; out of hospital cardiac arrest).

Region	Number of pediatric OHCA	Inhibitants (0<18 years of age)	Number of pediatric OHCA per 100,000 inhabitants (0<18 years of age)
1.Groningen	10	104,444	9.6
2.Friesland	7	121,646	5.8
3.Drenthe	9	85,462	10.5
4.Ijsselland	4	93,540	4.3
5.Twente	0	118,139	0
6.Noord-Oost Gelderland	3	139,854	2.1
7.Gelderland-Midden	7	112,424	6.2
8.Gelderland-Zuid	3	88,335	3.4
9.Utrecht	9	188,039	4.8
10.Noord-Holland-Noord	9	108.431	8.3
11.Zaanstreek-Waterland	6	54,063	11.1
12.Kennemerland	8	89,581	8.9
13.Amsterdam Amstelland	23	133,708	17.2
14.Gooi- en Vechtstreek	4	40,810	9.8
15.Haaglanden	13	168,848	7.7
16.Hollands-Midden	7	123,536	5.7
17.Rotterdam-Rijnmond	32	215,794	14.8
18.Zuid-Holland-Zuid	6	70,330	8.5
19.Zeeland	4	66,967	6.0
20.Midden-West Brabant	11	178,719	6.2
21.Brabant Noord	12	110,170	10.9
22.Brabant Zuid-Oost	4	115,405	3.5
23.Limburg-Noord	4	83,674	4.8
24.Limburg-Zuid	0	98,880	0
25.Flevoland	7	71,813	9.7

Centraal Bureau voor Statistiek, www.cbs.nl, bevolking per veiligeheidsregio.

Initial rhythm and advanced life procedures

Non-shockable rhythm was the most often observed initial rhythm (77%), asystole was identified in 62% and pulseless electric activity in 15% of pediatric patients. Shockable rhythms were present in 8% and varies with age (table 1). In 15% of the cases no record of initial rhythm could be found (table 1).

In pediatric patients endotracheal intubation is done by HEMS in 88%, 91% in first or second attempt. Eventually none of the intubations performed by HEMS were inserted into the esophagus. In 4% (6 cases) intubation was unsuccessful, this was caused by stiffness of the jaw or the pediatric patient had a syndrome associated with difficult airway. In one of these cases a surgical airway was performed, the other five remained on bag-valve-mask ventilation which was successful (adequate movement of the chest). In two cases dislocation of the endotracheal tube occurred, but this was quickly recognized and the tubes were immediately reinserted.

Nineteen (12%) intubations were performed by EMS. In ten cases EMS tried to intubate but failed. In four patients the endotracheal tube was placed in the esophagus and had to be correctly inserted by HEMS on arrival. One endotracheal tube was placed to deep and had to be corrected on HEMS arrival. One endotracheal tube was too small and ventilation was ineffective. This tube was replaced by HEMS on arrival. Insertion of a Laryngeal Mask Airway (LMA) was performed in ten cases, in one case this was not successful.

In OHCA cases caused by trauma, ten thoracostomies and two thoracotomies were performed.

HEMS established 32 intra osseous (IO) access. In one case HEMS used ultrasound for IV access. EMS performed 61 IO access procedures. Of them 16 (27%) IO needles/accesses were not placed correctly.

In 23 OHCA cases, CPR was discontinued on HEMS decision after evaluation on scene. EMS was not able to make the decision for discontinuing or not starting with CPR, but it was obvious for HEMS that these patients were diseased due to prolonged time before starting CPR or extensive trauma.

HEMS follows European Resuscitation Council guidelines [14] for administration of medication during CPR, as does EMS. HEMS more often administers adrenaline while EMS is allowed to give this medication as well, because EMS could not obtain IV/IO access and even when access was achieved EMS did sometimes not administer adrenaline. Before and after CPR, HEMS is allowed to give all kinds of medication not listed in nationwide EMS protocols, such as sedation, relaxation, antibiotics, blood pressure medication etc. which is frequently administered by HEMS.

Transport mode and timelines

77% calls were executed by helicopter and 23% by car. Median time from initial 112 call to HEMS arrival on scene is 18 minutes (range 3-40 minutes). HEMS responds by car if the incident is nearby, weather conditions are too poor to fly or if maintenance is performed on the helicopter.

Survival

In the 185 pediatric patients who could be followed up for mortality data, 21 patients survived one year after discharge from hospital (11.4%). Survival with a shockable rhythm was higher (18.2%) as compared to a non-shockable rhythm (5.3%). Of the 21 survivors, 11 suffered from drowning. The surviving patients who drowned are all in the age category 12-96 months of age. In the age group 1-12 months there were no survivors.

DISCUSSION

In this nationwide retrospective database study 202 pediatric patients with OHCA were identified. The highest number of OHCA in pediatric patients occurred in the two ambulance regions with the largest cities of the Netherlands. In these two cities (Amsterdam and Rotterdam) two out of four HEMS are situated. The volume of pediatric prehospital care is normally higher in urban regions than in rural areas [17,18] as can be seen in table 2. The other two ambulance regions where HEMS is stationed received 9.6 (Groningen) and 6.2 (Gelderland-Midden) pediatric OHCA per 100,000 pediatric inhabitants. These two HEMS are active in a more rural area. This can also be seen in the response times (table 4), the time from initial 112 call and HEMS arriving on scene, is prolonged in these two rural areas due to the increased distance to the scene. Other differences between the different HEMS team could not be found, e.g. difference in success rate for intubations, intra osseous insertion etc. due to small numbers.

This study showed a 11.4% survival which is a little higher than a previous study done in only one region in the Netherlands which showed a survival of 9% [9], but is within the normal to high range when compared to other studies [1-8]. In only one study a 19.4% survival [8] was found because they added respiratory arrest and cardiac arrest together. Six out of 31 pediatric patients survived, but four of them only had respiratory arrest and no cardiac arrest. The pediatric patients in our study were all in full cardiac and pulmonary arrest. Excluding this previous study, the Netherlands has a relatively high number of pediatric OHCA survival.

Although shockable rhythms are not frequent in children, the presence of VF or pulseless VT as initial rhythm represented higher chances of sustained return of spontaneous circulation and higher survival at hospital discharge when compared to asystole and PEA [19]. This study showed that in 14 out of 185 (8%) patients had a shockable rhythm and had a 18.2% chance of survival. There were even 2 patients in the age group 1-12 months who had an initial shockable rhythm (table 1). This percentage was also seen in a larger study in 1193 pediatric patients by Fukuda et al 20, which stated that 7.1% had a shockable rhythm in an out-of-hospital setting. The better prognosis in patients with shockable rhythms implies their greater reversibility potential. Therefore, focusing efforts on early CPR, shockable rhythm recognition, and rapid defibrillation should remain a priority alongside with focus on airway and ventilations.

The patients in the drowning group seem to be in favor of surviving. Of the 21 survivors, 11 (52%) suffered from drowning so they could be more in favor of surviving. Before the drowning occurs, these patients are healthy and only suffer from sudden hypoxia. If health care providers or lay persons can quickly react and reverse this hypoxia, these children seem to have the highest chance of survival. The patients with the lowest survival belong to the medical and trauma group.

10 OHCA occurred in pediatric patients during birth. Two (20%) survived one year after until discharge from hospital. In the Netherlands in 2016, there were 21,434 planned home births guided by midwives alone without further obstetric assistance, accounting for 12.7% of all births that year [16]. It seems that in only a small amount of patients assistance of HEMS is needed, which is in line with a previous study done in the Netherlands [16].

As can be seen in the result section, intubation by EMS has a high failure rate (46%) and should not be performed by EMS in the Netherlands anymore. This high intubation failure rate was also found by a previous study 21 in the

Netherlands. When placing an IO access HEMS has no failure rate. Failure rate by EMS for IO access is 27%.

Pediatric OHCA is a primarily deployment criteria for HEMS and thus all 112 calls regarding pediatric OHCA should lead to deployment of HEMS. Two regions have no deployments for HEMS in pediatric OHCA. These two regions (Twente and Limburg-Zuid) are the two regions that are the most far away to reach by helicopter. In the early years these two regions could receive additional medical help from a German HEMS but only during daylight. A few years ago it became standard to deploy HEMS from the Netherlands, also because they are available 24/7, but apparently still there are no deployments for OHCA in pediatric patients. Maybe paramedics in these regions don't want to wait for HEMS and perform a scoop and run to the nearest hospital. However a previous study by our group showed there were no survivors in the Netherlands in pediatric patients after scoop and run in OHCA was performed 21.

The regions with an urban area have more than 7 OHCA in pediatric patients per 100,000 pediatric inhabitants. Only one region (Utrecht) is below this number. Utrecht is an urban region and one could expect that there should be more pediatric OHCA's. One of the reasons could be that HEMS is not easily deployed in that region.

Study limitations.

Because only a nationwide mandatory reporting system for OHCA in pediatric patients, which is still not present in the Netherlands, would ensure capture all OHCA cases, we might have missed some cases. Although pediatric OHCA is a primarily deployment criteria for HEMS, we could have missed some cases where HEMS was activated but time to scene was prolonged and EMS performed a scoop and run to the nearest hospital which could have occurred in Twente or Zuid Limburg region.

Another limitation is the database itself. We searched 4 databases and found incomplete data which is an inherent limitation of a retrospective database research.

CONCLUSION

The Helicopter Emergency Medical Service are frequently called to pediatric OHCA in the Netherlands. Survival until discharge with a follow up to one year after the incident is 11.4% and higher than average in Europe. Overall incidence in the Netherlands is 3.5 OHCA per 100,000 pediatric inhabitants (0<18 years of age), but not all provinces in the Netherlands are equally represented in the number of pediatric OHCA. The age group 12 to 96 months and drowning show a relatively favorable outcome. A shockable rhythm is rare but can still be found. These patients have a higher chance of sustained return of spontaneous circulation and a higher survival at hospital discharge. EMS has poor success with pediatric intubation.

RECOMMANDATIONS

The data in this study suggests that better education/training/skills for the EMS providers could improve patient outcomes.

Create a national database for pediatric OHCA with neurological follow up in order to stratification of the outcome for survival.

ACKNOWLEDGMENTS

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CONFLICTS OF INTEREST

The authors report no conflict of interest.

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ETHICS APPROVAL

The Medical Ethical Committee of the Erasmus University Medical Center (MEC-2017-346) approved this study.

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CHAPTER 5

A Physician-Based Helicopter Emergency Medical Services Was Associated With an Additional 2.5 Lives Saved per 100 Dispatches of Severely Injured Pediatric Patients

Moors XRJ, Van Lieshout EMM, Verhofstad MHJ, Stolker RJ, Den Hartog D.

Air Medical Journal 2019 Jul - Aug;38(4):289-293

ABSTRACT

OBJECTIVE:

Physician-based helicopter emergency medical services (HEMS) provide specialist medical care to the accident scene in order to improve the survival of severely injured patients. Studies that focus on the role of physician-based HEMS in pediatric trauma are scarce. The aim of this retrospective, observational study was to determine the effect of physician-based HEMS assistance on the survival of severely injured pediatric patients.

METHODS:

All consecutive severely injured pediatric patients (age < 18 years and Injury Severity Score > 15) treated between October 1, 2000, and February 28, 2013, were included. The survival of patients who received medical care of physician-based HEMS was compared with the survival of patients treated by an ambulance paramedic crew (ie, emergency medical services group) only. A regression model was developed for calculating the survival benefit in the physician-based HEMS group.

RESULTS:

A total of 308 patients were included; 112 (36%) were primarily treated by emergency medical services, and 196 (64%) patients received additional physician-based HEMS assistance on scene. The model with the best diagnostic properties and fit contained physician-based HEMS assistance, 3 components of the Glasgow Coma Scale (eye, motor, and verbal) scored prehospitally (before intubation), ordinal values for the Injury Severity Scale, systolic blood pressure, and respiratory rate. This model predicted that 5 additional patients survived because of physician-based HEMS assistance. This corresponds with 2.5 additional lives saved per 100 physician-based HEMS dispatches for severely injured pediatric patients.

CONCLUSION:

The data suggest that an additional 2.5 lives might be saved per 100 physician-based HEMS dispatches for severely injured pediatric patients.

INTRODUCTION

Worldwide trauma remains among the top leading causes of death before the age of 40 years.[1] In the Netherlands, malformation at birth is the number 1 cause of death among children aged 0 to 1 year. From 1 to 14 years of age, trauma is the leading cause, and between 15 and 18 years of age, it is the second cause of death.[2]

In the last 20 years, a number of studies have been performed to assess the effects of the implementation of helicopter emergency medical service (HEMS). The vast majority of these studies showed a possible beneficial effect of HEMS on survival,[3-6] with a range from 2.8 to 19 extra survivors per 100 patients treated. However, all of these studies focus on an adult population. Very little is known regarding children. To the best of our knowledge, in the pediatric population, only 5 studies on HEMS and pediatric trauma exist.[7-11] Most of these studies focus on mode of transport, and it is difficult to identify if physician-based HEMS has added (medical) value[10] in the pediatric trauma population or improves survival. This study was performed to evaluate if physician-based HEMS improves outcomes in severely injured pediatric patients in the Netherlands.

The Netherlands has a population of over 17 million people and covers an area of 41,543 km2. Prehospital medical care is primarily provided by an emergency medical service (EMS) system covering the entire country and staffed by paramedics. These paramedics are registered nurses, of whom the vast majority have a background of intensive care unit, emergency department, or anesthesia departments. They receive an additional training of 9 months. The EMS in the Netherlands works according to a nationwide protocol with a precise description of procedures to follow. EMS teams travel by ground-based ambulance and aim to provide medical care at the incident site and transport the patient to an appropriate hospital. EMS only has a limited protocol and expertise in vitally compromised children.[12,13]

On top of this system, 4 physician-based HEMS teams cover approximately 95% of the surface of the Netherlands. Physician- based HEMS was introduced in 1995, enabling the transportation of a specialized medical team to support the ambulance crew at the incident scene. Since February 2011, physician-based HEMS availability is 24/7 countrywide. The team travels by helicopter or uses a special designed vehicle if weather conditions are too poor to fly or the destination is close by. A physician-based HEMS team consists of a board-certified anesthesiologist or trauma surgeon, a specialized nurse (EMS paramedic or registered nurse from the emergency department), and a helicopter pilot. Physician-based HEMS are dispatched either primarily by an EMS dispatch center based on infor- mation of the accident and according to nationwide criteria or secondarily by the EMS paramedics who are at the incident location asking for assistance because of the condition of the patient.

When HEMS became operational, EMS frequently asked for assistance in stabilizing vitally compromised or seriously injured children. Nowadays, HEMS is activated primarily in vitally compromised or seriously injured children. Currently, in the Netherlands, 21% of the patients treated by HEMS are children. This is unique for a European- based HEMS. Prehospital data on outcomes concerning pediatric EMS and/or physician-based HEMS in the Netherlands and other countries are lacking. Moreover, it would be difficult to compare our performance with studies performed in other countries because 1) our physician-based HEMS system is not primarily designed to transport the patient but rather to bring an experienced physician to the accident scene, 2) differences in physician-based HEMS team composition and dispatch criteria are present, and 3) differences in the study methodology and outcome measures used might hamper reliable comparison. The aim of the present study was to determine the effect of physician-based HEMS assistance (in combination with EMS assistance) versus paramedic-staffed EMS assistance alone on the survival of severely injured pediatric patients.

PATIENTS AND METHODS

Setting and Population

This retrospective, observational study was performed at a level 1 trauma center (1 of 4 level 1 trauma centers in the Netherlands with a physician-based HEMS) that serves the Southwest of the Netherlands with 4.9 million inhabitants. All consecutive severely injured pediatric patients (age < 18 years because in the Netherlands pediatric medicine consists of all patients under 18 years of age and Injury Severity Score [ISS] > 15) presenting at the emergency department between October 1, 2000, and February 28, 2013, were included from the National Trauma Registry. The National Trauma Registry does not include medical interventions. Exclusion criteria were interhospital transport, transport other than by EMS or physician-based HEMS, trauma mechanism other than blunt or penetrating trauma (eg, drowning, strangulation, electrocution, or inhalation injury), and patients for whom data were incomplete. The deployment of the physician-based HEMS changed from operating hours of 7:00 AM to 7:00 PM or daylight (whichever came first) to 24-hour availability from January 2009 (by helicopter in daylight and by car during nighttime). Since February 2013, physician-based HEMS is available 24 hours by helicopter. The team composition remained the same throughout the study period; just mode of transport to the patient is different. Nowadays, if the incident is nearby, the same team operates by a specially designed emergency vehicle instead of using the helicopter. The local medical research ethics committee exempted the study (no. MEC-2005-073).

Data Collection

The primary outcome was injury-related mortality within 30 days after admission. Injuries were coded using the Abbreviated Injury Score (Abbreviated Injury Score 98).[14,15] Data regarding age, sex, injury mechanism (ie, blunt or penetrating), type of prehospital care (ie, physician-based HEMS or EMS), ISS, Glasgow Coma Scale (GCS, when intubated before intubation and when not intubated on arrival at the emergency department), vital signs before intubation or on arrival at the emergency department (ie, systolic blood pressure, respiratory rate, and heart rate), and mortality were obtained from the National Trauma Registry (Landelijke Trauma Registratie). Missing data from the Landelijke Trauma Registratie were supplemented with data from hospital files. Three continuous variables were converted to an ordinal scale: GCS (RTS1), systolic blood pressure (RTS2), and respiratory rate (RTS3).

Statistical Analysis

Statistical analyses were performed using SPSS Version 21.0 (IBM Corp, Armonk, NY). Two groups were compared. Patients in the EMS group had received assistance from the ambulance paramedic crew only, and patients in the physician-based HEMS group had received additional care from a physician-staffed mobile medical team at the accident scene or during transport to the hospital. Descriptive analysis was performed in order to compare the 2 groups. Because all continuous variables were nonnormal, the statistical significance of the difference between the groups was evaluated using the Mann-Whitney U test. Categoric variables were compared using the chi-square or Fisher exact test.

The most commonly applied method for calculating the probability of survival of trauma patients is the Trauma Injury Severity Score (TRISS) methodology. In this methodology, the coefficients of the regression model were calculated from the Major Trauma Outcome Study population, a large North American trauma population.[16]

The TRISS methodology is only valid if the distribution of injury severity of the population under study equals that of the Major Trauma Outcome Study population. This is the case if the M statistic is 0.88 or higher.[17] For calculation of the M statistic, the revised coefficients of the National Trauma Data Bank for the TRISS methodology were used.[18] The M statistic in the current study population was 0.678, which shows that the TRISS methodology does not adequately compensate for confounders in the current population. Therefore, a custom-fitted binary logistic regression model was constructed in order to reliably calculate the probability of survival in the current study population based on the most accurate coefficients. A detailed procedure has been published previously.[6] First, correlation with survival was calculated for each variable. A Spearman rank correlation coefficient was calculated for nonnormal continuous variables and ordinal variables; a phi coefficient was determined for dichotomous variables.

Variables with a P value $<.05$ were tested in the multivariable model.

Next, a multivariable binary logistic regression model was built. Mortality served as the dependent outcome, and the study group (ie, physician-based HEMS or EMS) was included in all models. All possible combinations of variables were entered into the model to find the best model. The best model had a high goodness of fit (ie, P value for Hosmer-Lemeshow statistic $>$ .05), high discriminative ability (ie, large area under the receiver operating characteristic curve), and good diagnostic performance (ie, high specificity, sensitivity, positive predictive value, and negative predictive value).

The coefficients of the best model were used for calculating the probability of survival in 2 scenarios. The first scenario contained the observed data, with physician-based HEMS and EMS available. In the second scenario, all patients were hypothesized to have received EMS assistance only. The difference between the total observed survival in the first scenario and the total predicted survival in the second scenario was calculated as a measure of the survival benefit because of physician-based HEMS. The survival benefit is expressed as the number of lives saved per 100 physician-based HEMS dispatches.

RESULTS

During the study period, 366 severely injured pediatric patients were treated at the emergency department (Fig. 1). Ten patients were excluded because they were transported from another hospital, and data were incomplete for another 48 patients. A total of 308 patients remained for analysis: 112 (36%) in the EMS group and 196 (64%) in the physician-based HEMS group.

In the excluded group, 28 (48.3%) patients had received EMS assistance alone, and 30 (51.7%) had received additional physician-based HEMS assistance. The type of prehospital care (P = .105), ISS (P = .115), sex (P = .879), injury mechanism (P = .396), and mortality (P = .070) of the excluded patients did not differ statistically significantly from the included population (data not shown). However, the excluded group had a lower median age (9 years, 25th percentile-75th percentile: 3-15) than the included group (13 years, 25th percentile-75th percentile: 7-16, P = .003).

The baseline characteristics and vital parameters of the physician- based HEMS and EMS groups are shown in Table 1. The majority of patients were male (67.2%), the median age was 13 years, and 92.5% of the patients suffered from blunt trauma. These parameters were not statistically significantly different between the physician-based HEMS and EMS groups. Patients in the physician-based HEMS group had a lower median GCS (P < .001), lower systolic blood pressure (P = .021), and were more severely injured (median ISS: 25 vs. 19, P <.001) than in the EMS group. The respiratory rate (P = .260) and heart rate (P = .709) were similar in both groups.

Overall, 64 patients died: 52 (26.5%) in the physician-based HEMS group versus 12 (10.7%) in the EMS group. Univariate analysis showed this to be different (P = .001). The multivariable model was developed in order to correct for this inherent bias on mortality. Multivariable analysis also allowed isolating the effect of physician-based HEMS on mortality. Table 2 shows the correlation coefficients of the variables with mortality. Only the variables statistically significantly correlated with mortality were used as covariates in the multivariable model. All possible combinations were tested, and the 5 best models are shown in Table 3. The best model (Hosmer-Lemeshow coefficient: 8.962, P = .346, area under the curve = 0.904, sensitivity = 92.6%, specificity = 70.3%, positive predictive value = 71.4%, and negative predictive value = 92.2%) contained the type of prehospital care; separate eye, motor, and verbal scales of the GCS; ordinal variables for ISS; systolic blood pressure (RTS2); and respiratory rate (RTS3).

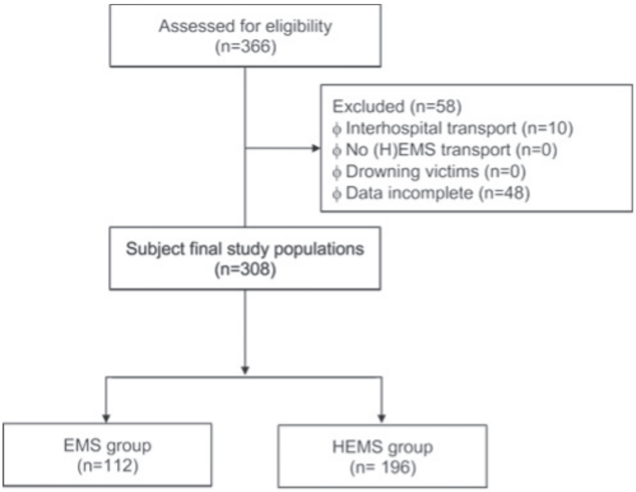

Figure 1. Study population by treatment.

The observed, unadjusted odds ratio for survival was 0.332 (95% confidence interval, 0.169-0.654) in the physician-based HEMS versus the EMS group. Using the model to compensate best for the con- founders, the adjusted odds ratio for survival was 1.208 (95% confidence interval, 0.466-3.128). A total of 144 patients survived in the physician-based HEMS group. Table 3 shows the top 5 models with the best fit. In the best model, 144 patients were predicted to survive in the scenario with physician-based HEMS available, and 139 patients in the scenario in which physician-based HEMS was not available. This projects to the 5 additional survivors (144 minus 139) resulting from physician-based HEMS assistance, which correlates with 2.5 additional lives might be saved per 100 physician-based HEMS dispatches for severely injured pediatric patients.

DISCUSSION

Physician-based HEMS-related survival remains a topic of debate, although beneficial effects of physician-based HEMS dispatch on survival have previously been described in adults.[3,4,5,6] By application of an adequate and custom-fitted regression model with a good discriminative power, the current study suggests that physician-based HEMS assistance resulted in up to 2.5 lives saved per 100 physician-based HEMS dispatches for severely injured pediatric patients. According to the Dutch Ambulance Academy, every paramedic should treat a critically ill or injured child once every 5 years, which means that exposure to vitally compromised children is limited. This is different in HEMS where 21% of patients treated are children, and exposure and expertise in critically ill or injured children are high and could be an explanation of lives saved by HEMS.

Overall mortality is 21%, and mortality in physician-based HEMS group is 27%. Patients with an ISS > 15 were selected, so only severely injured patients are included in these groups and are expected to have a higher mortality rate.

To the best of our knowledge, in the pediatric population, only 5 studies on HEMS and pediatric trauma exist. Three studies focus on mode of transport only.[7,8,11] In these studies, pediatric trauma patients transported by HEMS directly to a level 1 trauma center for children might save 1 life for every additional 41 to 47 children undergoing HEMS transport instead of ground EMS transport (2.1-2.4 lives saved per 100 HEMS dispatches in pediatric trauma). It is difficult to identify if HEMS has added (medical) value10 in the pediatric trauma population or improves survival. By applying an adequate and custom-fitted regression model with a good discriminative power, the current study suggests that physician-based HEMS assistance resulted in a mortality reduction up to 2.5 lives per 100 physician-based HEMS dispatches for severely injured pediatric patients. This is just lower than the published data in adults showing 2.8 to 19 lives saved per 100 patients treated.[3-6] In a previous study,[6] it was shown that dispatch of the same physician-based HEMS, as investigated in the current study, resulted in an additional 5.3 lives saved per 100 dispatches for adult trauma patients. However, a reduction in mortality of 2.5 lives per 100 physician-based HEMS dispatches is at the upper range of the published data for pediatric trauma (2.1-2.4 lives per 100 physician-based HEMS dispatches [7,8]).

Only 4% of all patients in EMS are pediatric patients,19 whereas in physician-based HEMS, 21% of all patients are pediatric patients. Despite the fact that pediatric patients treated by physician-based HEMS are more critically ill or more severely injured than the EMS population, the survival rate is higher. Others found a similar beneficial effect and explained this because HEMS performs Advanced Trauma Life Support on a higher standard than EMS and have much more pediatric experience.[20] EMS should call the physician-based HEMS in an early stage (if not primarily dispatched) when treating (severely) injured pediatric patients. Research in EMS states that Advanced Trauma Life Support skills rapidly deteriorate after training, indicating that frequent training and experience are needed to maintain these skills, which is quite challenging given the limited resources and competing needs for training.[21] Successful Advanced Trauma Life Support procedures and skills require training, skills, and ongoing experience to consistently perform these procedures in an effective, timely, and safe manner.[22]

The enrollment lasted for 13 years, and, thus, longitudinal changes could affect this study. However, according to the Dutch Nationwide Ambulance Academy, every paramedic should treat a critically ill or severely injured child once every 5 years. This number has not changed over the past years, so exposure to vitally compromised children was and is limited. We do not think this has an influence on the outcome in this study. What has changed is the operating hours of HEMS. Until January 2009, there were only 12 hours of HEMS availability; after this date, 24-hour availability was warranted. HEMS treated more patients because they doubled the hours of availability and also treated more pediatric patients. Since then, the number of patients treated is rising, but around 20% of patients treated are pediatric and this number is steady over the last years. We do not think this has an influence on the outcome in this study.

Table 1. Characteristics and vital parameters of the study population divided by HEMS and EMS assistance

	Overall (N=308)	HEMS (N=196)	EMS (N=112)	P-value
Male[1]	207 (67.2%)	125 (63.8%)	82 (73.2%)	0.102[a]
Age (years)[2]	13 (7-16)	12 (7-16)	13 (8-16)	0.218[c]
Blunt trauma[1]	285 (92.5%)	184 (93.9%)	101 (90.2%)	0.263[a]
ISS[2]	24 (17-29)	25 (18-34)	19 (17-26)	<0.001[c]
ISS Group[1]				
16-24	162 (52.6%)	85 (43.4%)	77 (68.8%)	<0.001[b]
25-49	128 (41.6%)	96 (49.0%)	32 (28.6%)	
50-74	15 (4.9%)	12 (6.1%)	3 (2.7%)	
≥ 75	3 (1.0%)	3 (1.5%)	0 (0.0%)	
GCS[2]	8 (3-14)	4 (3-12)	12 (8-15)	<0.001[c]
Eye[1]				
No eye opening	157 (51.0%)	127 (64.8%)	30 (26.8%)	<0.001[b]
Eye opening to pain	20 (6.5%)	9 (4.6%)	11 (9.8%)	
Eye opening to verbal	49 (15.9%)	23 (11.7%)	26 (23.2%)	
command	82 (26.6%)	37 (18.9%)	45 (40.2%)	
Eyes open spontaneously				
Motor[1]				
No motor response	107 (34.7%)	94(48.0%)	13 (11.6%)	<0.001[b]
Extension to pain	9 (2.9%)	7 (3.6%)	2 (1.8%)	
Flexion to pain	15 (4.9%)	11 (4.6%)	4 (3.6%)	
Withdrawal from pain	14 (4.5%)	4 (2.0%)	10 (8.9%)	
Localizing pain	53 (17.2%)	27 (13.8%)	26 (23.2%)	
Obeys commands	110 (35.7%)	53 (27.0%)	57 (50.9%)	
Verbal[1]				
No verbal response	149 (48.4%)	125 (63.8%)	24 (21.4%)	<0.001[b]
Incomprehensible sounds	33 (10.7%)	17 (8.7%)	16 (14.3%)	
Inappropriate words	17 (5.5%)	6 (3.1%)	11 (9.8%)	
Confused	24 (7.8%)	8 (4.1%)	16 (14.3%)	
Orientated	85 (27.6%)	40 (20.4%)	45 (40.2%)	
SBP (mmHg)[2]	125 (110-141)	123 (105-140)	130 (114-148)	0.021[c]
RR (breaths/min)[2]	18 (15-24)	18 (15-24)	20 (15-25)	0.260[c]
RTS1 (GCS)[1]				
GCS = 3	105 (34.1%)	92 (46.9%)	13 (11.6%)	
GCS 4-5	16 (5.2%)	12 (6.1%)	4 (3.6%)	<0.001[b]
GCS 6-8	42 (13.6%)	28 (14.3%)	14 (12.5%)	
GCS 9-12	43 (14.0%)	18 (9.2%)	25 (22.3%)	
GCS 13-15	102 (33.1%)	46 (23.5%)	56 (50.0%)	
RTS2 (SBP)[1]				
SBP <50 mmHg	12 (3.9%)	9 (4.6%)	3 (2.7%)	0.055[b]
SPB 50-89 mmHg	25 (8.1%)	21 (10.7%)	4 (3.6%)	
SBP ≥90 mmHg	271 (88.0%)	166 (84.7%)	105 (93.8%)	

	Overall (N=308)	HEMS (N=196)	EMS (N=112)	P-value
RTS3 (RR)[1]				
RR 0-5 breaths/min	14 (4.5%)	8 (4.1%)	6 (5.4%)	0.844[b]
RR 6-9 breaths/min	4 (1.3%)	2 (1.0%)	2 (1.8%)	
RR 10-29 breaths/min	253 (82.1%)	161 (82.1%)	92 (82.1%)	
RR ≥30 breaths/min	37 (12.0%)	25 (12.8%)	12 (10.7%)	
Heart Rate (HR)[1]				
HR 0 beats/min	10 (3.2%)	6 (3.1%)	4 (3.6%)	0.709[b]
HR 1-60 beats/min	10 (3.2%)	8 (4.1%)	2 (1.8%)	
HR 61-100 beats/min	132 (42.9%)	80 (40.8%)	52 (46.4%)	
HR 101-140 beats/min	130 (42.2%)	88 (43.9%)	44 (39.3%)	
HR ≥141 beats/min	26 (8.4%)	16 (8.2%)	10 (8.9%)	
Mortality[1]	64 (20.8%)	52 (26.5%)	12 (10.7%)	0.001[a]

Data are shown as 1number of patients with percentages, or as 2median with P25-P75. Statistical significance of difference between the HEMS and EMS group was tested using aFisher's Exact test, bChi squared analysis, or cMann Whitney U-test.

Eye/Motor/Verbal, individual components of GCS; HR, Heart Rate; ISS, Injury Severity Scale; RR, Respiratory Rate; GCS, Glasgow Coma Scale; RTS, Revised Trauma Score; RTS1, categorical variable for Glasgow Coma Scale; RTS2, categorical variable for blood pressure; RTS3, categorical variable for respiratory rate. SBP, Systolic Blood Pressure.

The retrospective design of the current study may be considered a limitation. Also, only pediatric patients who reached the hospital are included in this study. Pediatric patients who died prehospital or during transport are not included because this is not recorded in the National Trauma Database (Landelijke Trauma Registratie). Because physician-based HEMS is dispatched to high-impact trauma such as severe road traffic accidents at high speed, crashes with trucks, or a pedestrian hit by a car, as one would expect, pediatric patients who received physician-based HEMS assistance were more severely injured than patients in the EMS group. This was taken into account by adding ISS as a covariate in the multivariable model. Another limitation is that this study had a relatively small population of 308 patients, which made the multivariable modeling more challenging. However, the final model showed adequate diagnostic properties (ie, positive predictive value = 71.4% and negative predictive value = 92.2%).

Table 2. Correlation of variables with mortality

	Correlation Coefficient	P-value
Male[1]	0.001	0.997[a]
Age (years)[2]	0.007	0.905[b]
Blunt trauma[1]	0.068	0.235[a]
ISS[2]	0.349	<0.001[b]
ISS Group[2]	0.412	<0.001[b]
GCS[2]	-0.486	<0.001[b]
Eye[2]	-0.407	<0.001[b]
Motor[2]	-0.485	<0.001[b]
Verbal[2]	-0.452	<0.001[b]
SBP (mmHg)[2]	-0.299	<0.001[b]
RR (breaths/min)[2]	-0.154	0.007[b]
RTS1 (GCS)[2]	-0.456	<0.001[b]
RTS2 (SBP)[2]	-0.428	<0.001[b]
RTS3 (RR)[2]	-0.150	0.008[b]
HR (beats/min)[2]	-0.055	0.340[b]

HR, Heart Rate; ISS, Injury Severity Scale; RR, Respiratory Rate; GCS, Glasgow Coma Scale; RTS,Revised Trauma Score; RTS1, categorical variable for Glasgow Coma Scale; RTS2, categorical variable for blood pressure; RTS3, categorical variable for respiratory rate. SBP, Systolic Blood Pressure.

Table 3. Goodness-of-fit and discriminative ability of five best binary logistic regression models

Variables included in the model	N	H-L coefficient	**H-L p-value**	AUC	PPV	NPV
Basic + E + M + V + RTS2 + RTS3	308	8.692	0.346	0.904	71.4%	92.2%
Basic + E + M + V + RTS2 + RR	308	6.646	0.575	0.905	71.4%	92.2%
Basic + E + M + V + RTS2	308	9.953	0.268	0.904	71.4%	92.2%
Basic + RTS1 + RTS2 + RR	308	7.296	0.505	0.901	71.2%	91.2%
Basic + RTS1 + RTS2 + RTS3	308	7.714	0.462	0.898	70.7%	90.8%

The basic set of variables contained ISS (as category) and the type of pre-hospital care (*i.e.*, EMS or HEMS). The goodness of fit was determined using the Hosmer-Lemeshow statistic (H-L coefficient with p-value), and the discriminative ability was determined by the Area Under the receiver operating Curve (AUC). The positive predictive value (PPV) and negative predictive value (NPV) were calculated. The model with the best fit, indicated in bold, contained the basic set of variables with the RTS1 and RTS2 score.

E, Eye score of Glasgow Coma Scale; M, Motor score of Glasgow Coma Scale; V, Verbal score of Glasgow Coma Scale; RTS, Revised Trauma Score; RR, Respiratory Rate.

CONCLUSIONS

The data suggest an additional 2.5 lives might be saved per 100 dispatches of the physician-based HEMS in the Netherlands.

Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.amj.2019.04.003.

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CHAPTER 6

Prehospital blood transfusion in pediatric patients by a helicopter emergency medical service

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ABSTRACT

Objective:

In the prehospital setting, the Nijmegen and Rotterdam helicopter emergency medical services administer packed red blood cells to critically ill or injured pediatric patients. Blood is given on scene or during transport and is derived from nearby hospitals. We summarize our experience with prehospital blood use in pediatric patients.

Methods:

The databases from both the Nijmegen and Rotterdam helicopter emergency medical services were reviewed for all pediatric (< 18 years) patients who received packed red blood cells on scene or during transport to the hospital.

Results:

Between 2007 and 2015, 10 pediatric patients out of approximately 2,400 pediatric patients received blood in the prehospital setting. The median Injury Severity Score was 41. Seven hospitals delivered blood in the prehospital setting at the scene. All patients were in hypovolemic shock. Two patients died. Two patients were believed to be unexpected survivors; 1 was predicted by the Trauma and Injury Severity Score, and a second unexpected survivor was a neonate who was in hypovolemic shock and cardiopulmonary arrest.

Conclusion:

The incidence of prehospital use of blood in injured or critically ill children is low. This intervention presented a potential to limit acid-base disturbance, low hemoglobin levels, and coagulopathy in this group. We believe this cohort also contains 2 unexpected survivors.

INTRODUCTION

Trauma is the leading cause of death in children and young adults.[1] Brain injury remains the leading etiology in this age group. However, hemorrhage contributes to death in up to 30% of cases.[2-5] Despite advances in trauma care, hemorrhage continues to be the leading cause of potential preventable mortality in trauma. Prehospital transfusion of blood minimizes the delay and may decrease mortality and morbidity.[6] In the Netherlands, only doctors, nurse practitioners, and physician assistants are legally allowed to order blood transfusions. In the prehospital setting, a helicopter emergency medical service (HEMS) doctor can order blood either while on scene or before arrival according to the information provided by emergency medical service (EMS) personnel. Police or EMS personnel then collect packed red blood cells (PRBCs) from the nearest hospital to the accident site. Because it takes time to start transporting the patient (eg, extrication time), rather than waiting when arriving at the emergency department to undergo the massive transfusion protocol, PRBCs can be delivered at the incident site. Arrangements have been made with blood banks to facilitate this procedure and to warrant the safety and tractability of PRBCs.[7,8] Prehospital data concerning pediatric PRBC transfusion in the Netherlands and other countries are lacking.[9] In the Netherlands, PRBCs have been standard HEMS equipment since 2017, and they are stored in a tailor-made cooling bag. HEMS uses a preheating device for infusion to prevent hypothermia in the patient.

HEMS was introduced in the Netherlands in 1995, enabling the delivery of a medical team to the scene in addition to the regular ambulance crew. An HEMS team consists of a board-certified anesthesiologist or trauma surgeon, a specialized nurse (paramedic or registered nurse from the emergency department [ED]), and a helicopter pilot. If the weather prevails or in case the incident is near the helicopter station, a specially designed emergency vehicle is used to respond to these calls. HEMS is dispatched either primarily according to the national protocol by EMS dispatch or secondarily by the EMS personnel at the incident location. HEMS acts in close collaboration with EMS and works with identical medical protocols. When HEMS became operational, EMS frequently asked for assistance in stabiliz- ing vitally compromised or seriously injured children. Nowadays, HEMS is activated primarily in vitally compromised or seriously injured children. The objective of this report is to describe our experience with prehospital PRBC transfusion in critically ill or injured pediatric patients and to determine the safety of prehospital use of PRBCs in these children.

The Medical Ethical Committee of Radboud University Medical Center (MEC-2016-2323) approved this study.

METHODS

A retrospective analysis of 2 databases containing every deployment by Nijmegen or Rotterdam HEMS was performed. All children under the age of 18 years on the day of the emergency call were included during the time period of January 1, 2007, to November 30, 2015. All consecutive patients who received PRBCs in the prehospital setting were included. Patients primarily treated in other hospitals and then transferred to Erasmus Medical Center, Rotterdam, Netherlands, or Radboud University Medical Center, Nijmegen, Netherlands, were excluded. Clinical condition/judgment was used to initiate blood transfusion (ie, pulse rate, blood pressure, “blood on the floor and four more,” and nonresponder to fluid therapy). No blood analysis besides glucose testing at the scene was available.

After identifying all pediatric PRBC transfusion cases, we analyzed data regarding vital signs, laboratory findings, and outcome extracted from HEMS databases and local electronic hospital medical records. The primary outcome of this study was 24-hour and 30-day survival. The secondary outcome measures were the hemoglobin (Hb) concentration in the first blood gas analysis at presentation at the ED, trauma-induced coagulopathy (defined as an international normalized ratio >1.5 on admission to the hospital), shock on hospital admission (lactate > 4 mmol/L or baseexcess < -6 mEq/L, registered transfusion reaction, and the probability of survival to calculate unexpected survivors (Trauma and Injury Severity Score [TRISS] methodology).[10]

RESULTS

Ten patients out of approximately 2,400 pediatric patients (<0.1%) met the inclusion criteria of this retrospective multicenter descriptive case series. Two (20%) patients were female. The median age for all patients was 12.2 years with a range of 0 to 17 years. Patient demographics are summarized in Table 1. For the primary outcome, 8 patients survived to the 30-day interval, and 2 patients (#5 and 9) died in the first 24 hours. Eight patients suffered blunt trauma, 1 patient sustained a penetrating trauma to the abdomen, and 1 child exsanguinated during delivery because of disruption of the placenta. The median Injury Severity Score (ISS) was 41 with a range of 9 to 66; because of the absence of trauma in 1 patient, ISS could not be calculated.

Ten patients received a total of 5,060 mL PRBCs (Table 1). The most common indication for transfusion was blood loss or a nonresponder to fluid therapy, both with signs of hemorrhagic shock. Five patients underwent operative intervention (damage control surgery) during their hospital stay. The overall median length of intensive care stay for the cohort was 9 days with a range 0 to 31 days. TRISS methodology predicted 2 deaths (patients #5 and 9) by the severity of their injuries (39 and 0.3% probability of survival). A neonate in hypovole mic shock and cardiopulmonary arrest at birth was excluded from TRISS analysis because this was not induced by a trauma. TRISS also identified 1 survivor (patient #7) who was predicted to die (24% probability of survival). This patient sustained extensive trauma, was brought to the operating room, and was admitted 1 day in the intensive care unit.

The results of the patients' first blood analyses are shown in Table 2. The first laboratory findings showed that all Hb levels were well above the transfusion cutoff guidelines; however, PRBCs were given at the accident scene or during transport from the accident scene.

Patient number 9 suffered from cardiopulmonary arrest soon after arriving at the ED and died from his severe injuries (neurotrauma with no autonomic reflexes, bilateral open femur fractures, fractured pelvis, more than 10 rib fractures on the left side, and a lung contusion). No blood analysis was obtained during his short time in the ED. In all 10 cases, it took less time to transport the PRBCs to the patient instead of transporting the patient to a level

1 hospital and starting blood transfusion in the ED. As in other studies,[11,12] no transfusion reactions were reported.

DISCUSSION

We present the first multicenter cohort study of prehospital blood transfusion by HEMS in pediatric patients. One of the unexpected survivors could not be assessed using TRISS methodology because of a nontraumatic origin. This neonate showed cardiopulmonary arrest caused by hypovolemic shock at birth because of placenta disruption. After 90 mL (28 mL/kg) PRBC transfusion, the neonate gained return of spontaneous circulation and was transferred to the hospital. The weight of the neonate in the hospital was 3.2 kg, so the administration of 90 mL PRBCs added one third of the circulating volume of the neonate. The first laboratory findings showed an Hb level of 6 mmol/L, so the Hb level before transfusion would have been below the transfusion threshold. The neonate could not have survived with such a low Hb[13,14]; therefore, we consider this neonate an unexpected survivor. He survived in good condition and is developing in conformity with other children of the same age.

Only 2 out of 10 patients were unexpected survivors. More patients may benefit from early prehospital transfusion of PRBCs because blood must be obtained from the nearest blood bank, which is time-consuming. In some cases, patients already left the scene or failed in a rendezvous with blood brought by police or EMS and might have benefited from prehospital PRBC administration. Nijmegen HEMS started in February 2017 and Rotterdam HEMS started in May 2017 to carry 2 PRBCs in the helicopter for immediate disposal.

Regarding the lethal triad of death in trauma patients,[15,16] the acidosis in patient #6 was far below the normal value, which could have been a contributing factor to her death. One patient (#1) had a lactate level of 13.4 and a base excess of -23, most likely as a result of prolonged resuscitation because of exsanguination.

The blood the children received was cooled for preservation at 4°C. From 2017, when PRBCs became standard in Nijmegen and Rotterdam HEMS, they also introduced a preheating device for infusion to prevent hypothermia in these patients.

Table 1. Demographics, consumption of Packed Red Blood Cells and survival

Patient	Age/Sex	Mechanism of injury	ISS	Indication for PRBC's	Ml of PRBC's transfused prehospital/1st 24 hours of arrival/ ml per kg prehospital	24 hour/30 days survival	TRISS (probability of survival)
1	0/M	Exsanguination of fetus during delivery	NA	Blood loss	90/0/29	+/+	NA
2	16/M	Fall from height	34	Non responder	1000/0/22	+/+	99,2%
3	10/M	Penetrating wound	9	Blood loss	530/1325/17	+/+	95,1%
4	17/M	MVA	33	Blood loss	810/?/17	+/+	99,2%
5	14/M	MVA	43	Blood loss	540/0/14	-/-	39%
6	14/F	MVA	50	Non responder	540/1400/14	+/+	55,6%
7	16/F	MVA	57	Non responder	270/560/7	+/+	23,7%
8	2/M	MVA	34	Non responder	150/280/12	+/+	82,7%
9	16/M	MVA (suicide)	66	Blood loss	530/-/12	-/-	0,3%
10	17/M	MVA	43	Blood loss	600/1660/12	+/+	69,2%

MVA = motor vehicle accident; NA = not applicable

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Table 2. Results of the first blood analysis at Emergency Department

Patient (Age/sex)	Hemoglobuline mmol/L	pH	Lactate mmol/L	Base excess mEq/L	international Normalized ratio (INR)
1 (0/M)	6	7.12	13.4	-23	Not known
2 (16/M)	10.7	7.39	2.3	-0.8	1.1
3 (10/M)	5.2	7.20	5.3	-12	1.3
4 (17/M)	10.2	7.13	6.6	-13.2	Not known
5 (14/M)	8.7	7.33	2	-4.5	1.4
6 (14/F)	6.5	7.05	4.4	-11.6	1.4
7 (16/F)	7.9	7.27	2.5	-7.1	1.4
8 (2/M)	7.8	7.21	3	-5.9	1.4
9 (16/M)	NA	NA	NA	NA	NA
10 (17/M)	9.2	7.37	0.8	-3	1.2

NA: Not available

In this group, all patients had an international normalized ratio below 1.5, so they could not be classified as having trauma induced coagulopathy. This might be the result of the blood transfusion, but more comparative studies on this subject are needed. Maybe we could have given more blood but were cautious not to do so in order to prevent hypothermia or avoid unnecessary transfusion. This policy was supported by the finding that the first Hb levels were well above the transfusion threshold levels according to the guidelines.[17-19]

Although trauma with hemorrhagic shock is the main indication for prehospital PRBC transfusion, in this group there was also a child with a nontraumatic cause of exsanguination. Nontrauma patients may also benefit from prehospital blood transfusion.[20]

The value of prehospital red blood cell transfusion in adult trauma patients is controversial, and a recent systematic literature review in adult patients[21] found no hard evidence. There have only been a few studies performed in the pediatric population with a limited population. The Trauma and Hemostasis Oxygenation Research Network is a rapidly growing society that promotes best practices in hemorrhage resuscitation with an emphasis on remote damage control resuscitation for military and civilian practice. The current state of the art in remote damage control resuscitation focuses on providing the novel blood products, including leukocyte-reduced cold whole blood, to the field. In addition, novel storage methods, such as cold platelets and plasma, are becoming increasingly available as data emerges to their efficacy.[22] In our opinion, the availability of PRBCs will soon be followed by other blood products such as platelets and plasma.

CONCLUSION

In summary, we described a unique cohort of 10 severely injured or critically ill children who were transfused prehospitally with PRBCs. This intervention presented a potential to limit acid-base disturbance, low Hb levels, and coagulopathy in this group. We believe there were 2 unexpected survivors in this group. No transfusion- related complications were demonstrated. Larger comparative studies are needed to identify injured or ill children who may benefit from this treatment. We believe continued evaluation and refinement have the potential to benefit more severely injured and critically ill children in the prehospital setting.

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Jesper, Merijn, Floor
Bedankt!
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CHAPTER 7

Prehospital Management of Peripartum Neonatal Complications by Helicopter Emergency Medical Service in the South West of the Netherlands: An Observational Study

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ABSTRACT

Objective:

Emergency medical service (EMS) is responsible for prehospital care encompassing all ages, irrespective of injury cause or medical condition, which includes peripartum emergencies. When patients require care more advanced than the level provided by the national EMS protocol, an EMS physician-staffed Dutch helicopter emergency medical service (HEMS) may be dispatched. In the Netherlands in 2016, there were 21.434 planned home births guided by midwives alone without further obstetric assistance, accounting for 12.7% of all births that year. However, there are no clear data available thus far regarding neonates requiring emergency care with or without HEMS assistance. This article reviews neonates during our study period who received medical care after birth by HEMS.

Methods:

A retrospective chart review was performed including neonates born on the day of the dispatch between January 2012 and December 2017 who received additional medical care from the Rotterdam HEMS.

Results:

Fifty-two neonates received medical care by HEMS. The majority (73.1%) were full-term (Gestational age > 37 weeks). Home delivery was intended in 63.5%, 20% of whom experienced an uncomplicated delivery but had a poor start of life. The majority of unplanned deliveries (n = 17) were preterm (70.6%). Two were born by resuscitative hysterotomy; 1 survived in good neurologic condition, and the other died at the scene. Fifteen neonates (28.9%) required cardiopulmonary resuscitation; in 2 cases, no resuscitation was started on medical grounds, and 12 of the other 13 resuscitated neonates regained return of spontaneous circulation. In 33 (63.5%) of the neonates, respiratory interventions were required; 8 (15.4%) were intubated before transport. Death was confirmed in 5 (9.6%) neonates, all preterm.

Conclusion:

During the study period, 52 neonates required medical assistance by HEMS. The 5 infants who died were all preterm. In this cohort, adequate basic life support was implemented immediately after birth either by the attending midwife, EMS, or HEMS on arrival. This suggests that prehospital first responders know the basic skills of neonatal life support.

Little is currently known regarding neonates receiving urgent medical care by an emergency medical service (EMS) and/or a physician staffed helicopter emergency medical service (HEMS) in the Netherlands. In our country, HEMS is responsible for urgent medical care for patients of all ages and types of injury or illness.

In cases concerning neonates, HEMS is deployed in addition to EMS by the dispatcher if a complicated planned or unplanned home delivery, an injured or seriously ill pregnant woman, or a critically ill neonate is reported. In case the situation is under control by the standard procedures and can be managed according to the Dutch nationwide ambulance protocol before HEMS is at the scene, the EMS crew can cancel HEMS assistance according to the cancel criteria.[1]

In the Netherlands, HEMS is staffed by a senior anesthesiologist or trauma surgeon with a specialized nurse and a helicopter pilot. Every HEMS physician is minimally trained in advanced pediatric life support and receives additional training on neonatal life support during his or her annual training day. HEMS nurses are trained in neonatal life support and prehospital pediatric life support.

The EMS crew in the Netherlands is staffed by a specialized nurse with training in pediatric life support during his or her basic training. Each EMS nurse is assisted by a paramedic who drives the ambulance and is trained to assist the nurse.

The international literature shows a range of prehospital (planned and unplanned) deliveries of 0.0006% to 1.99%.[2-4] Historically, in the Netherlands, more women chose a home delivery[5,6] compared with Norwegian women (0.2%)[7] and Belgian women (1%).[8] In 2016, 12.7% Dutch deliveries were planned home births guided by specialized registered midwives, and an additional 17.3% delivered their child under the guidance of their midwife in a birth center attached to a hospital where an obstetrician, pediatrician, and anesthetist were directly available.[5]

Only women without any risk factors during their pregnancy are eligible for planned home delivery in the Netherlands.[9] In case of (suspected) complications during labor or a request for (epidural) pain relief, the patient is transferred to a nearby hospital.

In the Rotterdam HEMS dispatch region, there were approximately 40,000 to 45,000 deliveries in 2015.[6] Considering a planned home birth rate of 13%, there are around 5,000 to 5,500 home deliveries in this dispatch region each year.[4,5]

In the Netherlands, previous studies showed no difference in neonatal mortality in low-risk pregnancies for planned home births compared with obstetrician-led childbirth in a hospital.[10,11] Earlier international studies showed that peripartum mortality is higher in the group of unplanned prehospital deliveries compared with hospital deliveries[12]; the neonates who were deceased were of lower birth weight and had a lower gestational age.[2,7]

Our goal was to gain a greater understanding of the frequency and nature of prehospital neonatal emergencies in order to subsequently develop appropriate first responder training material and equipment requirements. The Medical Ethical Committee of the Erasmus University Medical Center (MEC-2018-1375) approved this study.

METHODS

This study was a retrospective database review of the Rotterdam HEMS, which included all patients born on the day of the dispatch between January 2012 and December 2017. Deployments canceled before the HEMS crew had seen the patient are excluded from this database. The charts were reviewed on patient demographics, (estimated) gestational age, (estimated) birth weight, prehospital interventions, and, if available, hospital follow-up and mortality.

From the patients not deceased during the initial assessment by the HEMS crew, we requested the information from the Dutch register of the "Gemeentelijke Basis Registratie" (GBA) registering all citizens by name, sex, date of birth, and, if applicable, date of demise. This information was obtained on June 18, 2018.

All data were analyzed using descriptive statistics with SPSS Statistics Version 24.0.0.1 (IBM Corp, Armonk, NY).

RESULTS

During the 6-year research period, there were 1,905 pediatric patients receiving medical care from the Rotterdam HEMS. Of these, 52 (2.7%) were born on the day of the dispatch (fig 1).

Patient Characteristics

Patient characteristics are depicted in Table 1. Of the 52 patients, 38 patients (73.1%) were full-term (gestational age > 37 weeks). Gestational age was

noted by the HEMS physician in the chart and verified in hospital records if available. There was a normal birth weight of ≥ 2,501 g or more in 26 (50%) of the infants. In 16 (30.8%) of the patients, no record was found of an estimated birth weight.

Table 1 Patient characteristics

	N=52	%
Sex		
Male	28	53.8
Female	12	44.2
Unknown	2	1.9
Full-term (≥37 weeks of gestation)		
Yes	38	73.1
No	12	23.1
Unknown	2	3.8
Birth weight		
ELBW (≤1000g)	6	11.5
VLBW (1000,1-1500g)	2	3.8
LBW (1501-2500g)	2	3.8
Normal (≥2500g)	26	50.0
Unknown	16	30.8

ELBW = extremely low birth weight; LBW = low birth weight; VLBW = very low birth weight.

Intended Location of Delivery

A home birth was intended in 33 (63.5%) of the patients; obstetric data are shown in Table 2. In 1 case, the home delivery was against medical advice because of a known breech position; all others were considered low-risk deliveries. Of the 17 (32.7%) unplanned out-of-hospital births, 2 mothers did not know they were pregnant and did not receive prenatal care. In 3 patients, delivery was planned in the hospital; however, the labor was progressing too rapidly for transport.

Resuscitative hysterotomy was performed for 2 patients by the Rotterdam HEMS crew.

One mother was found in asystole of unknown origin and duration. Hysterotomy was performed on HEMS arrival, 16 minutes after the initial call. At birth, the infant was in asystole and did not regain return of spontaneous circulation (ROSC).

The second mother complained of severe abdominal pain and vaginal bleeding before the witnessed arrest. Basic life support (BLS) was implemented immediately by the spouse, and the resuscitative hysterotomy was performed immediately after the arrival of the Rotterdam HEMS, 12 minutes after the initial call. The child regained ROSC 7 to 10 minutes after birth and has a normal neurologic development at 2 years of age. Both mothers died at the scene.

Table 2 Obstetric data

	N	%
Planned home birth	33	63.5
Prolonged labor	5	
Breech	2	
Unbilical cord strangulation	5	
Meconium	2	
Shoulder dystocia	4	
Precipitous Labor	2	
Partial abruption placentae	1	
Fetal bradycardia during delivery	1	
Normal delivery	6	
Labor not documented	7	
Unplanned out-of-hospital birth	17	32.7
Resuscitative hysterotomy	2	
Precipitous labor	5	
Preterm labor	12	
Breech	1	
Unknown pregnancy	2	
Unknown intended location of delivery	2	3.8

Table 3 Prehospital Interventions and Medication

	Overall, n (%)	Planned Home Dilivery (n=33), n	Unplanned Home Delivery (n=17), n
Respiratory support			
Only rescue breaths	6 (11.5)	6	0
Mechanical ventilation (bag/mask or endotracheal)	20 (38.5)	8	11
Intubation	8 (15.4)	1	7
Cardiopulmonary resuscitation	15 (28.9)	6	9
ROSC	12 (23.1)	6	6
No ROSC	1 (1.9)	0	1
No resuscitation started	2 (3.8)	0	2
Medication EMS		3	1
Adrenaline	1 (1.9)	0	1
Glucose	3 (5.8)	3	0
Medication HEMS			
None	42 (80.8)	29	13
Adrenaline	2 (3.8)	0	2
Atropine	1 (1.9)	1	0
Fentanyl	1 (1.9)	0	1
Midazolam	1 (1.9)	0	1
Glucose	6 (11.5)	3	2

EMS = emergency medical services; HEMS = helicopter emergency medical services; ROSC = return of spontaneous circulation

Prehospital Interventions

The HEMS physician noted in the charts that for all patients the necessary medical interventions were performed directly by the attending midwife or in case of an unguided delivery by EMS or HEMS on arrival. In 19 (36.5%) of the patients, no respiratory or cardiopulmonary interventions were necessary Table 3.

Six neonates were intubated as part of cardiopulmonary resuscitation (CPR). One was intubated because of prolonged bradycardia despite adequate bag mask ventilation and recovered after intubation without thoracic compressions. The last child was intubated because of respiratory insufficiency caused by suspected shunting due to maternal medication use; the mother used a selective serotonin reuptake inhibitor during pregnancy. This infant received midazolam and fentanyl to facilitate intubation.

Table 4 Mortality

	N	%
Deceased < 1 year (n=52)		
Yes	5	9.6
No	14	26.9
Unknown	33	63.5
Deceased/gestation		
Preterm	5 (n=12)	41.7
Full-term	0 (n=38)	0
Unknown	0 (n=2)	0
Deceased/birth weight		
ELBW	2 (n=6)	33.3
VLBW	2 (n=2)	100
LBW	0 (n=2)	0
Normal	0 (n=26)	0
Unknown	1 (n=16)	6.3
Deceased/planned location		
Planned home birth	0 (n=33)	0
Unplanned	5 (n=17)	32.7
Unknown	0 (n=2)	0
Deceased/resuscitation		
Thoracic compressions	3 (n=13)	23.1
No resuscitations started	2 (n=2)	100
No thoracic compressions	0 (n=37)	0
Deceased/intubation		
Intubation	2 (n=8)	25
No intubation	3 (n=44)	14.6

EBLW = extremely low birth weight; LBLW = low birth weight; VLBW = very low birth weight.

In 15 cases, bradycardia < 60 beats/min or asystole was the initial rhythm. In 2 patients, CPR was not started by HEMS on medical grounds. One infant was born alive with an estimated gestation of 16 to 20 weeks and a 400-g birth weight. The other was born in asystole at 24 + 0 weeks of gestation with dysmaturity, a birth weight of 400 g, and dysmorphias. Of the 13 cases of CPR, ROSC was achieved in 12. One child received 3 doses of adrenaline nasally by the EMS crew but no further medication by HEMS. Two other patients received adrenaline intravenously by HEMS.

Care After Delivery and Initial Stabilization

The HEMS crew determines the appropriate hospital and mode of transport for their patients (Fig. 2). The EMS crew requested HEMS assistance during the transport of 2 patients. None of these patients were transported by helicopter, which is typical in our country because of the short distances to an appropriate hospital.

In the Netherlands, 10 hospitals have a level 3 neonatal intensive care unit (NICU) available. In the study cohort, 24 (46.2%) of the newborns were transported to a hospital with a NICU available. Sixteen were transported to Erasmus University Medical Center Rotterdam-Sophia Children's Hospital, the only NICU in the South West of the Netherlands. One was transported to a NICU in Belgium because that was the nearest hospital.

Mortality

From this cohort, 5 neonates died confirmed by demise either during the initial assessment by HEMS or during their hospital stay. Of 13 children, we were unable to obtain data concerning mortality for the GBA because of insufficient demographic data in the medical chart.

Of the 5 neonates who died, the 2 who died at the scene were extremely low birth weight and extremely premature. No resuscitative measures were started on medical grounds by judgment of the HEMS physician Table 4.

One died on arrival at the hospital after secondary deterioration despite all resuscitative measures. This child was born at 24 + 3 weeks; there was anhydramnios due to premature prolonged rupture of membranes since week 18 of gestation. One neonate died after cardiopulmonary arrest in the mother; this child was born at 32 + 0 weeks of gestation by resuscitative hysterotomy. The last infant was born at 29 + 6 weeks with asystole at birth. This child regained ROSC after 20 minutes of CPR but died 1 day later in the NICU after withdrawal of care because of severe neurologic damage.

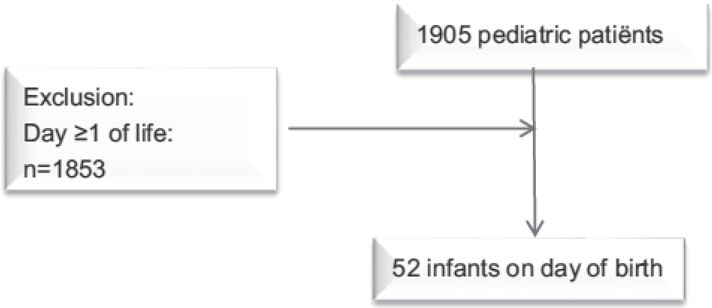

Figure 1. Inclusion/exclusion.

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DISCUSSION

To our knowledge, this is the first study reviewing HEMS assistance in neonatal emergencies on the day of birth in the Netherlands. During the study period, we found no mortality among the planned prehospital deliveries and unplanned full-term prehospital deliveries. However, we were unable to obtain GBA data on all children.

The infants who died in this cohort had a very poor prognosis to start; all were preterm and required CPR directly after birth. Previous studies also showed that mortality was related to the preterm infant with a low birth weight.[2,7]

There are strict criteria for home deliveries in our country; only women with no predetermined risk factors for complications during labor are eligible to start elective delivery at home.[9] The risk for urgent referral due to complications before or during labor in home deliveries is low (ie, 0.4% of all deliveries in the Netherlands).[13] Because of the short distances by road to a hospital, this is usually not a problem.

These strict criteria and the transfer to a hospital during labor might be an explanation why there were only 52 dispatches from an estimate of 30,000 to 35,000 planned home deliveries. Furthermore, this is a possible sign that home deliveries can be safe with the right safety measures. Another possibility is that these 52 are just the tip of the iceberg, considering the lack of data regarding resuscitation or lifesaving interventions in the newborn without HEMS dispatch. After normal delivery, approximately 5% to 10% of infants require some type of assistance after birth, such as bag mask ventilation for successful transition.[14] A previous study showed that approximately 6.4% of the neonates born by unplanned out-of-hospital delivery require prehospital resuscitation, and 14.8% require a form of airway management.[3]

As expected because of the dispatch criteria, this cohort shows a much higher incidence (63.5%) of patients requiring any respiratory support; 15.4% of patients required endotracheal intubation in the prehospital setting. In the Netherlands, HEMS expertise is required for neonatal intubation; this has been removed from the EMS protocol because of limited exposure. EMS does provide bag and mask ventilation, and it is known that training improves the effectiveness of this procedure.[15,16]

CPR is rare after a normal delivery and occurs in less than 0.5% of deliveries.2 As expected because of dispatch criteria, we found a much higher incidence (28.9%) of patients requiring CPR by HEMS. The high success rate of resuscitation in this cohort is potentially caused by the very short delay or no delay to start resuscitative measures by the attending midwife, EMS, or HEMS, depending on who is first at the scene.

In the Netherlands, the training of midwives includes neonatal BLS, and they are required to train in BLS at least 20 hours every 5 years to maintain their license. Their training provides a bridge of care while awaiting the arrival of EMS or HEMS who are trained in advanced life support.

Mandatory basic equipment for midwives includes a ventilation bag and masks suitable for a newborn, an 0.8-L tank of oxygen, suction equipment, and a gastric tube.[17] We found in the HEMS charts that when BLS was started immediately by the first responder, the situation was considerably different compared with a study of unplanned prehospital deliveries in Texas where up to 75% did not receive any resuscitative interventions at all, such as oxygen or bag mask ventilation, until they reached the hospital, resulting in more cardiopulmonary arrests.[2] Although no data are available to determine the effectiveness of paramedic airway management in the newborn baby,[3] it is obvious that withholding or postponing resuscitative measures can lead to deterioration of the neonate’s condition and eventually to death.

During the study period, 2 pregnant women were in cardiopulmonary arrest. This is a specific group, and emergency resuscitative hysterotomy is the only chance for mother and child.[18-20] Considering the low incidence, performing a resuscitative hysterotomy is restricted to HEMS in our country.

In this cohort, we found that the first responders (midwives, EMS, and HEMS) appeared to implement BLS and advanced life support algorithms appropriately based on the clinical judgment by the HEMS physician. However, possibly because of specific training and specialized equipment for neonatal emergencies, this is based on retrospective data in a small cohort.

In several other countries, the incidence of home births is much lower[2-4,7,8,10] but has been rising again over the last couple of years in, for example, the United States.[12] To ensure that planned or unplanned home deliveries are as safe as possible, there needs to be clear guidelines as to which women can deliver at home and who should guide them and when further assistance is necessary.

Although the number of home deliveries in our country is high, the exposure for first responders to neonatal life support is very low. Therefore, all personnel present at a childbirth and first medical responders should regularly update their training and equipment to at least perform basic neonatal life support for the premature and fullterm infant.

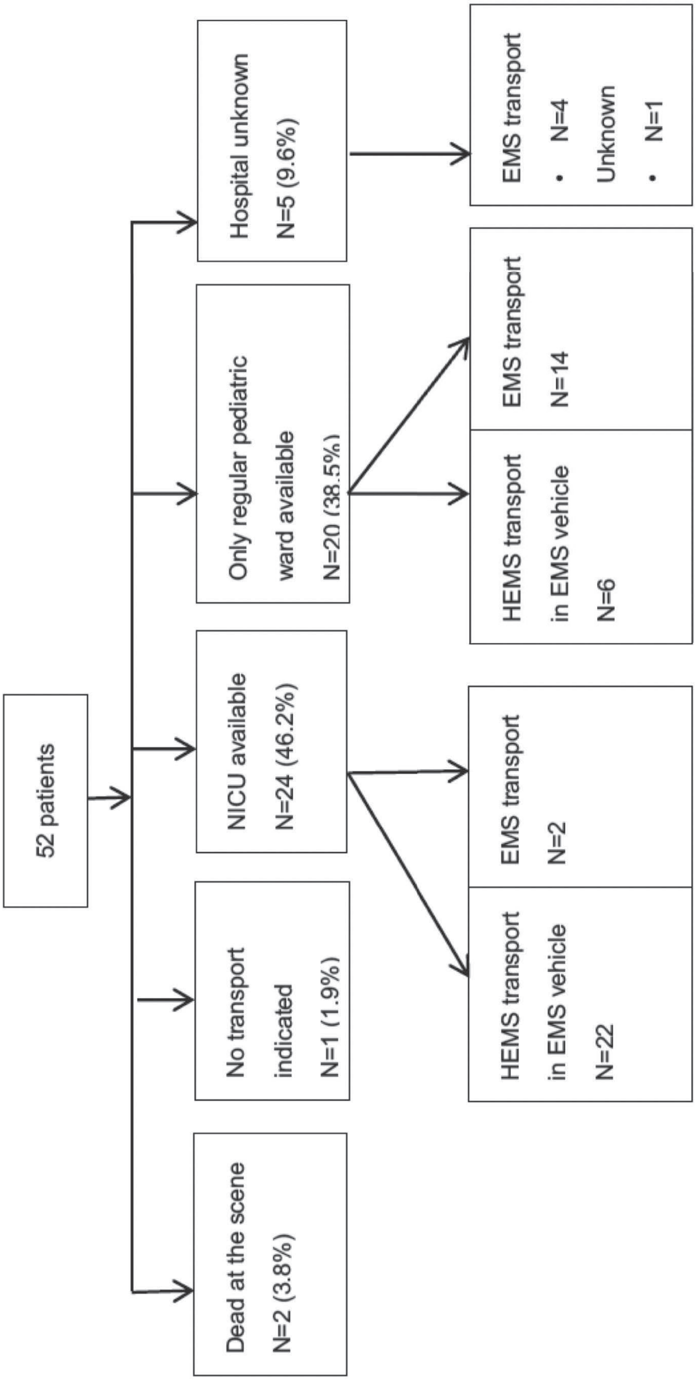

Figure 2. Transport and hospital of first admission.

Strengths and Limitations

To our knowledge, this is the first study addressing neonatal emergencies by HEMS; we found a small cohort of 52 neonates during this 6-year period. Because the HEMS physician did not always register the full name or only the mother's surname, we could not obtain GBA data for 13 infants. We did not include EMS data because they have registered dispatches for infants < 30 days of age without further specification. These dispatches accounted for 0.5% of EMS dispatches in 2016.[21] Furthermore, we have no information about neonates transported from a prehospital situation without HEMS to a NICU, emergency department, or pediatric ward. This is because of the wide variety of hospitals and locations within the hospital in the Netherlands and Belgium where these patients could have been transported from the dispatch region.

CONCLUSIONS

The absolute number of deliveries that require additional medical care besides the midwife in the prehospital setting appears to be very low. The Netherlands has always had a high incidence of home births compared with surrounding countries. The prehospital care has adapted to this situation (eg, by training all midwives in BLS, training of newborn life support for EMS, and, if necessary, deployment of HEMS). However the absolute number of neonatal emergencies remains low for both EMS and HEMS, so continuous training remains vital to provide an adequate level of care.

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Gracias
Jesper, Merijn, Floor
Bedankt!
BEDANKT

CHAPTER 8

Analysis of prehospital perimortem caesarean deliveries performed by Helicopter Emergency Medical Services in the Netherlands and recommendations for the future

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ABSTRACT

Background

Prehospital perimortem caesarean delivery (PCD) is a rarely performed procedure. In this study, we aimed to examine all PCDs performed by the four Helicopter Emergency Medical Services in the Netherlands; to describe the procedures, outcomes, complications, and compliance with the recommended guidelines; and to formulate recommendations.

Methods

We performed a population-based retrospective cohort study of all consecutive maternal out-of-hospital cardiac arrests that underwent PCD in the prehospital setting between May 1995 and December 2019. Registered data included patient demographics, operator background, advanced life support interventions, and timelines. Resuscitation performance was evaluated according to the 2015 European Resuscitation Guidelines.

Results

Seven patients underwent a prehospital PCD. Three mothers died on the scene, while four were transported to a hospital but died in the hospital. Seven neonates were born by PCD. One neonate died on the scene and six were transported to a hospital. Three neonates were eventually discharged from the hospital. Among the three surviving neonates, the periods from dispatch to start of PCD were 13, 14, and 21 min.

Conclusions

There was a low incidence of maternal perimortem caesarean deliveries in The Netherlands. Only some neonates survived after PCD. It is recommended that PCD be performed as quickly as possible. Due to the delay, the mother has a far lower chance of survival than the neonate. In fatal cases, autopsy is strongly recommended.

Keywords

Helicopter emergency medical service, Perimortem caesarean delivery, Maternal arrest, Resuscitative hysterotomy, Prehospital

INTRODUCTION

Little is known about the success rates and complications of prehospital perimortem caesarean deliveries (PCDs) performed by physician-led Helicopter Emergency Medical Services (HEMS). Only two studies have examined the incidence of maternal cardiac arrest in the out-of-hospital setting.[1,2] Few obstetrical providers encounter in-hospital acute maternal cardiopulmonary arrest (MCPA), and even fewer prehospital providers. However, the incidence of PCDs is increasing in the Netherlands.[3] There is currently no specific term for caesarean delivery during MCPA. The term PCD was introduced in 1986,[6] and was adopted by both the Society for Obstetric Anesthesiology[7] and the American Heart Association. In the event of cardiac arrest during pregnancy, PCD is considered essential for resuscitation of both the mother and fetus. PCD should only be performed from 20 weeks of pregnancy but preferably from 24/26 weeks when the pregnant uterus compresses the inferior caval vein. It is recommended that PCD be started after four minutes and performed within the next minute, to maximize the chances of return of spontaneous circulation (ROSC) through caval relief and uterine autotransfusion. Although PCD is not a complex procedure, the cognitive, operational, and emotional circumstances make it difficult, especially in the prehospital setting. Knowledge and performance of resuscitation techniques that account for a pregnant woman's unique physiology are crucial to maximize the chances of survival for both the mother and fetus.[4] The AHA issued a scientific statement on maternal cardiopulmonary arrest, stating that there is insufficient evidence to support prehospital PCD, and that prehospital providers should not be expected to perform PCD due to the limited resources available to perform advanced life support and lack of adequately trained personnel.[5] However, in 2019, the Paris Brigade Cardiac Arrest Group reported that prehospital PCD could improve the probability of the mother's survival,[2] highlighting the controversy amongst specialists.

In 1995, HEMS was introduced in the Netherlands, enabling the rapid delivery of a medical team to the scene, in addition to the regular ambulance crew. A HEMS team comprises a physician (board- certified anesthesiologist or trauma surgeon), specialized nurse (paramedic or registered nurse from the emergency department), and helicopter pilot. HEMS personnel receive additional training, such as managing obstetric emergencies and trauma (MOET), and annually practice surgical skills in a cadaver lab. On average, HEMS is airborne within two minutes after dispatch in daylight, and within five minutes at nighttime. The average flying times range from 8 to 13 minutes, depending on which HEMS is activated. In this retrospective study, we aimed to describe the experience of HEMS with PCD; to report PCD outcomes, complications, and compliance with recommended guidelines; and to make recommendations for the future.

METHODS

Ethics approval

This retrospective study was approved by the Medical Ethical Committee of the Erasmus University Medical Center (MEC-2019-0277).

Study design

We performed a retrospective analysis of all four HEMS databases from May 1, 1995 (the start of HEMS in The Netherlands) until December 2019. We identified all cases involving PCD, and collected information about these cases from the database. We further asked each individual doctor who performed a PCD to complete a questionnaire regarding personal skills and experience, and data missing from the database.

Study setting

The Netherlands has a population of over 17 million people, covering an area of 41543 km^2. There are four HEMS teams in the Netherlands—each covering one of four areas of the country. HEMS acts in close collaboration with emergency medical services (EMS), and follows the same medical protocols. Pregnant patients constitute <1% of all calls, such that expertise and experience are limited. Since June 2013, a nationwide protocol dictates that HEMS is always dispatched together with EMS in cases of cardiac arrest in a pregnant woman.

Selection of participants

We identified all patients who were pregnant and in cardiac arrest between May 1995 and December 2019, and analyzed the available data, including patient demographics, complications, and operator background. We also evaluated compliance with the guidelines for managing obstetric emergencies and trauma (MOET), which are now part of the European Resuscitation Guidelines issued in 2015.[8] Available maternal-specific resuscitation benchmarks based on the maternal algorithm included intravenous placement above the diaphragm, advanced airway insertion, timely perimortem caesarean delivery (started within four minutes of witnessed arrest, and achieved within one minute), type of incision (midline or lower transverse), and initial cardiac rhythm for pregnancies of >20 gestational weeks. Missing data are reported as unknown in the results. Pregnant patients with a gestational age of less than 20 weeks or who were quickly transferred to a hospital to undergo PCD in the emergency department were excluded. The study is registered under number MEC-2019-0277, and approved by the Institutional Review Board of the Erasmus MC.

RESULTS

Prehospital population and clinical characteristics of pregnant women. Since the start of HEMS in 1995, all four HEMS stations have received over 80 000 calls, of which around 35 000 were canceled by EMS prior to arriving. Thus, HEMS has treated approximately 45 000 patients. These cases included seven pregnant women with prehospital cardiac arrest, in three of the four HEMS areas.

Timelines

For all pregnant women who were in cardiac arrest, HEMS was called together with EMS to ensure rapid assistance. Table 2 shows the period from dispatch to start of PCD, which includes starting time, flying time, time to arrive at the scene from the landing location, and initiating the actual PCD. In all seven cases, CPR was initially performed by bystanders, policemen, or EMS. When HEMS arrived at the scene, they immediately started the PCD because basic life support and advanced life support had already been provided by EMS. None of the women was transported to perform PCD in hospital.

Maternal characteristics and outcome

The seven pregnant women had a median age of 29.6 years (range, 18-38 years) and were all in the last trimester of pregnancy (range, 31 weeks and 4 days to nearly 42 weeks). All had singleton pregnancies. Only one mother was obese (estimated weight of 140 kg). None of the mothers had comorbidities documented in the HEMS database (Tables 1 and 2). Of the seven women who underwent a PCD, three were pronounced dead on the scene. The remaining four women were transported to a hospital, two of whom exhibited ROSC at the scene. None of the four women who were admitted to a hospital survived. One woman died in the emergency department, one in the operating room, and two in the intensive care unit (both after five days and due to severe asphyxia).

Fetal outcome and neonatal survival

Seven neonates were born by PCD. One neonate died on the scene, and the other six were transported to the hospital. Of the six neonates admitted to a hospital, three died in the pediatric intensive care unit as a consequence of severe asphyxia. The remaining three babies were discharged from the hospital: two (cases five and seven) in good neurological condition, and the other (case two) in fair neurological condition (at 22 months of age, the patient can crawl and stand up, but doesn't talk). The three surviving neonates were born after the performance of PCD at 13, 14, and 21 min after dispatch (Table 3).

Cardiac arrest characteristics

One woman went into cardiac arrest after a car accident. All seven women had a non-shockable rhythm upon initial rhythm check by EMS or HEMS: five in asystole, and two with pulseless electrical activity

Table 1 Description of cases

Nr	Year, age, obstetric history, and weeks pregnant	Course of events	Discharge from hospital mother/ child
1	2003, 31 years, G1P0, 39 0/7	Road traffic accident while unrestrained in the front passenger seat. At 11 min after OHCA, PCD was performed via Pfannenstiel incision, which took ~2 min. Both mother and child gained ROSC, and were then transported to a hospital. The mother died the same day in the operating room following massive transfusion. The baby died 3 days later in the PICU due to severe neurological problems.	−/−
2	2014, 30 years, G4P3, 38 4/7	OHCA due to amniotic fluid embolism. At 21 min after starting CPR, PCD was performed via Pfannensthiel incision, which took 4-5 min. The mother did not regain a pulse but was transported to the ED and declared dead soon after arrival. The baby gained ROSC at 2 min after birth, stayed 11 days in the PICU, and was eventually discharged from the hospital. At 2 years of age, the patient is in fair neurological condition, can crawl and stand with no help, but is not talking yet.	−/+
3	2015, 18 years, G1P0, ±32	Unknown OHCA origin. At 18 min after starting CPR, PCD was performed via median incision, which took 1 min. Both mother and baby did not gain ROSC, died in the prehospital setting, and were not transported to the hospital.	−/−
4	2015, 32 years, G3P2, 41 6/7	OHCA due to amniotic fluid embolism. At 27 min after starting CPR, PCD was performed via median incision, which took 1 min. The mother had ROSC 30 min after starting CPR, and was transported to a hospital. After 5 days in the ICU, the mother died due to neurological problems. The baby had ROSC 20 minutes after PCD was performed, and was transported to a hospital. After 2 days in the PICU, the baby died due to neurological problems.	−/−
5	2015, 38 years, G2P1, 37	Uncertain cause of OHCA. Massive vaginal bleeding occurred, likely due to placenta previa. At 14 min after starting CPR, PCD was performed via median incision, which took 1 min. The mother died at the scene due to blood loss. The baby had ROSC at 9 min after starting PCD. After 6 days in the PICU, the baby was discharged from the hospital in good neurological condition.	−/+
6	2018, 28 years, G3P2, 35 5/7	OHCA due to lung embolism (confirmed by CT). At 32 min after OHCA, PCD was performed via median incision, which took 1 min. The mother was transported to a hospital while receiving CPR and with VF, and gained ROSC in the hospital >1 hour after CPR initiation. She was admitted, and died after 5 days in the ICU. The baby gained ROSC 1 min after PCD, and was transported to the hospital. After 5 days in the PICU, the baby died due to neurological problems.	−/−
7	2019, 30 years, G3P1, 31 4/7	OHCA due to lung embolism (confirmed by autopsy). At 18 min after OHCA, PCD was performed via median incision, which took 1 min. The mother never gained ROSC and died on the scene. The baby gained ROSC 12 min after PCD and was transported to the hospital. After 3 days in the PICU, MRI showed no hypoxic lesions. After 8 days in the PICU, the baby was discharged from the hospital in good neurological condition.	−/+

OHCA: out-of-hospital cardiac arrest; PCD: perimortem caesarean delivery; ROSC: return of spontaneous circulation; ED: emergency department; PICU: pediatric intensive care unit; ICU: intensive care unit; CPR: cardio-pulmonary resuscitation.

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Table 2 Maternal characteristics

Case	1	2	3	4	5	6	7
Year	2003	2014	2015	2015	2015	2018	2019
Parity	G1P0	G4P3	G1P0	G3P2	G2P1	G3P2	G3P1
Mother's age, years	31	30	18	32	38	28	30
Incision	Lower transverse abdominal	Lower transverse abdominal	Midline	Midline	Midline	Midline	Midline
Surgeon	Anesthesiologist	Trauma Surgeon	Anesthesiologist	Anesthesiologist	Anesthesiologist	Anesthesiologist	Trauma Surgeon
Procedure duration, minutes	2	4-5	1	1	1	1	1
Gestational age, weeks	39 0/7	38 4/7	+/-32	41 6/7	37 ?/7	35 5/7	31 4/7
CPR	+	+	+	+	+	+	+
1st Rhythm	asystole	asystole	asystole	PEA	asystole	PEA	Asystole
Diagnoses	Trauma RTA	Amniotic fluid embolism	Unknown	Amniotic fluid embolism	Uncertain, but vaginal bleeding	Pulmonary embolism	Pulmonary embolism
Obduction/CT performed	−/+	−/−	−/−	−/+	+/−	−/+	+/−
Time to ROSC (minutes)	28	–	–	30	–	>45	–
Survival	–	–	–	–	–	–	–
Time from dispatch to start of procedure	11	21	18	27	14	32	13
Transport to hospital	Y	Y	N	Y	N	Y	N
Left lateral tilt (upon HEMS arrival)	Y	N	Y	N	N	Y	N

Case	1	2	3	4	5	6	7
Intubation	HEMS	EMS	EMS	First i-Gel by EMS, intubated by HEMS	No	EMS	HEMS
Comorbidity	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Weight, kg	75	Normal posture	70	Normal posture	140	72	Normal posture

ROSC: return of spontaneous circulation; EMS: emergency medical service; HEMS: Helicopter Emergency Medical Service; RTA: road traffic accident; N.A.: not applicable.

Table 3 Neonatal characteristics

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Baby's weight, grams	3500	4000	1500-2000	4300	+/– 3000	2620	1900
CPR at birth	+	+	+	+	+	+	+
ROSC/Time to ROSC	+/5	+/2	–/–	+/20	+/4	+/1	+/12
Discharge from hospital	–	+	–	–	+	–	+
Intubation	HEMS	HEMS	HEMS	HEMS	HEMS	HEMS	None

CPR: cardiopulmonary resuscitation; ROSC: return of spontaneous circulation; HEMS: Helicopter Emergency Medical Service.

(PEA). Four women never gained ROSC, two women exhibited ROSC at the scene, and one showed ROSC at the emergency room after over one hour of CPR. None of the women were discharged from the hospital. Postmortem CT scanning was performed in only three cases. Among the three women who were not transported to a hospital, only one received an autopsy and a diagnosis (case seven). In one case, no autopsy was performed. In the other case, an autopsy was performed five days after death, and no distinct diagnosis was made that could explain the cardiac arrest. All seven neonates received CPR at birth. Six neonates gained ROSC, of whom four showed ROSC within five minutes or less (including two neonates who were discharged from the hospital). On the scene, it was difficult to assess whether a pulse was present (for example, due to bad lighting or noise); thus, in some cases, CPR was initiated but stopped after ultrasound confirmation of heart contractions.

Guideline compliance

Paramedics are not allowed to perform PCD; therefore, PCD could not be initiated until HEMS arrived. In all cases, CPR was started by EMS or bystanders. Not all women received endotracheal intubation. Three mothers were intubated by EMS, one by HEMS, one had a laryngeal mask airway (i-Gel©) inserted by EMS and was intubated by the HEMS physician upon arrival, and one was ventilated using bag-valve-mask ventilation. All women had an intravenous access above the diaphragm in one arm. All women received adrenaline according to protocol. Only one woman developed ventricular fibrillation and was shocked four times during CPR (case six). The period from dispatch to PCD initiation was well over ten minutes, with a maximum of 32 min. All median incision procedures took approximately one minute to perform. Incision by lower transverse abdominal incision (Pfannenstiel incision) took longer: two to five minutes. In four women, EMS or bystanders did not apply manual uterus displacement, which was corrected by HEMS upon arrival.

Debriefing

It is routine to have a debriefing after returning to the HEMS station with the team. In all the described cases debriefings and perinatal audits were held for all involved health care providers.

DISCUSSION

According to the nationwide database of the Dutch Heart Association,[9] 8000 out-of-hospital cardiac arrests occur each year, including only a few in pregnant women.10 In this retrospective study, we describe all seven perimortem caesarean deliveries (PCD) performed by HEMS in The Netherlands between 1995-2019. We found that the time from dispatch to PCD initiation (Table 2) was well over the recommended 4-5 min.[11] It is difficult to perform PCD within five minutes after cardiac arrest, especially in the prehospital setting,[8,12] and this criterion cannot always be met even for in-hospital PCDs.[3,11] In our present study, among the three neonates who survived, the times until PCD initiation were 13, 14, and 21min—well beyond the recommended 4-5 min. In the prehospital setting, the target of 4-5 min is not feasible since medical emergency units always take more time to arrive, even HEMS. Nevertheless, we recommend that PCD be performed as soon as technically possible. Although maternal survival is rare after >14 min, there is still a chance of neonatal survival, and no danger of further maternal damage. One could argue that maternal survival might be improved if PCD were performed by paramedics who arrive at the scene earlier; however, paramedics have no surgical experience and are not authorized to perform this procedure. In all seven patients, upon HEMS arrival, CPR had been started by EMS or started by bystanders and taken over by EMS. Four women were already intubated, and all women had an intravenous access above diaphragm. All patients initially had a non-shockable rhythm. HEMS was able to immediately start PCD upon arrival in all cases.

In 2015, the American Heart Association5 released a scientific statement indicating that prehospital PCD should not be performed due to the lack of adequately trained personnel, and that focus should instead be on providing basic and advanced life support, and quick transport to a facility that can perform PCD. In 2019, the Paris Brigade Cardiac Arrest Work Group described 16 pregnant patients in OHCA, and reported that prehospital PCD improved the likelihood of the mother's survival.[2] They also stated that basic and advanced life support are warranted when PCD can be performed by a trained doctor. In our opinion, the EMS teams in the Netherlands can secure the airway, insert an intravenous access cannula, provide medication according to the nationwide advanced life support protocol and, if necessary, defibrillate the patient—while HEMS can quickly perform the PCD.

Brain damage begins after five minutes of anoxia. Under the 4- to 5-minute guideline, PCD is to be initiated at four minutes, and be completed in a timely manner (within one minute) to deliver the fetus prior to the occurrence of brain damage. If a woman has a resuscitable cardiac arrest, her life may also be saved by a prompt and timely PCD during CPR. A neonate can survive and remain in good neurological condition after a longer period of anoxia. A small British study reveals that neonatal damage or death will not occur until after a 20-minute period of anoxia.[13] In the CAPS study,[14] maternal survival rates depended on the time from collapse to the start of in-hospital perimortem caesarean delivery. Pregnant patients receiving CPR who underwent in-hospital perimortem caesarean delivery and survived all had their perimortem caesarean delivery within 12 min. In the Netherlands, Dijkman reported no survival of pregnant patients when it took longer than 14 min to start in-hospital PCD.[3] In the prehospital environment, it is difficult to arrive on time to start PCD within 12-14 min.

The timing of performing a PCD is quite important for the survival of both mother and fetus. A recent British study describes a decrease of maternal survival depending on the interval between cardiac arrest and PCD14. In this study the survivors had a PCD between 0 and 39 min after their cardiac arrests. The median interval of the cardiac arrest/PCD period between survivors and those who died was respectively 3 and 12 min. This same article found that maternal survival doubled in women that were not transported to another place to perform the PCD. The neonatal survival decreases after an interval of more than five minutes. In the British study the difference in survival is 96% if delivered within 5 min and 70% if delivered after more than five minutes. An overview of the importance of the interval time is also given in the review article by Zelop et al[15].

The cause of cardiac arrest could be determined in only five cases in our study. We strongly recommend that this diagnosis be obtained through CT or MRI scanning and/or autopsy. Elucidating the cause is important for determining why women die, to potentially adjust training and create awareness amongst doctors and nurses. Furthermore, in individual cases, a diagnosis may reveal why resuscitation was not successful. Rarely, autopsy may lead to the identification of previously unknown inherited diseases. Finally, elucidation of the cause of death may provide some consolation to the relatives. In some countries, autopsy is obligatory for pregnant women; for example, it has been compulsory in Sri Lanka since 2008.

Although obstetricians might be more comfortable with lower transverse abdominal incisions, a midline incision may be recommended in some cases, especially for care providers having less experienced with lower transverse caesarean section. Notably, in our study, even the trauma surgeon took a longer time to perform PCD using a lower transverse abdominal incision. The midline procedure is technically easier because the abdominal wall is thinner, the resistance and structures in the abdominal wall are simpler, and the uterus is always immediately encountered upon cutting through the abdominal wall—thereby protecting other structures, such as the bladder and bowel. In this study, all PCDs performed via median incision took less time than those performed via lower transverse abdominal (Pfannenstiel) incision (Table 2). Using a vertical midline laparotomy incision will maximize exposure and allow the greatest access to facilitate the procedure[16], and is thus recommended. After delivery of the neonate and cutting the umbilical cord, the placenta may be left in place or manually removed.

In The Netherlands, the Managing Obstetric Emergencies and Trauma (MOET) course started in December 2003. During the early years of HEMS in The Netherlands, obstetric emergencies were not in the dispatch protocols. This changed in June 2013, when the nationwide protocol for HEMS activation was adjusted, with the addition of complications during birth or pregnancy. In these cases, HEMS is primarily activated, together with EMS. This may explain why almost all PCD since our study were performed during the last five years. The first PCD was after a car accident, which is a primary HEMS deployment criterion.

CONCLUSIONS AND RECOMMENDATIONS

This was the first study to report the outcomes of a cohort of pregnant woman who suffered out-of-hospital cardiac arrest, and received prehospital treatment by physician-led HEMS in The Netherlands. We found a low incidence of PCDs during maternal out-of-hospital cardiac arrests. In the prehospital setting, even with HEMS availability, the 4- to 5-minute guideline was not achieved in any case. While we still recommend that perimortem caesarean delivery be performed as early as possible, one must realize that the delay in the prehospital setting means that the likelihood of saving the mother is far lower than that of saving the neonate. In prehospital resuscitations and PCD, special attention should be paid to performing intubation (with capnography), manual uterine displacement to avoid aortocaval compression, and using a midline rather than a lower transverse (Pfannenstiel) incision.

In cases of maternal death, autopsy is strongly recommended to identify the cause of cardiac arrest and to understand the failure of the procedure. Cardiac arrest is so rare, especially in young women, that it is mandatory to investigate its cause as thoroughly as possible. If autopsy is not allowed or refused, a full-body MRI or CT scan may serve as an alternative.

CREDIT AUTHOR

All authors have made substantial contributions to all of the following: (1) the conception and design of the study, or acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content, (3) final approval of the version to be submitted.

CONFLICTS OF INTEREST

None.

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obrigado
Gracias
Jesper, Merijn, Floor
Bedankt!
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CHAPTER 9

Summary

Nederlandse samenvatting

SUMMARY

In this summary the overview and conclusions of the different chapters of this thesis are described.

Endotracheal intubations (ETI) are frequently performed on critically ill or severely injured patients and remains the best method for securing the airway. In order to achieve adequate tissue oxygenation and ventilation while preventing aspiration the airway needs to be managed. It is essential during resuscitation and critical care to establish and maintain the patient's airway by ETI. By its very nature, out-of-hospital environments provide unique challenges while intubating a pediatric patient making this a potentially risky procedure. The objective of this retrospective study is to examine the first attempt and overall success rate of out-of-hospital emergency pediatric intubations by the Rotterdam HEMS during a six year period (2012-2017). A cohort of 280 pediatric patients from this period are described in **Chapter 2**. From this retrospective study it can be seen that:

Pre-hospital intubations of severely injured or critically ill pediatric patients has had a high success rate when performed by the HEMS physicians in the Netherlands. The first attempt ETI success rate was 227 (81%) and the overall ETI (after one or more intubation attempts) success rate was 276 (98.5%). A surgical procedure was performed in one case to clear the airway.

During CPR the ETI assisted with medication, at least an induction with a hypnoticum (Etomidate, Propofol or Ketamine) in combination with a muscle relaxant (Rocuronium or Suxamethonium) and sometimes an opioid (Fentanyl) had a significantly higher first attempt success rate than ETI without medication (88.5% vs. 67.7%, p=0.0002).

Anesthesiologists intubated 238 pediatric patients and trauma surgeons intubated 35 pediatric patients, there was no significant difference in the success the physician irrespective of their background in either anesthesiology or trauma surgery (p=0.09).

When examining intubations with or without medication the anesthesiologists had a significantly better success rate than the trauma surgeons. Medication assisted first attempts: 95% CI (2.8485 to 39.24547) p=0.0133.

This emphasizes the value of the HEMS teams with the inclusion of a board-certified physician. It also indicates that the threshold for deployment of HEMS teams should be low especially in cases of a potentially compromised airway in pediatric patients.

There has not been any significant collection of data regarding in-hospital pediatric cardiac arrest in the Netherlands, with regards to out-of-hospital pediatric cardiac arrest details are even more scarce. A collection of data has been made and is, for the first time, included in **Chapter 3**. In this chapter the data is retrospectively evaluated for all out-of-hospital pediatric patients (0-17 years) with cardiac arrests over a six year period (2008-2014) that were attended to by the Rotterdam HEMS and included 210 cases:

- 9 patients (4%) were lost in follow up and cannot be assessed in this retrospective review as to whether they had survived or were discharged from hospital.
- Of the remaining 192 patients, 29 (15%) survived to discharge from hospital and the majority survived in good neurological condition.
- In the survivor group, all patients showed return of spontaneous circulation (ROSC) before leaving the incident scene.

A collection of data on a national scale was done including all four HEMS entities to obtain a national insight into pediatric OHCA's. This data is reviewed in **Chapter 4** this is again the first time this nationwide study has been made. The national pediatric OHCA review covers a two year period (2015-2017) and a year follow up. This data indicates that the HEMS teams have been frequently dispatched to pediatric OHCA's attending to 202 cases:

- 17 patients (8.5%) were excluded from the review due to missing data.
- 21 patients (10%) survived one year after discharge from hospital.
- Survival of patients with a shockable rhythm was higher (18.2%).
- Survival of patients with non-shockable rhythm was (5.3%).
- Of the 21 surviving patients 11 were suffered from drowning incidents. All these survivors were in the age category 12-96 months. There were no survivors in the age group 1-12 months.
- The overall national incidence rate is 3.5 out-of-hospital cardiac arrested children per 100,000 pediatric inhabitants (0-<18years)

The intubation success rate (first and second attempt) of HEMS teams performed by the physician is 91%. In comparison to other countries survival is normal to high.

Two groups seem to have a relatively favorable outcome, the 12-to-96-month age group and the second group involved in drowning incidents.

The HEMS provide a wide variety of procedure and bring essential medical expertise to the field which are not provided by the regular EMS.

Below the age of 40 years, trauma remains amongst the top causes of death. In the Netherlands however, for children 0 to 1 years old the primary cause of death is congenital malformation. For children from 1 to 14 years old trauma is the leading cause of death and in the age group 15 to18 years it is the second most leading cause of death.

In order to establish if there is a difference in the the survival rate between HEMS and EMS dispatches, i.e. does the fact that physician is embedded in the HEMS have added value, a review of severely injured Pediatric patients under the age of 18 years old with an Injury Severeity Score of >15 over a 12.5 year period (2000 to 2013) was performed. This was based on patients who were presented to the emergency department of the Erasmus Medical Centre. The results of this study are presented in **Chapter 5**. During the period under review 366 severely injured pediatric patients were treated by the emergency department:

- 10 patients (2.7%) were excluded as they had been transferred from other hospitals and did not comply with the HEMS/EMS dispatch criteria.
- 48 patients (13%) were excluded due to there being insufficient data or records.
- Of the remaining 308 patients, 112 (36%) were patients initially treated by the EMS services and 196 (64%) were initially treated by the HEMS and EMS services.

In order to objectively compare the two services, four parameters were considered

- Systolic blood pressure
- Glasgow Coma Scale prior to intubation
- Injury Severity Score
- Respiratory rate

Based on these criteria 5 patients survived, which translates to a success rate of 2.5 per 100 dispatches treated by the HEMS teams for sererely injured pediatric patients.

In trauma blood loss leads to hypothermia, acidosis and coagulopathy, collectively known as the "Triad of Death" which lead to an increased risk of morbidity and/or mortality. Bleeding control, particularly in instances of external bleeding, can be easily controlled using simple techniques such as the application of sufficient pressure to staunch blood flow. In severe cases however, such as internal bleeding, controlling blood loss can be a lot more challenging. For pediatric patients in a hospital environment these severe cases of blood loss control can be done by administering various blood products. For instances where there is a delay in the delivery of the pediatric patients from the scene of the incident to the hospital or situations where the patients are entrapped at the incident scene blood products can be administered at the scene to minimize blood loss.

The experiences of both the Nijmegen and Rotterdam HEMS teams administering out-of-Hospital uncross-matched packed red blood cells to critically ill or severely injured pediatric patients are reviewed in **Chapter 6**.

Of the 2,400 pediatric patients under review 10 patients (0.4%) met the criteria for the retrospective review. For the initial results:

- 8 patients survived the 30 day interval. Two patients were unexpected survivors, one was predicted by the trauma and severity injury score, the other was a neonate who was in hypovolemic shock and cardiopulmonary arrest.
- 2 patients died within the first 24 hours.

The incidents of out-of-hospital use if blood products for critically ill or severely injured pediatric patients is low. The administration of blood products, however, allowed for the limitation of acid based disturbances, low hemoglobin levels and coagulopathy in this group.

EMS is responsible for all pre-hospital care for all ages irrespective of cause of injury or medical condition and includes peripartum emergencies. In comparison to the neighboring countries, the Netherlands has always had a much higher incidence of home deliveries. Consequently the pre-hospital care services has been adapted to accommodate these circumstances. This is done by:

- training all midwives in Basic Life Support (BLS)
- training EMS teams in newborn life support
- deployment of HEMS teams

in 2016 there were 21,434 planned home births in the Netherlands guided by midwives alone without the need for any further obstetric assistance. This was 12.7% of all births that year. There is no clear data available, however, regarding neonates requiring emergency care with or without HEMS assistance. In **Chapter 7** a review is made of neonate cases that received medical care after birth from the HEMS. During the study period (2012 to 2017) 52 neonates required medical assistance from the HEMS. 33 (63.5%) home births were attended to. In this cohort adequate basic life support was implemented immediately after birth either by the attending midwife, EMS or HEMS on arrival. Of the 5 neonates who died, 2 had extremely low birth weights and were extremely premature. Based on the medical grounds and judgement of the HEMS physician no resuscitation measures were started.

Pre-hospital perimortem caesarean deliveries (PCD) are rarely performed. This is the first review to study the outcomes of a cohort of 7 pregnant women who suffered an out-of-hospital cardiac arrest and received pre-hospital treatment by the HEMS teams in the Netherlands, these results are included on **Chapter 8**.

- There is a low incidence of PCD's (<0.1% of all dispatches).
- In the pre-hospital setting, even with HEMS attendance, the 4 to 5 minute guideline was not achieved in any of the cases.
- All mothers died either prior to or on arrival in hospital.
- 3 babies were discharged from hospital, 2 in good neurological condition and 1 in fair neurological condition (at 22 months the child can crawl, stand but cannot talk).

- The 3 surviving neonates were born after the performance of a PCD at 13, 14 and 21 minutes after dispatch.

The performing of a perimortem cesarean delivery should be done as soon as possible, the delay in the pre-hospital situation means that the likelihood of saving of the mother is far lower than saving that of the neonate.

In pre-hospital resuscitations and PCD's special attention needs to be paid to:

- Performing intubation (with capnography).
- Manual uterine displacement to avoid aortocaval compression.
- Using a midline rather than a lower transverse (Pfannenstiel) incision.

In cases of maternal death, an autopsy to identify cause of cardiac arrest and to understand the reason for procedure failure is strongly recommended. Cardiac arrest, and especially in young women, is so rare that it should be mandatory to investigate the cause as thoroughly as possible. If an autopsy is not allowed, or permission is refused, then a full body MRI or CT scan may be an alternative.

In this thesis a various number of prehospital themes are described and evaluated. General discussion can be found in **chapter 10** and recommendations are formulated in **chapter 11**.

NEDERLANDSE SAMENVATTING

Deze samenvatting geeft een overzicht van de verschillende hoofdstukken die in deze thesis aan bod komen.

Endotracheale intubatie wordt frequent uitgevoerd bij gewonde of ernstig zieke kinderen en blijft de gouden standaard om een luchtweg te zekeren. Het doel van luchtweg management is om adequate weefsel oxygenatie en ventilatie te verkrijgen en kans op aspiratie te minimaliseren. Daarom is dit een van de hoekstenen van resuscitatie. Er zijn echter unieke uitdagingen in prehospitale omstandigheden als een zorgverlener een kind intubeert en dit zorgt ervoor dat het een risicovolle medische handeling is. Het doel van dit retrospectief onderzoek is om in een prehospitale omgeving te bestuderen wat het slagingspercentage is bij de eerste intubatiepoging en het algehele slagingspercentage van kinderintubaties door mobiel medisch team (MMT) artsen in een periode van 6 jaar (2012-2017). In **Hoofdstuk 2** wordt een groep beschreven van 280 kinderen die geïntubeerd werden door MMT-artsen van Rotterdam. Prehospitale intubaties van gewonde of ernstig zieke kinderen hebben een hoge slagingskans als deze geïntubeerd worden door het MMT. Het intubatie succespercentage bij een eerste poging is 81% en het algehele slagingspercentage is 98,5% na 1 of meerdere pogingen. In één casus is een chirurgische luchtweg aangelegd. Endotracheale intubatie met behulp van medicatie (ten minste een inductiemiddel (etomidate, propofol of ketamine) in combinatie met een spierverslapper (rocuronium of suxamethonium), soms aangevuld met een opiaat (fentanyl)) heeft een hogere slagingskans bij een eerste poging dan een intubatiepoging zonder medicatie (tijdens reanimatie) (88,5% versus 67,7%, p = 0.0002). De MMT-artsen die anesthesioloog zijn hebben 238 kinderen geïntubeerd, terwijl de traumachirurgen er maar 35 hebben geïntubeerd. In de hele groep is er geen verschil in slagingspercentage indien er geïntubeerd is door de anesthesioloog of de traumachirurg (p=0.09). In de groep kinderen die geïntubeerd is met behulp van medicatie, hebben de anesthesiologen een betere slagingskans in de eerste poging 95% CI (2.8485 to 39.2547) p = 0.0133. Dit onderzoek onderstreept de additionele waarde van het MMT en de drempel om het MMT te consulteren zou laag moeten zijn als gewonde of ernstig zieke kinderen een definitieve luchtweg middels endotracheale intubatie moeten krijgen.

Er is weinig Nederlandse data gepubliceerd over kinderreanimaties die plaatsvinden in het ziekenhuis, laat staan kinderreanimaties die plaatsvinden buiten het ziekenhuis. In **hoofdstuk 3** worden de eerste resultaten gepubliceerd waar er retrospectief gekeken is naar alle kinderreanimaties (0 tot 18 jaar) buiten het ziekenhuis in een periode van zes jaar (2008-2016) en die behandeld werden door het Rotterdamse MMT. Een totaal van 201 kinderreanimaties die buiten het ziekenhuis plaatsvonden werden geselecteerd uit de database. De gegevens van negen patiënten (4%) waren onvolledig in de database en konden niet vervolgd worden of deze patiënten de reanimatie overleefden en vervolgens uit het ziekenhuis ontslagen konden worden. Van de 192 overgebleven patiënten, werden er 29 ontslagen uit het ziekenhuis (15%) waarvan het overgrote deel in een goede neurologische conditie. In de groep van overlevenden viel het op dat deze allemaal al een geslaagde reanimatie hadden op de plek van het incident, dat wil zeggen dat het kind ter plaatse weer een herstel van eigen circulatie kreeg. Om een antwoord te kunnen geven op een landelijk cijfer voor incidentie en overleving, is er een tweede retrospectieve studie gedaan naar kinderreanimaties buiten het ziekenhuis in een periode van 2 jaar (2015-2017) met een follow up van 1 jaar. Deze studie wordt gepresenteerd in **hoofdstuk 4**. Deze landelijke studie presenteert voor het eerst een landelijke incidentie en overleving van kinderreanimaties in Nederland. Gedurende deze studieperiode zijn er 202 kinderreanimaties geïdentificeerd. 17 patiënten zijn geëxcludeerd vanwege missende basisgegevens. 185 patiënten werden, indien van toepassing, vervolgd tot 1 jaar na ontslag. 21 patiënten overleefden tot 1 jaar na ontslag (11,4%). Patiënten met een defibrilleerbaar ritme hadden een hogere overleving (18,2%) dan patiënten met een niet defibrilleerbaar ritme (5.3%). Van de 21 overlevenden, werden er 11 getroffen door verdrinking. De overlevenden in de groep van verdrinking waren allen in de leeftijd van 12 tot 96 maanden oud. In de leeftijdsgroep van 1 tot 12 maanden oud waren er geen overlevenden. De incidentie van prehospitale kinderreanimaties in Nederland is 7,4 per 100.000 kinderen (0 tot 18 jaar). Het succespercentage van intubaties bij kinderen door artsen van het MMT in de eerste en tweede poging is 91%. Overleving is normaal tot hoog vergeleken met andere landen. Niet alle veiligheidsregio's in Nederland zijn evenredig verdeeld in het aantal kinderreanimaties. De leeftijdsgroep van 12 tot 96 maanden en patiënten die verdrinken lijken een relatieve betere overleving te hebben. Het MMT voert een groot deel van de medische handelingen uit en heeft medische expertise die niet geleverd kan worden door de reguliere ambulancezorg.

Wereldwijd blijft trauma één van de top oorzaken van overlijden onder de leeftijd van 40 jaar. Prenatale afwijkingen zijn in Nederland de grootste doodsoorzaak van kinderen in de leeftijd vanaf de geboorte tot één jaar. Trauma is de belangrijkste oorzaak van overlijden in de groep van één tot 14 jaar en van 15 tot 18 jaar de tweede doodsoorzaak[4]. Om te onderzoeken of er een verschil is in overleving tussen kinderen behandeld door het MMT in samenwerking met de ambulance versus alleen behandeld door het ambulanceteam zijn alle ernstig gewonde patiënten (onder de 18 jaar en Injury Severety Score >15) nagekeken in een periode van 12,5 jaar (2000-2013). De resultaten staan beschreven in **hoofdstuk 5**. Gedurende deze studieperiode zijn 366 ernstig gewonde kinderen behandeld op de afdeling spoedeisende hulp van het ziekenhuis. Tien patiënten werden geëxcludeerd omdat de behandeling reeds gestart werd in een ander ziekenhuis en de patiënten interhospitaal zijn getransporteerd. De data waren incompleet van 48 patiënten. Er bleven 308 patiënten over voor analyse, 112 (36%) in de ambulance groep en 196 (64%) in de groep van patiënten die werden behandeld door het mobiel medisch team samen met de ambulancehulpverleners. Het model met de beste diagnostische waarde bevat een aantal onderdelen, namelijk: patiënten behandeld door het MMT, drie componenten van de Glascow Coma Score (oog, motorische en verbale score) voordat de intubatie is uitgevoerd en waarden van de Injury Severity Score (maat voor ernst van letsel), systolische bloeddruk en ademhalingsfrequentie. Dit model voorspelt dat er vijf additionele levens gered zijn door het MMT. Dit komt overeen met 2,5 additionele levens gered per 100 MMT inzetten voor ernstig gewonde kinderen.

Bloedverlies leidt tot onderkoeling (hypothermie), toename in zuurgraad van het lichaam (acidose) en stollingsstoornissen (coagulopathie) en staat bekend als de "triad of death". Deze trias leidt tot een verhoogde kans op mortaliteit en/of morbiditeit. Om een eenvoudige bloeding te stelpen kan het soms volstaan om rechtstreekse druk uit te oefenen op de wond. Het kan een uitdaging zijn om een grotere bloeding te stelpen welke zich bijvoorbeeld inwendig bevindt. Als deze patiënt in het ziekenhuis behandeld wordt, is de kans groot dat deze een of meerdere bloedproduct(en) ontvangt als onderdeel van een normale behandeling. Als deze patiënt zich buiten het ziekenhuis bevindt, kan deze ook gebaat zijn bij een of meerdere bloedproduct(en) omdat bijvoorbeeld de tijd tot bevrijding uit een wrak langer duurt of omdat het langer duurt voordat de patiënt in een ziekenhuis behandelt kan worden met bloedproducten. In **hoofdstuk 6** wordt een overzicht gegeven van de ervaringen met het prehospitaal toedienen van O negatieve rode bloedcelconcentraat door het MMT van Nijmegen en Rotterdam aan ernstig zieke of gewonde kinderen. De transfusies werden geïnitieerd door de arts van het MMT op basis van klinische symptomen en richtlijnen. De twee MMT's van Nijmegen en Rotterdam werkten samen en stelden hun data voor deze evaluatie ter beschikking. Tien kinderen van de ongeveer 2,400 patiënten (0-18 jaar) voldeden aan de inclusiecriteria van dit retrospectieve multicenter onderzoek. Acht patiënten overleefden tot minimaal 30 dagen na opname, twee patiënten overleden in de eerste 24 uur van opname. In de groep van overlevenden waren ook twee onverwachte overlevenden. Eén was voorspeld te overlijden door de Trauma en Injury Severity Score en de ander was een pasgeborene die gereanimeerd moest worden op basis van een hypovolemische shock. De incidentie van prehospitaal toedienen van bloedproducten bij gewonde of ernstig zieke kinderen is laag. Deze interventie kan in potentie limiteren van het zuur-base disbalans, het krijgen van een laag hemoglobinegehalte en coagulopathie in deze groep.

De ambulancedienst is verantwoordelijk voor zorg van patiënten in alle leeftijdscategorieën, onafhankelijk van hun letsel en/of medische conditie. Dit is inclusief de zorg aan patiënten met een acute zorgvraag rondom de partus. Als deze groep patiënten meer zorg nodig hebben dan beschreven in het nationale ambulanceprotocol kan hulp van het MMT ingeroepen worden. In 2016 werden er in Nederland 21.434 geplande thuisgeboortes uitgevoerd met ondersteuning van een verloskundige. Dit is 12,7% van alle geregistreerde geboortes in dat jaar. Er is weinig data gepubliceerd over wanneer en hoe vaak pasgeborenen acute medische zorg nodig hebben met of zonder hulp van het MMT. Deze studie is verricht om inzicht te verkrijgen in pasgeborenen die acute medische hulp nodig hadden van een MMT en is gepresenteerd in **hoofdstuk 7**. Gedurende de studieperiode van zes jaar (2012-2017) werden 52 pasgeborenen geïdentificeerd die acute medische zorg nodig hadden van het MMT. Vijf baby's overleden waarvan twee op de plaats van het incident ten gevolge van extreem laag geboortegewicht en extreme prematuriteit. Hierdoor werd de beslissing gemaakt door de MMT-arts geen reanimatiepoging te ondernemen. In deze studie werd adequate Basic Life Support (BLS) gegeven door de verloskundige, het ambulancepersoneel en/of leden van het MMT. Nederland heeft altijd een hoog percentage aan thuisbevallingen gehad vergeleken met landen om ons heen. De prehospitale zorg is hierop ingesteld (onder andere door training van verloskundigen in BLS, training van Neonatal Life Support (NLS) door ambulancepersoneel en als het noodzakelijk is, assistentie van het MMT).

Een prehospitaal uitgevoerde perimortem keizersnede komt niet vaak voor. Dit was de eerste studie waar de incidentie en overleving onderzocht werd van prehospitaal uitgevoerde perimortem keizersnede door het MMT in Nederland. Een groep van 7 patiënten voldeden aan de inclusiecriteria en is beschreven in **hoofdstuk 8**. Er werd een lage incidentie gevonden van een prehospitaal uitgevoerde perimortem keizersnede. In de prehospitale omgeving, zelfs met de beschikbaarheid van een MMT, kon er in geen enkele casus voldaan worden aan de 4-5 minuten regel. Alle zeven moeders zijn overleden. Drie baby's zijn ontslagen uit het ziekenhuis; twee in een goede neurologische conditie en een in een redelijke neurologische conditie (op de leeftijd van 22 maanden kan het kind wel kruipen en staan, maar nog niet praten). De drie neonaten die het overleefd hebben waren geboren met een perimortem keizersnede na 13,14 en 21 minuten nadat het MMT was opgeroepen en de moeder reanimatiebehoeftig was. Toch blijft het advies om zo snel mogelijk te starten met een prehospitale perimortem keizersnede, maar moet men zich wel realiseren dat door het tijdsverlies de neonaat meer kansen maakt dan de moeder. Indien een zwangere in een reanimatiesetting komt met een eventuele perimortem keizersnede moet er speciale aandacht zijn voor intubatie (met capnografie), manuele uterus verplaatsing (zodat de druk op de onderliggende vaten wordt verminderd) en de keizersnede moet middels een incisie in de midline gemaakt worden in plaats van de gebruikelijke Pfannenstiel incisie (horizontale lage incisie). Indien de moeder komt te overlijden wordt autopsie ten zeerste aanbevolen om de oorzaak te achterhalen en misschien een oorzaak te vinden van het falen van de procedure. Een reanimatie tijdens de zwangerschap is zo zeldzaam, zeker bij jonge vrouwen, dat het verplicht zou moeten worden dit te onderzoeken. Indien autopsie niet wordt toegestaan is een MRI of een CT wellicht een alternatief.

In deze thesis wordt een variatie aan onderwerpen behandeld en geëvalueerd. De algemene discussie kan gevonden worden in **hoofdstuk 10**. Aanbevelingen worden gedaan in **hoofdstuk 11**.

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Danke
obrigado
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Bedankt!
Trauma Heliko
DE TRAUMAH
BeDANkT

CHAPTER 10

General Discussion

GENERAL DISCUSSION

In order to provide the appropriate and adequate standard of medical care to vitally compromised or severely injured pediatric patients in the pre-hospital situation healthcare providers must have a high degree of ability and competence. Insight and understanding of procedures and applications can be obtained from studying the appropriate literature and attending relevant courses and seminars but there is no substitute for actual hands on experience and exposure. The importance of this exposure and experience of dealing with vitally compromised and seriously injured pediatric patients is illustrated in this thesis. To achieve the required levels of ability and maintain competency it is necessary to have frequent and appropriate exposure to vitally compromised and severely injured pediatric patients in real pre-hospital environments. There is no simple empirical rule to quantifying how much exposure or how often this exposure must be had in order to determine if the health care provider has fulfilled the requirements to qualify as a physician fit for HEMS duties. Learning curve graphs have been drawn for pediatric intubations, intra osseous access and are available in the relevant literature however they form only a very minor part of the treatment required when dealing with pediatric patients. Due to the lack of exposure it is difficult for Emergency Medical Service (EMS) to acquire the necessary competency levels. There are in excess of 800 ambulances manned by more than 6000 personnel in the EMS compared with only four helicopters with a complement of eighty personnel in the HEMS facility. Not only do the HEMS have fewer personnel who are therefore more likely to attend more dispatches but the HEMS services operate in a larger area with different more specific criteria for dispatch. The national percentage of pediatric patients seen by the HEMS has risen in recent years by 22%, on average a HEMS physician treats a pediatric patient in full cardiac and respiratory arrest once every quarter. The evidence illustrates that HEMS physicians gain experience rapidly and often enough to achieve high levels of competence.

It is difficult to compare outcomes of our studies to the (international) literature. In the Netherlands dispatch criteria for HEMS deployment are different as compared to other countries. HEMS is activated not only in trauma cases, but also in a (seriously) ill pediatric patient, home delivery with complications, etc. This could be a main reason why the pediatric population treated by HEMS is greater in the Netherlands. Another reason is that HEMS can be staffed in different ways, for example with only paramedics, which is different compared to the Netherlands where HEMS is physician-staffed. HEMS in the Netherlands is not a mode of transportation from one hospital to another, but has a primary goal on stabilization of critically ill or seriously injured patients at the incident site[1,2]. As in many other countries/studies the pediatric population managed at the incident site by HEMS is limited, sparse data on the treatment of pediatric emergencies are available[3-5]. Furthermore, there are no specialized pediatric HEMS , but in few occasions a HEMS team with a pediatric intensivist transport a critically ill or severely injured pediatric patient from one hospital to another. Data on the dispatches of a paramedic staffed service in pediatric emergencies show different results compared to our data[6]. This comparison may suggest the requirement of a more sophisticated educational program for paramedics[7] or the need for an upgrade to a physician based service.

The available data in the documentation has been invariably incomplete or not available, this complicates compiling coherent data to be able to draw conclusions or outcomes. The data for every patient should be standardized and the recording of this data needs to be mandatory. In addition to standardizing the data, having the data digitally recorded will make the information portable and accessible to HEMS physicians. This will enable prompt data recording and recovery to and from the patient monitor. In addition a nationwide database needs to be established and registry of cases needs to be obligatory for every hospital, EMS and HEMS system and include all out-of-hospital, in-hospital and post-hospital outcome data and include basic data of every resuscitated pediatric patient. With a national database the collective data will provide more data pertaining to small groups of patients and provide more information on which to base and investigate treatments and outcomes.

In the group of patients with cardiopulmonary arrest it was found that all survivors had Return Of Spontaneous Circulation (ROSC) prior to leaving the incident scene. In cases where there was rapid collection and delivery of the patient (so called scoop and run) with ongoing CPR, these patients all died. Performing high quality Basic Life Support (BLS) in the back of a moving ambulance has been shown to be moderate to poor. The study in **Chapter 4** shows that it is important to take time at the scene to set up and perform good quality BLS as well as Advances Life Support (ALS). This improves the survival of pediatric patients, there should no longer be any more rapid collection and delivery of pediatric patients in out-of-hospital cardiopulmonary arrest situations. To perform high quality BLS and ALS demands a lot of competence from the health care providers.

LAY-PERSONS

In **Chapter 4** a national data review on the incidence and outcomes of pediatric out-of-Hospital cardiopulmonary arrest (OHCA) has been performed for the first time. A recommendation is that a mandatory national database registering all pediatric OHCA's in the Netherlands needs to be created. Besides keeping a record of these incidents the database will create an awareness to health care providers as to why these patients go into OHCA and prevent it from happening. The shockable rhythm has been found to be most favourable for the sustained return of spontaneous circulation. Three patients were defibrillated using an automatic external defibrillator (AED) without the EMS or HEMS in attendance. Lay persons are extremely important as they can initiate Basic Life Support (BLS) including defibrillating the patient well before the arrival of EMS or HEMS services. The nationwide database could help accentuate the importance of initiating BLS and promote interest among lay people to learn BLS skills.

EMS

EMS personnel in the Netherlands follow a nationwide protocol for treating patients and are allowed to perform a number of BLS and ALS procedures such as intra-osseous access and intubation. The nationwide protocol also states which medication can be given to patients. There is little data on the success rates of ALS procedures in the pediatric population as there are not a lot of seriously injured or vitally compromised pediatric patients that are treated by the EMS. Due to the limited amount of live experience available EMS personnel train for these procedures on mannequins. In addition EMS personnel take care of all ages and various medical emergencies making it difficult with the limited time to train on all medical emergency subjects adequately. It has been established in the literature that the skills gained during training decrease after training this, in combination with limited actual live exposure make it difficult for EMS in treating pediatric patients. This is further illustrated in various chapters.

On close examination of pediatric Intubations performed by EMS it has been established that the success rates were far lower when performing pediatric edotracheal intubations, this reinforces the case for all pediatric patients that need to be intubated in the pre-hospital situation be performed by HEMS physicians. This is also the standpoint of the Nederlandse Vereniging voor Medisch Managers Ambulancezorg (NvMMA) and the main reason the national protocol has been changed and the abandonment of pediatric intubations by EMS and only allowing for the performing of bag-mask ventilation or the insertion of a laryngeal mask airway.

Intra-osseous (IO) access is required when an intravenous access is difficult or cannot be achieved. This type of access is regularly used in cardiopulmonary arrest situations in pediatric patients. Not all IO access data could be retrieved, however it is noticeable that the failure rate is higher among EMS patients than that of HEMS patients. Noted among the complications in IO access by EMS are:

- Skin lesions (burn wounds due to turning of needle into the skin due to needle size being too small)
- Lower limb compartment syndrome due to incorrect placement.

Live experience with these types of Advanced Life Support procedures is necessary to adequately perform under these stressful circumstances.

HEMS

The objective of this thesis is to determine whether the levels of competence and ability provided by the HEMS physicians, with the degrees of exposure and experience obtained in the pre-hospital situation equal the in-hospital medical standards for vitally compromised and/or severely injured pediatric patients

The objective of airway management is to achieve adequate tissue oxygenation and ventilaton while avoiding aspiration. To achieve this objective the standard method of managing the patient's airway securely is by endotracheal intubation. The environment and circumstances at the scene of the out-of-hospital location often creates unique and potentially risky situations when intubating pediatric patients. The success rate of endotracheal intubation depend on:

- The patient group being investigated.
- The qualifications of the health care provider performing the intubation.

On the basis of these criteria in **Chapter 2** the performance of the HEMS is reviewed, and it is established that the HEMS do have a high success rate when intubating pediatric patients which is in fact comparable to that achieved by health care professionals in the in-hospital environment. In the study period there were 1905 pediatric patients, of which 361 (19%) were intubated. This indicates that the HEMS do experience frequent exposure to attending to vitally compromised or severely injured pediatric patients ensuring maintenance of high levels of competence and ability. With regard to the qualification of the health care provider a review of the anesthesiologists and trauma surgeons establishes that for both groups a high rate of success has been achieved with no discernable difference between the two groups, however, the number of intubations performed by the trauma surgeons was low and therefore perhaps did not provide adequate information to influence the success rate results. In the period under review there were a total of eleven physicians in the Rotterdam HEMS only two of which were trauma surgeons. The two surgeons intubated a total of 35 pediatric patients which is lower than the statistical average which was 50 if the surgeons are included in the overall analysis. The reasons for this discrepancy can be attributed to the surgeons applying a different criteria threshold for performing pediatric intubations and opting to transport the pediatric patients earlier to hospital prior to intubation. There is a sound basis for the evaluation of each pediatric intubation case within the HEMS contingent and review the relevance of differing threshold criteria. There is a significant difference between the medicine-assisted intubations performed by physician with an anesthetic background than those coming from a surgical background in favour of the anesthesiologists. Medication assisted 1st pass

95% CI (2.8485 to 39.2547) p=0.0133. The reason for the discrepancy may be attributed to the trauma surgeons not being exposed frequently enough to these pediatric intubation cases, this is a sound basis for the trauma surgeons being annual training within the Pediatric Anesthesia Department performing pediatric patient intubations to ensure the competence and ability standards.

There is no national database for pediatric out-of-hospital or in-hospital cardiopulmonary arrests. In **Chapter 3** a critical review of pediatric out-of-hospital cardiac arrests (OHCA) performed by the Rotterdam HEMS has been made in order to determine whether, in a portion of the Netherlands, the degree of exposure to pediatric OHCA patients was adequate to ensure necessary exposure. The findings have been that exposure to critically compromised and severely injured pediatric patients is high and there is adequate knowledge and exposure to maintain high medical standards. The success rate for Advanced Life Support (ALS) skills, such as intubation and/or intra-venous access, within the HEMS is high, and can be found in **Chapter 2** where a review of pediatric patients requiring intubation is presented.

Establishing if there is any added value to the pediatric population by deploying the HEMS with regards to improved survival is difficult. In **Chapter 5**, reviewing the pediatric trauma patients during a study period of 12.5 years where 308 patients were attended to by both EMS and HEMS teams the outcomes are compared. The comparison took into account, and corrected accordingly for, the various ISS scores of the incidents. Despite the HEMS teams having dealt with on average incidents where there were higher ISS ratings, implying that the patients are less likely to survive, the patients appeared to benefit from the medical care provided and more patients survived. This study indicates that the HEMS assistance, with a physician in attendance, a reduction in mortality of up to 2.5 lives per 100 dispatches. According to the Dutch Ambulance Academy, every paramedic treats, at least once, a critically ill or severely injured child every five years. In comparison the HEMS currently are treating pediatric patients on average at 22% of all dispatches. The exposure and experience with critically ill or severely injured pediatric patients is therefore high and is a factor as to why there is a reduction in the mortality mentioned. More neurological and follow up research needs to be done over an extensive period and scored appropriately in order to evaluate whether these patients are growing up to have normal lives and not just an increase in the number of lives saved.

In **Chapter 6** the administration of Packed Red Blood Cells (PRBCs) transfusions in the pre-hospital situation was investigated. The database from the Nijmegen and Rotterdam HEMS services was small, 10 patients. In all 10 dispatches it was quicker to transport the PRBC units to the patient than it would have been to transport the patient to a level 1 hospital for transfusion at the Emergency Department. The skill and expertise to identify pediatric patients who are at risk and are in need of immediate blood transfusions is within the HEMS team's capability. Of the 10 patients in the study 2 were "unexpected" survivors, one was predicted not to survive by virtue of the high Trauma and Injury Severity Score, the second -a neonate- was in hypovolemic shock and cardiac arrest during a home birth. The possibilities of these 2 patients having survived without the administration of PRBCs by the HEMS is nil. Since 2017 in addition to transporting PRBCs the HEMS also has a pre-heating system so that less time is lost when starting a transfusion. With this faster reaction to administering blood transfusions there are immediate benefits to pediatric patients, these need to be identified and recorded and in turn the algorithms need to be amended so that efficiencies in blood product usage and ultimately costs can be improved. In the in-hospital setting patients can be treated with a variety of blood products in addition to PRBCs. There is overwhelming evidence in the pre-hospital setting that the early administration of other blood products, other than PRBCs such as whole blood to trauma patients in hemorragic shock can be very beneficial. This forms a basis for an international randomized control study into investigating and identifying the best strategy as to which blood products are best to be used in the pre-hospital setting including efficiencies of usage. This study should be done in pediatric patients as well.

Emergency Medical Services (EMS) is responsible for pre-hospital care including all ages, irrespective of injury cause or medical condition including peripartum emergencies. In the event of a complicated planned or unplanned home delivery, or in the event of an injured or critically ill pregnant woman or neonate being reported the dispatcher will deploy the HEMS in addition to the EMS. In comparison to the neighbouring countries the Netherlands has historically had a high incidence of home births . In 2016 12.7% of all Netherlands deliveries were planned home births under the guidance of specialised registered midwives, 17.3% of births were delivered in dedicated birth centres which are attached to a hospital again the deliveries are under the guidance of specialized registered midwives. Being attached to a hospital the services of obstetricians, pediatricians and anesthesiologists are available. The percentage of home deliveries is gradually decreasing, only women who have been without risk during their pregnancy are eligible for planned home deliveries. Previous international studies have indicated that the peripartum mortality of unplanned pre-hospital deliveries is higher than that for in-hospital cases. In order to better understand the reasons for this imbalance and ascertain the effectiveness of dispatching the HEMS a study has been undertaken reviewing the frequency of dispatch of HEMS teams to assist with home deliveries and the consequences of these dispatches. The number of deliveries requiring additional medical care is very low, during the study period 52 neonates required medical assistance from the HEMS. Five of infants who died were all pre-term and had lower birth weights. In addition to further improve the pre-hospital success rate the care provided has been adapted by providing BLS training to midwives, newborn life support for EMS teams. The number of neonatal emergencies is low which therefore requires continual training to be done so that competence and ability levels are maintained at a high level. Despite the low numbers of neonatal emergencies, and the reluctance of some pregnant women to have additional screening, the need for additional screening and determination of risks of patients needs to be considered for home deliveries.

In **Chapter 8** an analysis of pre-hospital perimortem caesarean deliveries (PCD) performed by the four HEMS entities from 1995 to 2020 has been made. During this period 7 cases of PCD were identified. In the event of cardiac arrest during pregnancy PCD is considered essential for resuscitation of both mother and fetus, however this should only be performed from 20 weeks of pregnancy but preferably from 24/26 weeks when the pregnant uterus compresses the inferior caval vein. The recommendation is that after four minutes of CPR the PCD is started and performed within one minute to maximise the chances of return of spontaneous circulation (ROSC) through caval vein relief and uterine autotransfusion. While this is the in-hospital guideline, this was reviewed as to its applicability to the pre-hospital setting. In all 7 identified cases this guideline was not met by the HEMS teams, however 3 neonates survived. They were respectively born after the performance of PCD at 13, 14 and 21 minutes after dispatch which is well beyond the prescribed 4-5 minute guideline. The recommendation is that while the PCD needs to be performed as early as possible the 4-5 minute guideline needs not necessarily be adhered to in the pre-hospital setting. The delay in the pre-hospital setting does mean that saving the mother is far lower than saving the neonate. A neonate can survive and remain in good neurological condition after a longer period of anoxia than the mother, a study done in British confirms this study's finding that neonatal damage or death will not occur until after a 20 minute period of anoxia. In pre-hospital resuscitations and PCDs special attention needs to be paid to:

- Performing intubation, with capnography
- Manual uterine displacement to avoid aortocaval compression.
- Using a midline rather than a lower transverse (Pfannenstiel) incision as there is more access to the uterus in emergency situations.

Throughout this thesis the advanced life support procedures performed by the HEMS has been reviewed and found to provide a high success rate. Considering the high volume of pediatric patients the exposure and experience gained keeps the skills level of the HEMS teams necessarily high for the adequate treatment of severely injured or vitally compromised children.

The ability to be able to think clearly and act responsively in the various and varied situations in the pre-hospital emergency situation is essential and stressful. The effect of the stress factor is not part of any of this research. Due to the frequent exposure to vitally compromised and severely injured pediatric patients there is a degree of preparedness within the HEMS teams that makes the environment less stressful for them resulting in the high success rates. The effect of daily stress on HEMS teams needs to be investigated.

The Netherlands has a unique pre-hospital care health system which makes it difficult to compare with neighbouring countries. The organisation and structure of the EMS is changing from crews that are highly educated and experienced nurses to personnel that have Bachelor medische hulpverlener (BMH) and Lange tranche verpleegkundige training. These initially are less experienced personnel. In the changing environment it is difficult to quantify and evaluate the added value the HEMS provides to the overall pre-hospital health care. This thesis, however, does provide the initial foundations for this evaluation by outlining the added value provided from a pediatric patient perspective.

There is an ongoing change to the provision of pediatric intensive care in the Netherlands leading to greater concentration of complex pediatric care at Pediatric Intensive Care Units (PICU) in the large academic university hospitals. This concentration of specialisation will increase. For instances where specialist care cannot be provided or pediatric patients in smaller hospitals these patients need to be transferred to the appropriate centres. Currently this transfer is performed by the EMS with specialist assistance provided by the PICU with a pediatric intensive care doctor and nurse in attendance. The arranging and dispatching of the expanded EMS team is time consuming at a critical phase of the patients treatment. In comparison the HEMS are on standby and can be dispatched rapidly to the pediatric patients at the hospital where they are being treated and can accompany the patient to the PICU, a far more rapid response. The role to be performed by the HEMS in the changing environment and especially with regards to travel distance, availability, interhospital transportation or stabilization of vitally compromised or severely injured children in rural hospitals needs to be reviewed and protocols for activating the HEMS amended.

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Danke
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Gracias
Bedankt!
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CHAPTER 11

Recommendations

RECOMMENDATIONS

On the basis of this research there are aspects of the services and modus operandi of the HEMS that need further attention, the following recommendations are made:

1. Create a national database, this will provide a broader and more representative pool of data for future research, more data on which to evaluate treatment procedures and the outcomes for every pediatric patient. This database needs also to be structured in such a way that an annual update can be recovered for each physician recording performance and outcomes of all Advanced Life Support (ALS) procedures including intubations, intra-venous or intra-osseous access. This record will enable any adjustments to the individual physicians ongoing training and maintenance of the necessary high level of ability and competence required for the care of severely injured or vitally compromised pediatric patients. The collection of this data should be done, using Bluetooth interaction for recovery of patient data from the patient monitor and by the physician either en-route back with the patient or shortly thereafter.
2. For physicians, who have a trauma surgery training, additional yearly training within the pediatric anesthesia department on pediatric patient intubation is required to achieve parity across the service.
3. Create a national database for pediatric out-of-hospital cardiopulmonary arrest registering all incidences and outcomes. This database can be used both for training purposes as well as creating awareness both within the health care professional community as well as the general public. Public awareness is important particularly in the pre-hospital phase and promote public interest in performing BLS procedures.
4. The so called "scoop and run" practice for pediatric patients in an out-of-hospital cardiac arrest scenario needs to be considered only as a last resort, current statistics show that there have been no survivors when this practice has been followed.
5. Emergency Medical Services (EMS) personnel should not perform intubations on pediatric patients, the use of bag-mask ventilation or Laryngeal Mask Airway (LMA) followed by a gastric tube insertion should be performed instead.

6. There is a need for additional research into the role of warmed uncross matched packed red blood cells and their combination with other blood products in the survival of pediatric patients experiencing hemorrhagic shock. The research needs to identify which patients will benefit most from this intervention and the relevant algorithms need to be amended to reflect this thereby reducing waste and costs.
7. Caution needs to be exercised by EMS when performing Advanced Life Support procedures such as intra-osseous cannulation. If there is a possibility for EMS personnel to delay such performance until the HEMS personnel arrive then this can be done under direct supervision to ensure adequate insertion.
8. The protocol for deployment of HEMS personnel needs to be adjusted to a lower threshold in instances where there are pediatric patients who are severely injured or are vitally compromised.
9. Home birth numbers in the Netherlands are decreasing making it important for both EMS and HEMS to undergo continuous training particularly in aspects of neonatal life support and advanced life support, BLS training should be continued for the midwives.
10. The 4-5 minute guideline before performing perimortem caesarian delivery in the pre-hospital setting should be abandoned, even with HEMS presence and availability. The recommendation for PCDs to be performed as soon as possible needs to remain however realizing that in these situations the chances of survival of the mother is far lower than that of the neonate. When performing the PCD a midline incision should be used as it is
    - Both technically easier and the abdominal wall is thinner.
    - The resistance and structures in the abdomen wall are simpler.
    - The uterus is always immediately encountered when cutting through the abdominal wall and protects other structures such as bladder and bowel.

In cases of maternal death an autopsy is recommended so as to identify cause of cardiac arrest and understand reason for failure of ther procedure.


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List of Abbreviations

LIST OF ABBREVIATIONS

AED	Automated External Defibrillator
ALS	Advanced Life Support
BLS	Basic Life Support
BMH	Bachelor Medische Hulpverlener
CI	Confidence Interval
CPR	Cardiopulmonary Resuscitation
CT	Computer Tomography (scan)
ED	Emergency Department
EMS	Emergency Medical Service
ETI	Endotracheal Intubation
GBA	Gemeentelijke basisadministratie persoonsgegevens
GCS	Glasgow Coma Score
Hb	Hemoglobin
HEMS	Helicopter Emergency Medical Service
ICU	Intensive Care Unit
IO	Intra-Osseous
ISS	Injury Severity Score
IV	Intra-Veneous
LMA	Laryngeal Airway Mask
MMT	Mobiel Medisch Team
MOET	Managing Obstetric Emergencies and Trauma
MRI	Magnetic Resonance Imaging
NICU	Neonatal Intensive Care Unit
NLS	Neonatal Life Support
NvMMA	Nederlandse Vereniging voor Medisch Managers Ambulancedienst
OHCA	Out of Hospital Cardiac Arrest
PCD	Perimortem Caesarean Delivery
PhPLS	Prehospital Pediatric Life Support
PICU	Pediatric Intensive Care Unit
PRBC	Packed Red Blood Cell
RTS	Revised Trauma Score
SPSS	Statistical Package for the Social Sciences
STRISS	Trauma Injury Severity Score


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PhD Portfolio

PHD PORTFOLIO

Name PhD student: drs. X.R.J. Moors
Erasmus MC Department:
Anesthesiology

PhD period: 2017-2021
Promotor: Prof. dr. R.J. Stolker,
Co-promotoren: dr. D. den Hartog, dr. RJ Houmes

1. PhD training

	Year	Workload	
		Hours	ECTS
General courses			
Good Clinical Practice (BROK)	2018		1.5
Research Integrity	2017		0.3
Specific courses			
Paris rescue ECMO course	2019	16	0.6
Prehospital Surgical Skill Course	2018	18	0.6
Battlefield Advanced trauma Life Support (Defensie Nederland)	2018	27	0.9
Seminars and workshops			
Moeilijke kinder luchtweg cursus (Instructor, Ede Hospital)	2019		1.0
Jurylid Nederlandse kinderreanimatie competitie (Venticare)	2019	10	0.3
Kinder anesthesiologie (Instructor, NVA dagen)	2019	40	1.0
Jurylid Nederlandse kinderreanimatie competitie (Venticare)	2018	10	0.3
Surgical Skills (ErasmusMC)	2018	4	0.2
Presentations			
Prehospital pediatric trauma and spine management (Sophia)	2020		1.0
Pediatric airway (HAGA Hospital)	2019		1.0
Prehospital airway management (Ambulance School, RAV BrabantMWN)	2019		1.0
Acute pediatric patient (Masterclass Ambulance) x2	2019		2.0
Pediatric Trauma (European Society of Pediatric Anesthesia)	2019		1.0
Perimortem caesarean delivery (PREM congress)	2019		1.0
Acute Zorg Congres (Den Bosch)	2019		1.0
Werkgroep Educatieve Symposia (WES) (ErasmusMC)	2019		1.0
Prehospital pediatric trauma (SKA & BAPA anual scientific meeting)	2019		1.0
Pediatric trauma (Elisabeth Hospital Tilburg)	2019		1.0
Reginaal symposium Het Ernstig Gewonde Kind	2018		1.0
Traumatic Airway Symposium (Radboud UMC)	2018		1.0
Perimortem caesarean delivery (Erasmus MC - Sophia)	2018		1.0
HOTT procedure, traumatic cardiac arrest (Ambulance) x2	2018		2.0
National and international conferences			
The Big Sick congress, Air Zermatt	2020	32	0.9
Berlin Intensiv Transport Kurs	2019	32	0.9
HEMS congress Warsow	2018	32	0.9
Other			
Kinderchirugie leerboek. Hoofdstuk 4, Prehospitale zorg aan kinderen, triage en (secundair) transport.	2018	65	2.0

	Year	Workload	
		Hours	ECTS
2. Teaching			
Lecturing			
Prehospital Pediatric Life Support (Course Director)	2020	20	0.6
Neonatal Advanced Life Support (Instructor)	2020	20	0.6
Prehospital Pediatric Life Support (Instructor)	2019	20	0.6
Prehospital Pediatric Life Support (Course Director)	2019	20	0.6
Advanced Pediatric Life Support (Instructor)	2019	27	0.9
Prehospital Pediatric Life Support (Course Director)	2018	20	0.6
Advanced Pediatric Life Support (Instructor)	2018	27	0.9
Neonatal Advanced Life Support (Instructor)	2018	20	0.6
Advanced Pediatric Life Support (Instructor)	2017	27	0.9
Prehospital Pediatric Life Support (Course Director)	2017	20	0.6
Keuze onderwijs student geneeskunde (2018 and 2019)	17-19	12	0.6
MEPA arts assistenten Anesthesiologie (ErasmusMC)	2018	20	0.3
Supervising practicals and excursions, Tutoring			
Supervising Medical student			
S. Bouman (building database and research on 3 publications)	2018-2019		1.5
TOTAL			36.7

1,0 ECTS = 25-30 uur

1,5 ECTS = 1 week (→ 1 dag = 0,3 ECTS)

PhD gem. 30 ECT


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List of Publications

LIST OF PUBLICATIONS

1. Pediatric out-of-hospital cardiopulmonary resuscitation by helicopter emergency medical service, does it has added value compared to regular emergency medical service?

   Moors XRJ, Rijs K, Den Hartog D, Stolker RJ.

   Eur J Trauma Emerg Surg. 2018 Jun;44(3):407-410.

2. Prehospital blood transfusions in pediatric patients by a helicopter emergency medical service.

   Moors XRJ, Bouman SJM, Peters JH, Smulders P, Oude Alink MB, Den Hartog D, Stolker RJ

   Air Med J. 2018 Sep;37(5):321-324.

3. A physician-based helicopter emergency medical services was associated with an additional 2.5 lives saved per 100 dispatches of severely injured pediatric patients.

   Moors XRJ, van Lieshout EMM, Verhofstad MHJ, Stolker RJ, Den Hartog D.

   Air Med J. 2019 Jul-Aug;38(4):289-293.

4. Are on-scene blood transfusions by a helicopter emergency medical service useful and safe? A multicentre case-control study.

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

   Eur J Emerg Med. 2019 Apr;26(2):128-132.

5. Retrospective Analysis of out-of-Hospital Paediatric Intubation by a Dutch Helicopter Emergency Medical Service.

   Moors Xavier RJ, Oude Alink Michelle B, Bouman Stef JM, Den Hartog Dennis, Houmes Robert Jan and Stolker Robert Jan.

   Clin Pediatr Res 2019, 3(1):56-62.

6. Analysis of prehospital perimortem caesarean deliveries performed by Helicopter Emergency Medical Services in the Netherlands and recommendations for the future.

   XRJ Moors, TH Biesheuvel, J Cornette, MG Van Vledder, A Veen, M de Quelerij, EEM Weelink, JJ Duvekot
   Resuscitation 2020

7. Prehospital Management of Peripartum Neonatal Complications by Helicopter Emergency Medical Service in the South West of the Netherlands: An Observational Study.

   Michelle B Oude Alink, **Xavier R.J. Moors**, Rogier C.J. de Jonge, Dennis den Hartog, Robert Jan Houmes, Robert Jan Stolker.

   Air Medical Journal 2020

8. Characteristics, management and outcome of prehospital pediatric emergencies by a Dutch HEMS.

   Michelle B Oude Alink, **Xavier R.J. Moors,** Karrar S, Houmes RJ, Den Hartog D & Stolker RJ

   Eur J of Trauma Emerg Surg. 2021

9. Nationwide retrospective analysis of Out-of-Hospital Pediatric Cardio Pulmonary Resuscitation treated by Helicopter Emergency Medical Service in the Netherlands.

   Moors XRJ, Oude Alink MB, MD, Bouman SJM. Schober P, De Leeuw MA, Hoogerwerf N, Bergsma TM, Den Hartog D, Houmes RJ, Stolker RJ

   Accepted Air Medical Journal

10. Association between shockable rhythms and long-term outcome after pediatric out-of hospital cardiac arrest in Rotterdam, the Netherlands: an 18-year observational study.

    M. Albrecht, R.C.J. de Jonge, V.M. Nadkarni, M. de Hoog, M. Hunfeld, J.A.E. Kammeraad, **X.R.J. Moors**, L. van Zellem, C.M.P. Buysse.

    Resuscitation 2021

11. Incidence of severe critical events in paediatric anaesthesia (APRICOT): a prospective multicentre observational study in 261 hospitals in Europe.

    Habre W, Disma N, Virag K, Becke K, Hansen TG, Jöhr M, Leva B, Morton NS, Vermeulen PM, Zielinska M, Boda K, Veyckemans F; APRICOT Group of the European Society of Anaesthesiology Clinical Trial Network.

    Lancet Respir Med. 2017 May;5(5):412-425.

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Gracias
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About the author

ABOUT THE AUTHOR

Xavier Moors werd geboren op 10 september 1977 te Heerlen. Na het behalen van zijn VWO-diploma aan het Antonius Doctor College te Kerkrade, begon hij in 1997 aan de Katholieke Universiteit Leuven aan geneeskunde na te zijn uitgeloot in Nederland. Uiteindelijk werd hij ingeloot aan de Erasmus Universiteit te Rotterdam en heeft daar zijn studie geneeskunde afgerond.

Gedurende de opleiding geneeskunde werkte hij full-time bij een ambulancedienst als ambulancechauffeur en dit heeft veel invloed gehad op zijn verdere carrière.

Xavier heeft zijn artsexamen afgelegd in 2006 en kwam direct in opleiding tot anesthesioloog, afdeling Anesthesiologie van het Erasmus MC te Rotterdam (Prof. Dr. Klein en Prof Dr. Stolker). De perifere opleiding werd genoten in het Albert Schweitzer ziekenhuis te Dordrecht (Dr. Koopman-van Gemert). Het laatste halfjaar van de opleiding werd besteed aan een stage Kinderanesthesiologie. Dit beviel zo goed dat na de registratie als anesthesioloog in oktober 2011 hij een fellow periode kinderanesthesiologie volgde naast een functie als MMT-arts.

Tijdens de opleiding tot anesthesioloog is hij steeds prehospitaal blijven werken in diverse functies, onder andere als ambulanceverpleegkundige, medisch manager ambulancedienst en baanarts bij diverse (sport) evenementen.

Onderwijs heeft ook een grote rol gespeeld. Zo is hij in 2008 begonnen als ALS instructeur en inmiddels is hij instructeur voor diverse kindertrainingen zoals de Advanced Pediatric Life Support en Prehospital Pediatric Life Support. Sinds 2014 is hij bestuurslid van de stichting Spoedeisende Hulp bij Kinderen en sinds 2019 bekleedt hij de functie van voorzitter.

Xavier is getrouwd met Mirjam en wonen met hun drie kinderen Evi (2008), Dex (2012) en Cas (2014) in Breda.


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Dankwoord

DANKWOORD

Het dankwoord, een belangrijk gedeelte want dit is (vaak) het stukje wat het meest gelezen wordt. Ook ik mag er eindelijk een schrijven. Een proefschrift schrijf je niet alleen, ook hier is samenwerking (net zoals op straat) met velen een essentieel onderdeel en iedereen die hier in meer of mindere mate aan heeft bijgedragen wil ik graag bedanken.

Mijn promotor, Prof. dr. Stolker, beste Robert Jan, hartelijk dank dat je me hebt opgenomen in de staf en dat je me de mogelijkheid hebt geboden om me tijdens mijn (kinder) anesthesiologische loopbaan bezig te houden met het onderzoek dat heeft geleid tot dit proefschrift. Dank voor de ondersteuning en het in mij gestelde vertrouwen.

Mijn copromotor, dr. den Hartog, beste Dennis. Bedankt voor het kritisch doorlezen van de artikelen, je steun en het in mij gestelde vertrouwen. (Volgende keer als ik bij je thuis kom wil ik wel iets te drinken ;-))

Mijn copromotor, dr. Houmes, beste Robert Jan. Samen zijn we collega's op de Lifeliner2. Ik waardeer je als een kritisch denkende collega. Bedankt voor je steun.

Geachte leden van de promotiecommissie Prof. dr. M. De Hoog, Prof. dr. H. Moll, Prof. dr. M. Sabbe, hartelijk dank dat jullie in de commissie willen deelnemen en tijd hebben gemaakt om mijn proefschrift door te nemen.

Michelle Oude Alink, dankzij jou kwam alles in een stroomversnelling en gingen we met flinke stappen vooruit. Onwijs bedankt voor de samenwerking, met z'n tweeën ging alles makkelijker! Ik kijk uit naar jouw 'boekje'!

Stef Bouman, je zou even iets komen doen maar bent gewoon blijven "plakken" en zo kwam jouw naam op meerdere artikelen. Van geneeskundestudent naar IC-arts in Breda en uiteindelijk in opleiding tot Anesthesioloog in het MUMC. Ik verheug me op de dag dat we collega's zijn.

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Dr. van Lieshout, beste Esther. Ontzettend bedankt voor je hulp met de statistiek van hoofdstuk 4, zonder jou was het artikel niet op deze manier gelukt. Ieder zijn vak.

Anesthesiologen, operatieassistenten, anesthesiemedewerkers en andere medewerkers van het OK van het Sophia Kinderziekenhuis. Wat een voorrecht is het om hier te werken. Ouders vertrouwen ons met hun dierbaarste bezit en wat een bevlogenheid is er dan te zien bij alle collega's. Met name bedankt aan de anesthesiemedewerkers en AIOS die alleen op de kamer bleven als ik nog even snel iets moest doen voor mijn onderzoek en alle KINDERanesthesiologen (hier mag het gewoon) die ervoor zorgen dat collega's schaarse non- clinicals krijgen.

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Collega's van de ambulancedienst te Gouda, toen nog de ISMH, nu de RAV Hollands Midden. De eerste stappen in de prehospitale acute geneeskunde in Nederland mocht ik hier zetten en wel als ambulancechauffeur (en ik had niet eens een auto in het begin!). Ik heb veel van jullie geleerd en ben jullie ontzettend dankbaar dat ik deze kans heb mogen krijgen. Aart, de door jou geleerde vaardigheden gebruik ik nu nog steeds dagelijks. Ik ben toch een straatjongetje gebleven ;-).

Ambulancehulpverleners en medewerkers van de RAV Brabant Midden-West-Noord. Ook hier zijn we begonnen met wetenschappelijk onderzoek en steeds meer medewerkers raken betrokken en bevlogen. Wat leuk om dit te zien. Ik ben echt trots op onze RAV en onze medewerkers die er werken. Niet voor niets worden we door zovelen nauwlettend gevolgd. En dan onze medische staf en de PA's en VS'en, wat ontzettend leuk om met jullie te mogen werken. Jullie enthousiasme is aanstekelijk en wat hebben we er met z'n allen een mooie baan van gemaakt!

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Stichting Spoedeisende Hulp bij Kinderen. Misschien wel zonder het te beseffen, maar jullie hebben echt veel invloed gehad in mijn medische (kinder) carrière. Van het lesgeven van diverse kindercursussen in Riel tot en met lesgeven in Suriname aan toe. Het is een hele eer om voorzitter te zijn van de SHK, die heel veel betekend heeft en betekent voor artsen, PA's Vs'en en verpleegkundigen en daarmee ook de kinderen die op een of andere manier in contact komen met het medische circuit.

Air Alliance Medflight (Stella & Gert). Where else can you work on your PhD at Flight Level 350 on route to different cities in Europe, Africa or even Asia. An office with a view, a cup of coffee and a box full of Haribo! Thanks for having me on the team.

Dan mijn werkfamilie:

Alle (oud) HEMS Commanders Lifeliner 2 (Gert, Marco, Geert, Kris, Rik, Gepco, E.J., Patrick, Roel en Roy), oftewel de piloten van “onze” gele helikopters. Jullie kijken al niet meer op als wij weer een of ander bizar verhaal vertellen over een hulpverlening tijdens het eten. Door weer en wind brengen jullie ons veilig op de plek waar we moeten zijn, met soms zelfs nog medische tips (Rik) waarvoor onwijs bedankt! Één van de hoogtepunten van de dag blijft het ontbijt samen, gezellig eten en kletsen waar we helaas steeds minder tijd voor hebben omdat we alweer een oproep hebben.

Alle (oud) MMT-artsen Lifeliner 2 (Ingrid, Iscander, Ruben, Isabelle, Alexander, Patricia, Robert-Jan, Philippe, Mark, Eric “Bokkie”, Dinis, Caspar, Perjan, Oscar, Jeanne) , dank voor de ontzettend fijne samenwerking! De database was een grote bron voor de vele onderzoeken. Mooi om onderdeel te mogen zijn van zo’n “bevlogen” (ik maak ‘m gewoon) team. Het blijft een voorrecht om hier te mogen werken!

Alle (oud) HEMS Crew Members Lifeliner 2 (Albert, Christian, Jan, Floris, Jorrit, Tirza, Jeroen, Maaike, Charlotte, Petra, Wim B, Wim T, Henk, Winfried “Fifi”), oftewel de verpleegkundigen. Vaak zijn we samen op pad en moeten we het maar zien te doen. De cijfers in dit boek zijn kinderen. Kinderen waar wij medische zorg aan hebben verleend. Alleen jullie weten hoe het echt was, wat we meemaakten, welke verhalen er schuilen achter elk cijfertje of hulpverlening. Veel tijd brengen we met elkaar door en we delen veel lief en leed met elkaar. Gelukkig delen we ook vaak dezelfde humor, vandaar de sterke band die we hebben (ook jij Albert). We few, we happy few, we band of brothers.

In het bijzonder wil ik mijn paranimfen bedanken, mijn 2 collega’s Felix van Lier en Eric Bokhorst oftewel Flix en Bokkie. Ondertussen gaan we al heel wat jaartjes terug, wie had dit allemaal kunnen weten toen wij in 2006 aan de opleiding anesthesiologie begonnen? Fijn dat jullie op deze dag ook aan mijn zijde kunnen staan.

Felix, of gewoon Flix. Van de Piper (met 90 knopen) naar de DA-40, Cirrus SR20 en nu gewoon de 22 volledig FIKI (met soms over de 200 knopen!). We hebben al best wat avonturen beleefd en landen aangedaan, soms ook met onze kinderen Evi en Tjebbe, gelukkig kan de koptelefoon achter in het toestel losgekoppeld worden. In de uurtjes op grote hoogte kwam vaak ook onderzoek aan bod, want ja, wat doe je anders?! Bedankt voor het aanhoren en je steun (zeker ook bij de laatste loodjes!). Tijd voor de volgende trip in de LLG.

Bokkie, soms weet je pas echt wat je hebt als je het verliest. In dit geval ging jij bij het MMT werken en verliet je de kinderanesthesiologie voor de Intensive Care Kinderen, een logische stap. Het gevolg was dat je opeens na jaren geen kamergenoot meer was en ik je minder zag. Ik mis de gesprekken, het effe zeiken over iets, luisterend oor en vooral dingen uithalen die eigenlijk......... Ik weet dat je nog steeds in hetzelfde gebouw werkt, we zijn beiden druk, maar we blijven maatjes!

In mijn persoonlijk leven dank ik al mijn vrienden en familie voor een luisterend oor. Femke, bedankt voor het voorstellen aan mijn vrouw, met Kevin heb ik zelfs nog een tijd een ruimte gedeeld. Ook Debbie en Hans en Hedwig en Annemiek en Michiel bedankt voor de gezelligheid. Jullie hebben ooit een filmpje van ons gemaakt waarbij alles is uitgekomen, zo goed kennen jullie ons.

Dian, zonder jou zou alles in de soep lopen en kunnen wij de dingen doen die we doen. Onwijs bedankt voor alles en de visjes die je voor me klaarmaakt!

Pap en mam, wat zouden jullie trots zijn geweest nu dat jullie twee kinderen allebei gepromoveerd zijn. Ik weet zeker dat jullie meekijken vanuit ergens en erbij zullen zijn.

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Evi, Dex en Cas. Onze drie kinderen, onze drie unieke temperamentvolle kinderen. Maar goed, met ons als ouders hadden we dat ook kunnen verwachten. Ik ben zo ontzettend trots op jullie.

Dr. Mirjam, of eigenlijk gewoon Schwazie voor mij. Je zei het al eens, want jij mocht nu eenmaal je dankwoord eerder schrijven dan ik: “the sky is the limit, maar niet voor ons....”. Wat hebben we veel meegemaakt en veel lief en leed gedeeld. Samen kunnen we alles (aan)! En oh ja, bedankt dat je me af en toe weer eens op de grond zet met beide benen. Love you!


geen
staan
stil'
moment
BEDANKT
HELD
DANKT
BEDANKT