Prehospital medical care in children by a Helicopter Emergency Medical Service

From incident to outcome

Bas Gerritse

Prehospital medical care in children by a Helicopter Emergency Medical Service Bas Gerritse

SHK

Acute Zorgregio Oost

Prehospital medical care in children by a Helicopter Emergency Medical Service

From incident to outcome

Bas Gerritse

Thesis Radboud University Nijmegen Medical Center

ISBN: 978-90-9025603-0

This thesis was prepared at the department of Anesthesiology, Pain, Palliative Medicine and Intensive Care, Radboud University Nijmegen Medical Center, Nijmegen, The Netherlands.

Cover illustration: René Ligtenberg, Malden
Lay out and printing: Optima Grafische Communicatie, Rotterdam.

Prehospital medical care in children by a Helicopter Emergency Medical Service

From incident to outcome

Een wetenschappelijke proeve op het gebied van de Medische Wetenschappen

Proefschrift

ter verkrijging van de graad van doctor
aan de Radboud Universiteit Nijmegen
op gezag van de rector magnificus prof. mr. S.C.J.J. Kortmann
volgens besluit van het college van decanen
in het openbaar te verdedigen op vrijdag 12 november 2010
om 10.30 uur precies

door

Bastiaan Martijn Gerritse

geboren op 5 mei 1963
te Voorburg

Promotor:
Prof. dr. G.J. Scheffer

Copromotor:
Dr. J.M.Th. Draaisma

Manuscriptcommissie:
Prof. dr. A.J. van Vught, UMC Utrecht
Prof. dr. R. de Groot
Prof. dr. C.J.H.M. van Laarhoven

Publication of this thesis was supported by: Stichting Spoedeisende Hulp bij Kinderen, Abbott Nederland and Acute Zorgregio Oost.

For the children

CONTENTS

Chapter 1

Introduction and outline of the thesis

INTRODUCTION

Prehospital medical care in most developed countries is provided by an Emergency Medical Service (EMS) staffed by nurses or paramedics, with the eventual support of a physician transported by car or helicopter. The method of transporting a physician to the incident scene by helicopter is called a Helicopter Emergency Medical Service (HEMS).

In the Netherlands, Helicopter Emergency Medical Services were introduced in relation to the establishment of regional trauma centres. These regional trauma centres were realised in 1996 as a result of a long debate on how trauma care could be improved. This policy resulted from discussions questioning the quality of trauma care, which were initiated as long ago as the 1980s. The report on a prospective multi-centre trial performed by Draaisma and Goris described suboptimal trauma care in general hospitals.[1] Draaisma concluded that the primary care for trauma patients in the Netherlands was not very well organised; national guidelines for resuscitation in the field and triage were deficient.[2] Studies from outside the Netherlands reported improvements in the trauma care after the implementation of an integrated system. Central elements of these studies were: advanced life support in the pre-hospital phase and triage in the field with the subsequent transport of the severely injured patients to regional trauma centres. The introduction of Mobile Medical Teams was part of the establishment of regional trauma teams. Ten hospitals were designated regional trauma centres; the trauma centres in Amsterdam, Rotterdam, Nijmegen and Groningen were also supplemented with a HEMS.

It was subsequently demonstrated that the Helicopter Emergency Medical Services provided significant benefits for severely injured trauma patients and performed crucial life saving interventions. HEMS was also proven to be cost-effective with respect to quality of life and life years gained.[3,4,5] However, research has also shown that the benefits of an HEMS can be disappointingly small if no strict selection criteria for the activation of the service are applied.[6] For example, HEMS care in relation to cardiovascular problems in adults was shown to have only minor benefits.[7]

The medical care administered to vitally compromised children in the field is the ultimate test for all the professionals involved. The EMS and the HEMS have to demonstrate optimal medical and organisational skills under the emotional pressure caused by situations in which children are involved. Paediatric emergencies constitute only a minority of all the cases the EMS and HEMS are confronted with, but these cases involve a wide range of age-specific, anatomical and physiological factors.[8] Even if a lot of effort and personnel is invested in a single case, the outcome may still be disappointing. For example, the survival rate in paediatric out-of-hospital cardiac arrests is less than 10%.[9] In Finland the availability of an HEMS to cover a large area has proven extremely helpful even though paediatric patients needing advanced life support measures is not a frequent occurrence.[10] Furthermore, the Emergency Trauma Service of the Children's National Medical Centre, Washington DC, USA, demonstrated that helicopter transport was associated with better survival rates among injured children in urban environments.[11] A careful study of the documented cases of children treated in the field may contribute to improving the quality of care provided by the physicians involved.[12,13] However, the high level of quality delivered by Helicopter Emergency Medical Services in documented adult cases may not be duplicated in the paediatric population. Obstructed airways in children, the most important paediatric diagnostic entity, are often not treated adequately.[14] At an international level extensive research has been conducted into the potential benefits and drawbacks of HEMS to supplement the standard EMS. As the organisation and training of pre-hospital medical care providers is often specific to a country, national data and results cannot easily be extrapolated.[15]

As stated before, the HEMS in the Netherlands were initially established for trauma patients in the field, both adults and children. Because the EMS generally had less experience with the latter, the HEMS was also called in for general paediatric resuscitation or in cases of children with a severe illness. Often the EMS paramedic will be the first properly trained aid provider on the scene, but the experience level of Dutch paramedics with regard to vitally endangered children is minimal. Fourteen hundred paramedics are actively employed in the Netherlands. Of the approximately 340,000 emergency ambulance callouts each year, 7,000 (2%) involve resuscitation.[16,17] On average a paramedic will perform 4.8 resuscitations per year. The resuscitation of children is a very small percentage and it may be years before a paramedic is called upon to perform resuscitation on a child. Because of this low exposure it would seem virtually impossible to develop a routine for incidences of paediatric resuscitation.

All HEMS physicians in the Netherlands have been trained in accordance with the Advanced Paediatric Life Support (APLS) guidelines, which were introduced in the Netherlands by the Dutch Foundation for the Emergency Medical Care of Children.[18] These guidelines use the so-called ABC system, similar to the system introduced by the Advanced Trauma Life Support (ATLS) group.[19]

In an ideal situation the HEMS should provide optimal medical care with limited loss of time after arriving at the incident scene of a vitally compromised child. The interventions should be performed in the 'sweep and treat' mode: only the most necessary procedures are performed, with the least amount of time lost at the scene or during transfer. Previously, the management of the patient consisted of either a 'scoop and run' or a 'stay and play' procedure: either the swiftest transfer to the hospital, or the maximum number of possible interventions at the scene. If an airway is threatened by obstruction this should be remedied at the scene; the second intravenous access can also be obtained during transportation. The secondary survey as described in the ATLS/APLS should be performed during transfer. It is essential that all the relevant data are communicated to the receiving hospital in advance: mechanism, injury / trauma, primary survey and treatment received. The expected time of arrival of the medical team at the emergency ward, and the medical staff required after arrival, should also be communicated in the standard fashion. The objective should be to achieve a seamless transfer of the patient from the scene to the hospital, without any unnecessary loss of time or any reduction in the quality of the medical care.

The purpose of this thesis is to investigate whether the introduction of a HEMS in the eastern part of the Netherlands fulfilled the objective of providing optimal medical care to vitally compromised children in the field. For children, in particular, did the outcome with respect to morbidity or mortality improve compared to the period before the introduction of the HEMS? No data is available in the Netherlands regarding the pre-hospital care for vitally compromised children provided by the EMS before the HEMS became available. Consequently, it is not possible to make a comparison between the time before and after the introduction of the HEMS. Another method would be to perform a prospective, randomised trial to determine the benefits of HEMS for children; the randomisation would consist of providing or withholding a medical intervention, triage or transport. A trial of this nature in vitally compromised children in the field is not feasible; it would be hampered by methodical, legal and ethical objections.

However, the author of this thesis has assumed that important lessons may be learnt from studying data of the medical care provided to children by the HEMS.

The analysis of this data was used to answer the following questions:

1. **Dispatching.** What were the HEMS calls made by the dispatcher, classified by indication and dispatch region?
2. **Epidemiology.** What is the epidemiology of the vitally compromised children for whom the HEMS is called out?
3. **Intervention.** Which medical interventions were provided by the HEMS? Was there a benefit or a disadvantage to the HEMS intervention? Were the medical interventions properly applied?
4. **Outcome.** What was the outcome in respect of the children who were treated by the HEMS in comparison to peer groups?

The data used for this thesis was compiled from all HEMS calls involving children (under the age of eighteen) in the period from March 1st 2001 to January 1st 2008, for which the HEMS Nijmegen (Lifeliner 3) was activated. The HEMS Nijmegen had 6,749 callouts in this period, 891 of which involved children. These 891 HEMS callouts are the basis of the studies described in this thesis. The author of this thesis was involved as a HEMS physician in a significant number of cases. A research database was constructed by using the data from the HEMS database and adding relevant information from hospital files.

The studies are fully described in the next chapters of this thesis. Chapter 2 is a review of the history and epidemiology of the vitally compromised child. Chapters 3 and 4 describe emergency dispatching for all patients and dispatching for children in particular. The study in chapter 5 evaluates the medical procedures provided by the HEMS in relation to the medical procedures provided by the EMS. Endotracheal intubation is a procedure that entails a risk under any conditions, but especially in the field. Data on paediatric endotracheal intubation is provided in chapter 6. Iatrogenic tracheal stenosis is one of the complications after endotracheal intubation; chapter 7 gives an overview of the potential risk factors. A relatively large amount of time in every trauma case in the field is invested in the application of spine immobilisation. The scientific foundation for spine immobilisation in children is described in a review of medical literature in chapter 8. Chapter 9 describes the application of a pre-hospital intra-osseous access device. A case study and additional remarks on the application of pre-hospital ultrasound are provided in chapter 10.

Does the actual medical care provided by the HEMS physician comply with the APLS guidelines? An evaluation by an expert panel on the pre-hospital care of vitally compromised children is given in chapter 11. A long-term follow-up study of the health-related quality of life of the children involved is described in chapter 12. The final chapter contains a summary and recommendations in English, French and Dutch.

REFERENCES

1. Draaisma JMTh, Haan AFJ , Goris RJA. Preventable trauma deaths in the Netherlands – A prospective multicenter study. J Trauma 1989;29:1552-1557
2. Draaisma JMTh, Evaluation of Trauma Care, with emphasis on hospital trauma care. Thesis, Katholieke Universiteit Nijmegen, 1987
3. Hübner BL. Evaluation of the immediate effects of preclinical treatment of severely injured trauma patients by Helicopter Trauma Team in the Netherlands. Thesis, Vrije Universiteit Amsterdam, 1999
4. Olden GDJ. Evaluation of early trauma care. Thesis, Katholieke Universiteit Nijmegen, 2003
5. Ringburg AN. Helicopter Emergency Medical Services, effects, costs and benefits. Thesis, Erasmus Universiteit Rotterdam, 2009
6. Naylor DC. McLellan BA. Air ambulances: missions of mercy or flights of futility? Lancet 1996 (347) 1348
7. Hotvedt R, Kristiansen IS, Forde OH, Thoner J, e.a. Which groups of patients benefit from helicopter evacuation? Lancet 1996 (347)
8. Albrech M, Berner J, Altemeyer KH. Kindernotfalle in Luftrettungdienst. Notfall und Rettungsmedizin. 2000(3) 156-169
9. Kuisma M, Suominen P, Korpela R. Paediatric out-of-hospital cardiac arrests – epidemiology and outcome. Resuscitation 1995 (30), 141-150
10. Suominen P, Silfvast T, Korpela R, Erosuo J. Pediatric prehospital care provided by a physician-staffed emergency medical helicopter unit in Finland. Pediatric emergency care 1996 (12) 169-172
11. Moront ML, Gotschall CS, Eichelberg MR. Helicopter transport of injured children: system effectiveness and triage criteria. Journal of Pediatric Surgery 1996 (8), 1183-1188
12. Ballnus S, Moller JC, Friedrich HJ. Evaluation der dokumentierten notartzlichen Versorgung van Kindern im Einzugsgebiet des Universitatsklinikums Lubeck. Problembereiche der Qualitatssicherung in der Versorgung padiatrischer Rettungsdienstpatienten. Notarzt 2002;18:187-191
13. Voorde P vd, Sabbe M, Calle P, Idrissi SH, Christiaans D. Closing the knowledge-performance gap: an audit of medical management for severe paediatric trauma in Flanders. Resuscitation 2008;79(1):67-72
14. Möller JC, Ballnus S, Kohl M, Gopel M, Barthel W. Evaluation of the performance of general emergency physicians in pediatric emergencies: Obstructive airway diseases, seizures and trauma. Pediatric Emergency Care 2002 (18), 424-428
15. Ummenhofer W, Scheidegger D. Role of the physician in prehospital management of trauma: European perspective. Current Opinion in Critical Care 2002;8:559-565.
16. BVA. Beroepsvereniging Ambulance zorg, facts en figures. Zwolle 2005, http://www.beroepsverenigingambulancezorg.nl
17. Zwakhals SLN, Kommer GJ. Bijdrage aan het RVZ advies over de inrichting en doelmatigheid van de acute zorg. Briefrapport 111/03 VTV LZ.RIVM. Sept 2003
18. Turner NM, Vught AJ van. Advanced Paediatric Life Support. Elsevier Gezondheidszorg, Maarssen 2006
19. American College of Surgeons. Advanced Trauma Life Support Course, student manual.

Chapter 2

The vitally compromised child: history and epidemiology

Published as: BM Gerritse
De geschiedenis van het vitaal bedreigde kind.
In: Het vitaal bedreigde kind, hoofdstuk 1,
redactie NM Turner, JJLM Bierens, Elsevier gezondheidszorg Maarssen, 2005

2.1. THE HISTORY OF THE VITALLY COMPROMISED CHILD

In the 21st century, a vitally endangered child is regarded as pitiful, defenceless and utterly dependent. Many want to dedicate themselves to the welfare and safety of these children when they become patients. An adult will go to great lengths to save a vitally endangered child, irrespective of whether or not there is a biological relationship between them.

Throughout history, this concept has changed considerably. The highest ideal for the citizen of the Roman Empire is to obtain glory and to be tough. As a result the reaction of Roman parents upon the birth of a child is slight revulsion rather than love; unwanted babies can be rejected without problems. The babies are not given a name until sometime after their birth, and are raised strictly and distantly in order for them to become hard and ambitious citizens. Child mortality is high; only fifty percent of Roman children reach puberty and it is unusual to mourn the death of a child.[1]

The best impression of how people felt about children in the Middle Ages is probably given to us by medieval literature and paintings. Medieval literature describes children without affection. *'Of all the characteristics in which the medieval age differs from the modern, none is so striking as the comparative absence of interest in children'.*[2] In medieval stories, children mainly fulfil the role of the person who dies through drowning, suffocation or being left behind in a forest. Medieval paintings rarely show displays of affection or the raising of children. *'The Christ child is of course repeatedly pictured, usually in his mother's arms, but prior to the mid-14th century he is generally held stiffly, away from her body, by a mother who is aloof even when nursing. ... the holy infant lies alone, quite naked and uncovered, while an unsmiling mother gazes at him abstractedly. Her separateness from the child was meant to indicate his divinity.'* [2]

The website http://www.biblical-art.com/ shows biblical tableaux throughout the ages: from the Renaissance onward baby Jesus is being held by Mary with increasing affection. Perhaps it is impossible to develop an emotional bond with children when two out of three children die. Child mortality was much higher in the Middle Ages than it was among the Romans. After the collapse of the West-Roman Empire the entire infrastructure deteriorated, from the water supply and sewer facilities through to medical care.

The chances of survival are better for children from noble families, but the mother-child relationship is no more affectionate. For instance, it is common practice to use a wet nurse to feed infants, have children raised by servants and marry them off around age 10. Little attention is paid to the life or suffering of a child before its fifth year of life, and after the seventh year the individual is considered a miniature adult. It is likely that the relative emotional emptiness of childhood in the Middle Ages is the reason for the indifferent attitude of medieval adults when it comes to the suffering and death of fellow humans. [2]

The fact that the current privileged position of children is a far more recent phenomenon is demonstrated by the so-called 'angel makers', who operated in the Netherlands until the end of the 19th century. Angel makers are women who completely swaddle a baby until it gets dehydrated and dies. Sometimes the child is given gin so that it falls asleep and dies more quickly. The parents receive the proceeds from the child's life insurance policy and, after paying the angel maker, are able to get through the winter with the rest of the family.[3]

However, in the 19th century the tide of how children are viewed turns, as a result of which the life of a child is now considered very valuable. French philosopher Jean-Jacques Rousseau is the first to write positive philosophical treatises on children, youth and child-raising.[4] The child is seen as a source of hope, virtuousness and emotion, and as the foundation of the family. Children become the most important building blocks of a well-functioning society. Of course the child needs to be brought up properly, but it is particularly the childish innocence that is considered a reflection of the best characteristics of the adult.[5] It is also during the Victorian era that the phrase 'Women and children first!' is used for the first time. *Children first* remains the number one rule in emergencies around the world and is therefore also the title of the book describing the history of the United Nations Children's Fund (UNICEF).[6] The motto of UNICEF is that by promoting the health, education and protection of children, human civilisation as a whole is being improved: when you save a child, you save the future of the world. The leaders of the world gathered in the year 2000 to set down the Millennium Declaration, a series of collective priorities for the advancement of humankind, as well for the immediate survival for a significant portion of it. Millennium goal four is the reduction of child mortality by two-thirds in the year 2015. The child mortality has diminished from a mortality of 11 million children in the year 2000 to 8.8 million in the year 2008, what can only be seen as a relative improvement. Child mortality is mostly due to preventable causes: diarrhoea, malaria, neonatal infection, pneumonia, preterm delivery, or lack of oxygen at birth.[7]

2.2 THE EPIDEMIOLOGY OF THE VITALLY ENDANGERED CHILD

2.2.1 Vitally endangered infants

Nearly half of all Dutch persons who die between the ages of 0 and 24 do so during their first year of life. Two thirds of the infant mortality in the first year of life occurs in the first 28 days after birth, especially among infants with a low birth weight and in association with congenital defects. In 1997 a publication from the WHO showed that sudden infant death syndrome was the main cause of death in the Netherlands in the period from 28 days up to 1 year after birth.[8] Incidences of sudden infant death syndrome were halved in the period between 1986 to 1991, probably because parents were advised not to let babies sleep on their stomachs anymore.

The Netherlands is in 11th place on the infant mortality list of the European Union, with 5.2 dead infants per 1000 live births. With respect to the life expectancy of men and women the Netherlands also consistently rates worse compared to the rest of the European Union. The average infant mortality in 2001 of all countries in the European Union taken together is 4.6 per 1000 live births.[9]

A population study in the United Kingdom shows that the chances of neonatal death are greater if the age of the mother is under 20 or over 40, if the mother is carrying twins, in lower income groups and among women of Indian or Pakistani origin.[10] In the United Kingdom the number of early neonatal deaths was brought down by the introduction of neonatal intensive care. The number of late neonatal deaths declined through the improvement of social conditions.

Studies into the cause of unexpected child deaths show that half of the incidences are preventable if care providers make different treatment decisions.[10] For instance, neonatal death as a result of a ruptured uterus is preventable in 75% of cases in the United Kingdom if the decision to use a caesarean section is made earlier. In the Netherlands three factors that determine the risk of death around the time of birth have increased or not decreased. These are the relatively high age of mothers (and the associated increased chance of multiple-birth pregnancies), the ethnic background of the mother and smoking during pregnancy.[11]

2.2.2 Child mortality after infancy

In the Netherlands more boys than girls die between the ages of 1 - 14 (58% vs. 42%). In 28% of cases these deaths are caused by accidents and poisonings, with skull fractures/ brain damage being the main cause of death.

Over a 4-year period in Arizona, Rimsza researched whether the death of children after infancy could have been prevented and whether, in hindsight, there were reasons to suspect child abuse as the cause of death.[12]. Rimsza determines that in children aged 0 - 17 the death was avoidable in 29% of cases. The percentage of preventable deaths ranges from 5% (neonates) to 56% (children over the age of 9). Of the children who died whilst being a passenger in a vehicle 82% of deaths could have been avoided if they had been wearing a seatbelt. Ninety percent of drowning cases could have been prevented with better supervision and the installation of a safety fence around the pool. Deaths as a result of child abuse (2% of the total number) are caused through neglect or the infliction of direct physical injury. In 5 out of 67 cases of deaths from child abuse a natural or accidental cause of death was ruled initially. In 40 out of 67 deaths the father, the mother's partner or the mother herself caused the death.

2.2.3. The vitally endangered child as a result of traffic accidents in the Netherlands

In the Netherlands, 50 to 60 children between the ages of 0 and 14 die in traffic accidents every year. The risk of death calculated per kilometre is 5 to 20 times higher for young cyclists than for adult cyclists, and for young pedestrians this risk is 20 to 35 times higher than for adult pedestrians.[13]

Around 1,000 children are admitted to hospitals every year as a result of traffic accidents. The fact that traffic safety for children has improved strongly is demonstrated by a nearly 30% drop in deaths resulting from traffic accidents in the past 10 years. Children on bicycles in the 10-14 age group have the highest mortality. They probably ride the bike themselves, but at younger ages there are also fatal accidents in children who are a passenger on a bicycle. Of all bicycle accidents 26% is in the 0-4 age group, and 8% in the 5-9 age group.

In car-related accidents the mortality of children also declines at a higher age. Fatal accidents involving children nearly always occur as a result of a collision with a second vehicle.[13]

The SWOV (*Foundation for Traffic Safety Research*) proposes a number of measures to further improve traffic safety for children. Different types of traffic must be kept separate through the introduction of a traffic and transport system. Safe driving speeds, combined with infrastructural measures, must also be imposed in residential areas. By focusing on updating European regulations, the fronts of vehicles must be made safer in the future. Especially in the Netherlands, where a relatively high number of bicyclists are involved in accidents compared to other countries, vehicles with lower-impact fronts could result in a strong drop in the number of deaths.

2.2.4 The effects of informing parents

Influencing high-risk behaviour by means of providing information in an Emergency Department can be effective. Claudius performed a prospective study in the Emergency Department of the Children's Hospital in Los Angeles.[14] In this study both the risks related to the reason for de hospital visit and potential other risks in the family's living environment are mapped out by means of a structured questionnaire. Using the answers to this questionnaire, the medical personnel in the Emergency Department provide the parents with advice on how to prevent injury to the child in future. A follow-up study shows that in nearly half of these families the advice is actively followed. The studies conclude that information on safety given by care providers in the Emergency Department has a higher impact than information provided by the government.

2.3 THE INFLUENCE OF SOCIAL GROUP, ETHNIC ORIGIN AND COUNTRY OF BIRTH ON THE DEATH RISK OF CHILDREN

In 2002 the average mortality rate among children under the age of 5 throughout the world was 81 per 1000 children. In 1960 child mortality in the world was still as high as 198, in 1980 it was 118, and in 1990 it was 94. The relative decline is therefore getting less. However, the differences between countries are great and vary from Sweden (3 per 1000 inhabitants) and the Netherlands (5 per 1000 inhabitants) to most of the African countries where the child mortality figure is in excess of 200 per 1000 inhabitants. Libya has the lowest child mortality figure in Africa with 19 per 1000 inhabitants.[3] Five and a half million children die each year as a result of malnutrition. Other important causes of death in children are malaria, AIDS and childhood diseases. The overall child mortality figure in the world has been dropping in recent years, but in 12 of the 203 countries it is actually increasing.

In the United States black children are three times more at risk from dying as a result of an accident before the age of 1 than white children. The risk of being murdered is five times higher in black children up to the age of 1. [15]

Although the death risk has decreased in all social groups in Europe over the past two years, discrepancies between individual groups have remained.[10] For children in the lowest social group the risk of dying as a result of an accident is twice as high as the highest social group. In the English city of Wolverhampton a comprehensive analysis of the welfare of children was conducted with an interval of 20 years.[16] This study shows that the health risk of children is reduced as a result of the improvement of the socio-economic situation. Over a period of 20 years the second generation of Asian immigrants has fully assimilated with the autochthonous British population both in terms of social standing and child mortality. Apparently the social environment of the young mother is more important than her genetic origin.

In the Netherlands the situation with regard to perinatal death among ethnic groups was also studied.[17] The study showed that the perinatal death rate of children of ethnic-African mothers is twice as high as children of white mothers, and that the main reason is the higher prevalence of premature births. Among Hindu women and women originating from the Mediterranean perinatal deaths are also higher than among autochthonous Dutch women. However, in these groups the socio-economic status is not a statistically significant factor. The mortality rate of Turkish and Moroccan children is twice as high as that of autochthonous Dutch children.[18] The discrepancies are greatest in cases of infection (relative risk 2.2), metabolic disorders (relative risk 2.0), and accidents and drowning (relative risk 1.9). Only 56% of Turkish and Moroccan girls aged 13-14 have been taught to swim, whereas for autochthonous Dutch girls this is more than 95%.

Research by Van der Wal shows that Turkish and Moroccan children who live in the Netherlands die in Turkey or Morocco as a result of traffic accidents or infections relatively often. After a comprehensive information campaign and an active immunisation campaign, travel-related deaths among these at-risk groups have declined strongly.[19]

A classic example of the effect the social environment has on the survival chances of a vitally endangered child is the sinking of the Titanic in 1912. The survival rate of children in first and second class was 100%, whereas only 34% of children travelling in third class survived. This latter figure is the same as the survival chances of an adult man travelling in first class. Because the vast majority of children were travelling in third class 50% of all children on board the Titanic ultimately died. "Women and children first" was heard comprehensively on board the sinking ship, and the subsequent accident report shows that there was enough room for the children on board the lifeboats.[20]

Children have existed as a separate and recognized group within Western society for less than 200 years. These days, vitally endangered children receive a lot of attention in emergency medicine in the Netherlands. This attention must not only focus on medical matters, but also on the causes and consequences of being vitally endangered. Consciously or sub-consciously, the parents are often a determining factor. The socio-economic status, behaviour or residential situation of the parent are contributing factors to potentially life-threatening situations and the child's chances of survival. Children constitute a special and vulnerable group, but the extra protection and care they need is not yet complete and finalised. Through the right attention from adults - parents, care providers, politicians and others - the greater proportion of child mortality in the world could be prevented.

REFERENCES

1. McEwan I. Rubicon, the triumph and tragedy of the roman republic. London, Abacus 2003
2. Tuchman BW. A distant mirror, the calamitous 14th century. Harmondsworth: Penguin Books 1979
3. Centrum voor Mondiaal Onderwijs. Kindersterfte in Nederland. Sectorwerkstuk, 2005. http://www.cmo.nl/index.html
4. Rousseau JJ. Emile ou de l'éducation. Genève, 1762
5. Walter L. The invention of childhood in Victorian autobiography, in George P. Landow, ed., Approaches to Victorian Autobiography. Athens, Ohio. Ohio University Press 1979:64-87
6. Black M. Children first: the story of UNICEF, Past and Present. Oxford University Press, New York City 1996
7. Unicef millennium development goals. 4. Reduce child mortality. http://www.unicef.org/mdg/childmortality.html
8. World Health Organization. Highlights on health in the Netherlands. 1997. http://www.euro.who.int/eprise/main/who/progs/chhnet/home.
9. CBS. Centraal Bureau voor Statistiek. Jeugd 2003, cijfers en feiten http://www.cbs.nl/nl/publicaties/recent-verschenen/jeugd/jeugd-2003.htm
10. Platt MJ. Child health statistics review. 1998. Arch Dis Child 1998:79:523-527.
11. RIVM. Rijksinstituut voor Volksgezondheid en Milieuhygiëne Nationaal Zorgkompas Volksgezondheid. 2005 http://www.rivm.nl/vtv/object_document/o2316n18836.html
12. Rimsza ME, Schackner RA, Bowen KA, Marshall W. Can child deaths be prevented? The Arizona child fatality review program experience. Pediatrics 2002;110(1)
13. SWOV. Stichting Wetenschappelijk Onderzoek Verkeersveiligheid. Factsheet: verkeersveiligheid van kinderen in Nederland. 2004. http://www.swov.nl/nl/publicaties/index.htm
14. Claudius IA, Nager A. The utility of safety counseling in a pediatric emergency department. Pediatrics 2005;115:e423-e427
15. Tomashek KM, Hsia J, Iyasu S. Trends in postneonatal mortality attributable to injury, United States 1988-1998. Pediatrics 2003;111:1219-1225
16. Moore A. Changing patterns of childhood mortality in Wolverhampton. Arch Dis Child 2005;90:687-691
17. Enk A van, Buitendijk SE, Pal KM van der, Enk WJ van, Schulpen TW. Perinatal death in ethnic minorities in the Netherlands. J Epidemiol Community Health 1998;52:735-739
18. Schulpen TWJ, Steenbergen JE, Driel HF van. Influences of ethnicity on perinatal and child mortality in the Netherlands. Arch Dis Child 2001;84:222-226
19. Uitenbroek DG, Wal M van der, Weert-Waltman L van. The effect of a health promotion campaign on mortality in children. Health Education Research 2000;15:625-634
20. Anesi C. The Titanic Casualty figures (and what they mean). 2005. http://www.anesi.com/titanic.htm

Chapter 3

Helicopter Emergency Medical Services in the Netherlands: important differences between the deployment frequencies of different dispatch regions

Published as:
Helikopter Mobiel Medische Teams in Nederland.
Belangrijke verschillen in inzetfrequentie tussen meldkamer regio's.
Joris Lemson MD[1], Pierre M van Grunsven MD, PhD[2], Inger B Schipper MD, PhD[3], Jens P Valk MD[4], Herman MT Christiaans MD[5], Bastiaan M Gerritse MD[6], Gert Jan Scheffer MD, PhD[6]

Nederlands Tijdschrift voor Geneeskunde 2008;152(19), 1106-1112

1. Department of Intensive Care, Radboud University Nijmegen Medical Center, Nijmegen, the Netherlands
2. Medical Director Regional Ambulance Service Gelderland Zuid, Nijmegen, the Netherlands
3. Trauma Centre South-West Netherlands, Erasmus Medical Center, Rotterdam, the Netherlans
4. Department of Anesthesiology, University Medical Center Groningen, Groningen, the Netherlands
5. Department of Anesthesiology, Free University Medical Center, Amsterdam, the Netherlands
6. Department of Anesthesiology, Radboud University Nijmegen Medical Center, Nijmegen, the Netherlands

ABSTRACT

Objective: To investigate whether Helicopter Emergency Medical Services are optimally deployed in all emergency dispatch centres.

Design: Descriptive, retrospective.

Method: Initially, we assessed whether data from different ambulance regions could be compared effectively if they were related to the number of inhabitants per region. Data concerning the number of inhabitants, number of deaths caused by trauma, number of traffic accidents with injury, number of emergency call-outs by ambulance services and HEMS deployment were collected from several governmental databases for the period 2002-2005. The correlation coefficients between these data and the number of inhabitants were calculated. Subsequently, we determined the number of HEMS deployments per 100.000 inhabitants per year per emergency dispatch centre. The number of HEMS dispatches from the 4 HEMS coordinating dispatch centres was compared to the number of dispatches from the 17 other emergency dispatch centres.

Results: There was a strong correlation between the number of deaths caused by trauma, the number of traffic accidents with injury, emergency call-outs from ambulance services, and the number of inhabitants per region (correlation coefficients: 0.90-0,98). On average there were 2664 HEMS calls per year. The average number of HEMS calls per emergency dispatch centre per year was 110 (range:2-403). The number of HEMS deployments per 100.000 inhabitants per year was 10,5 (0,9-27,8). Emergency dispatch centres coordinating HEMS conducted significantly more HEMS with a lower cancellation rate.

Conclusion: By relating the deployment of HEMS with the number of inhabitants per region, a comparison can be made of the deployment frequencies in different emergency dispatch regions. The deployment of HEMS proved to differ significantly between emergency dispatch centres.

INTRODUCTION

Since 1995 our country has had Helicopter Emergency Medical Services (HEMS), also referred to as 'trauma helicopters', on standby. The tasks and the expectations regarding their deployment are described in the government's 'Policy Vision on Emergency Care 2006-2010'[1]. A HEMS is made up of a medical specialist (anaesthesiologist or surgeon-emergency physician), a nurse and a pilot. In close collaboration with the ambulance service they provide specialist acute pre-admission care. HEMS is mainly deployed for accidents, whereby their main task is to quickly and efficiently perform medical interventions to stabilise vital functions that could otherwise not be done until the patient arrives at the clinic. Similar pre-admission treatment systems have been in use for some time in many European countries.[2-6]

In our country the acute pre-admission care is co-ordinated by 24 dispatch centres for ambulance care (MKA = Meldkamer Ambulancedienst). The HEMS is notified and co-ordinated by the 4 MKA of the regions in which they have their permanent base (Groningen, Nijmegen, Amsterdam and Rotterdam). For logistical reasons, the remaining 20 dispatch centres can only call out a HEMS through these coordinating MKA. When the first ambulance arriving at the scene determines that the support of a HEMS is no longer needed then a HEMS that is already airborne is sent back to base. It may be expected that this facility is used in the same manner in all the regions. However, there appear to be considerable regional differences.[7] If an available HEMS erroneously fails to be called out this may have consequences for the quality and outcome of the pre-admission care to trauma patients. In many cases it is not known how often the HEMS has been deployed by different dispatch centres in recent years. We are setting up this study to take an inventory of the distribution of HEMS deployment in the different MKA regions.

Because the regions differ with respect to the number of inhabitants, rural or urban character and infrastructure, it is difficult to make an accurate comparison. For this reason the study poses two questions: (a) Are inhabitant numbers per region an adequate parameter for the anticipated number of HEMS deployments? (b) What is the distribution of HEMS deployments per 100,000 inhabitants across the MKA regions?

DATA AND METHODS

In order to determine whether the number of inhabitants per region is an adequate parameter for the anticipated number of HEMS deployments, we have collected data that reflects the demand for advanced acute pre-admission care: data on deaths resulting from trauma, inhabitant numbers, the number of traffic accidents resulting in physical injury and the number of emergency runs made by ambulances.

The parameter 'deaths resulting from trauma', also referred to as 'deaths from external causes', relates to the number of persons who died as a result of a traffic accident, a fall from a great height, drowning, poisoning, suicide, murder and manslaughter and other non-natural causes of death. This information was obtained, per dispatch centre for the years 2002-2005, from the database of the Central Statistics Bureau (http://statline.cbs.nl). Inhabitant numbers in the aforementioned period were obtained from the same source. The number of traffic accidents resulting in physical injury was obtained, per dispatch centre for the years 2002-2005, from the database of the Foundation for Traffic Safety Research (www.swov.nl/cognos/cgi-bin/ppdscgi.exe). The number of A1 runs (these are emergency runs whereby the ambulances use their lights and sirens) per dispatch centre region in the year 2001 was known, as were the inhabitant numbers per region in 2001.[8 9] We determined the correlation between the number of inhabitants per region and the aforementioned indexes by calculating the correlation coefficients with associated 95% reliability intervals.

In addition, the absolute number of ambulance runs per 100,000 inhabitants with interquartile extremes (distribution measure) per region was determined for the indexes. The classification of the dispatch centre regions has changed in recent years, which is why we converted all data to the situation as it was at the end of 2005.

In order to estimate the flying times we used a standard geographical map of the Netherlands to calculate the shortest, longest and average distances between the four HEMS stations and all the MKA regions. These distances were converted into flying minutes on the basis of a speed over ground of 220 km/h under standard atmospheric conditions. The cross-border deployment of Belgian and German HEMSs was included in these calculations. The shortest flying time from the nearest HEMS station was used as the flying time from the four HEMS stations to the different MKA regions.

Data on call-outs, deployments and cancellations of the four Dutch HEMS for the period 2002-2005 was obtained from the various HEMS databases.

The correlation between parametrical variables with a normal distribution was determined with the aid of the Pearson correlation coefficient: in all other cases the Spearman rank correlation coefficient was used. A difference between two groups with unequal numbers was determined using the Mann-Whitney U test. For statistical calculations GraphPad Prism 4 (GraphPad Software; San Diego, US) and MedCalc 8 (MedCalc Software; Mariakerke, Belgium) were used.

RESULTS

In the research period (2002-2005) there was an average of 2,664 HEMS call-outs per year. The median cancellation percentage was 43.8 (extremes: 24-64). Figure 1 shows the number of national call-outs and cancellations.

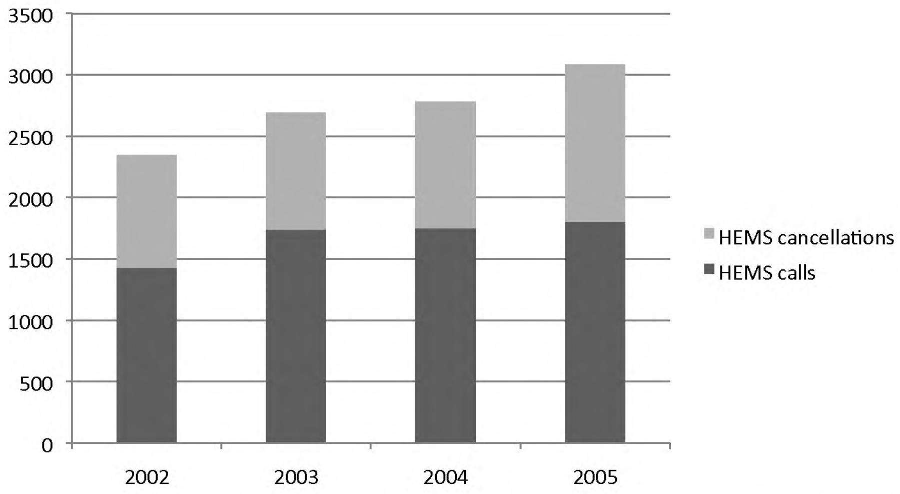

Figure 1. HEMS calls and cancellations of the 4 HEMS in the Netherlands from the year 2002 until 2005

Figure 2a. The number of call-outs per MKA region. The average number of call-outs per MKA was 110 per year, with a variation range from 2 to 403.

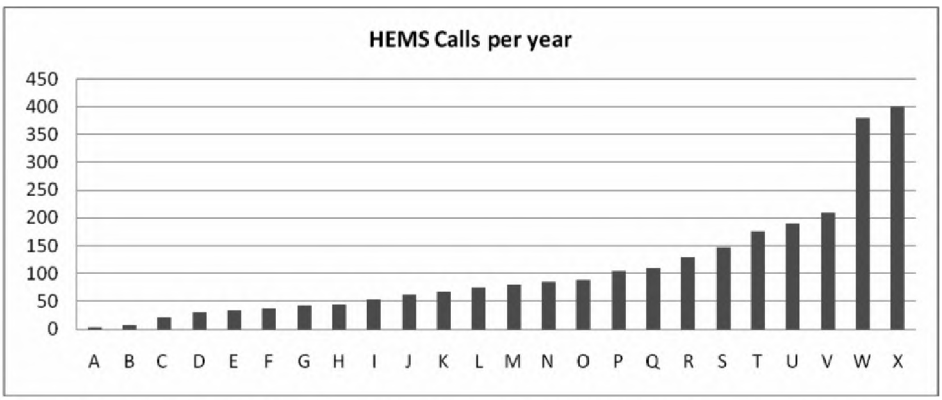

Figure 2a. The dispatch regions U,V,W and X are the four HEMS coordinating dispatch regions.

Figure 2b. Comparison between the number of HEMS calls per year and the number of HEMS calls per 100.000 inhabitants per year. The columns represent a dispatch region (MKA) and are the mean number of calls from the year 2002-2005. The dispatch regions U,V,W and X are the four HEMS coordinating dispatch regions. Dispatch regions A,B and H are blanks in the lower graph, as they are partially provided by HEMS from outside the Netherlands.

Table 1 shows the deaths resulting from trauma, the number of traffic accidents resulting in physical injury and the number of A1 runs made by ambulance services per 100,000

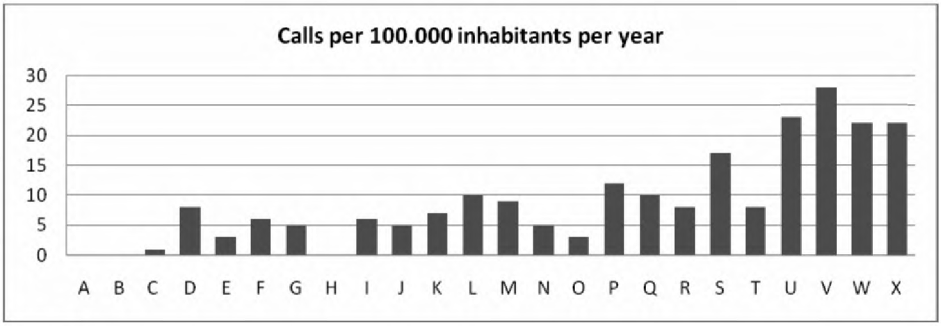

Figure 2b.

inhabitants per dispatch centre region. The four HEMS-coordinating dispatch centres were located in the regions W, X, U and V.

Table 1. Overview per 100.000 inhabitants of the dispatch region: trauma death (http://statline.cbs.nl), morbidity by traffic accident (www.swov.nl/cognos/cgi-bin/ppdscgi.exe) and EMS A1 calls.[8,9]

Dispatch Region	Trauma death per 100.000 inhabitants	morbidity by traffic accident 100.000 inhabitants	EMS A1 calls per 100.000 inhabitants
A	35,7	186	1911
H	31,6	245	1997
B	31,7	268	1567
C	31,9	251	1281
E	35,1	273	1582
O	30,3	225	1566
G	35,5	319	1364
J	30,1	242	1697
N	26,4	227	2542
F	31,6	224	1746
I	35,6	200	3363
K	30,8	230	1685
D	36	183	2419
R	33,1	239	2118
T	31,5	236	1668
M	29,9	206	1450
L	24,8	216	2671
Q	36,1	179	1691
P	30,2	179	1691
S	33	249	1966
W	34,6	193	2659
X	37,4	249	3587
U	31,1	205	1603
V	37,5	224	2383

In a comparison based on the aforementioned parameters there was no discernible difference between the HEMS-coordinating dispatch centres and the other dispatch centres (deaths resulting from trauma: p = 0.1; traffic accidents resulting in physical injury: p = 0.6; A1 runs made by ambulance services: p = 0.1). There is a strong correlation between the indexes in Table 1 and the inhabitant numbers of the different MKA regions. The coefficient for correlation between deaths resulting from trauma and number of inhabitants was 0.98 (95%-BI: 0.94-0.99; $p < 0.0001$), the coefficient for correlation between traffic accidents resulting in physical injury and number of inhabitants was 0.94 (95%-BI: 0.86-0.97; $p < 0.0001$) and between A1 runs of ambulance services and number of inhabitants it was 0.90 (95%-BI: 0.80-0.95; $p < 0.0001$).

In the calculation of the number of HEMS deployments, three MKA regions were not taken into consideration (Zeeland, South Limburg and Twente), because they are partially serviced by a foreign HEMS. Table 2 only contains data on the 21 MKA regions that are serviced completely by the four Dutch HEMS. In addition to the cancellation percentage, this table reflects the number of HEMS deployments per 100,000 inhabitants per year, broken down by dispatch centre region, for the years 2002-2005. The average number of deploy-

Table 2. Overview of HEMS calls from 2002-2005 per 100.000 inhabitants, cancellation percentage and flight times from the HEMS bases to the dispatch regions. Data of dispatch regions A,B and H are not stated, as they are partially provided for by HEMS outside of the Netherlands. W,X, U and V are HEMS coordinating dispatch regions.

Dispatch Region	HEMS 2002	HEMS 2003	HEMS 2004	HEMS 2005	Cancel percentage	Minimal Flight time	Maximal Flight time	Mean Flight time
C	0,4	0,4	1,4	1,4	50	13	31	22
E	1,7	4,1	3	2,2	46,8	6	20	13
O	3,8	4,3	4,6	4,4	49,1	3	12	7,5
G	4,1	3,9	4,2	6,2	51,8	4	8	6
J	3,9	5,1	5,4	5,4	47,6	8	20	14
N	2,8	5	6,6	8,5	50,2	3	8	5,5
F	4,3	5,7	5,1	8,2	29,1	4	17	10,5
I	3,4	6,2	11,1	4,7	33,9	1	6	3,5
K	5,2	8	6,6	8,1	43,8	3	13	8
D	6,2	3,7	9,9	10,3	48,9	3	8	5,5
R	5,8	8,1	7,6	9	64,3	7	18	12,5
T	7	9,4	7,3	7,1	51,5	8	18	13
N	6,4	6,5	9,2	13,1	32,1	2	15	8,5
L	7,9	11,7	10	11,2	55,2	5	20	12,5
Q	7,9	8	12,3	13,7	39,6	6	24	15
P	14,6	12,2	9,9	12,6	42,9	5	13	9
S	14,6	16,4	20,1	18,4	40,9	2	18	10
W	18,3	21,8	20,1	27,3	26,3	1	11	6
X	22,4	25,1	22,2	22,1	30,7	1	8	4,5
U	30,8	27,9	18,4	16,6	36,3	1	15	8
V	23,3	22,5	27,2	38,3	23,5	1	14	7,5
mean	6,2	8	9,2	9	43,8	3	15	8,5

ments per year was 10.5 per 100,000 inhabitants per MKA region (extremes: 0.9-27.8). These averages are shown in Figure 2b.

Table 2 also shows the flying time per MKA region. The shortest flying time was 1 minute, the longest was 31 minutes. If the regions Zeeland, South Limburg and Twente are included, the median of the average flying times to the 24 regions is 9.6 minutes. These times do not include the average start-up time of 2 minutes. There was no statistically significant correlation between the number of HEMS deployments and the average flying time per MKA region.

Table 3 shows the differences between inhabitant numbers, callouts, deployments and cancellations and average flying times between the HEMS-coordinating MKA regions

Table 3. Comparison of the four HEMS coordinating dispatch regions and the other 17 dispatch regions. Calls are the initial dispatching of HEMS, care is the actual number of incidents care for in the field.

Properties	HEMS coordinating dispatch regions	Other dispatch regions
inhabitants, n	$3,5x10^6$	$11x10^6$
HEMS calls per year	818	672
HEMS calls per 100.000 inhabitants per year (P25-P75)*	34,8 (31,5-36,5)	12,6 (8,5-18,7)
HEMS care per 100.00 inhabitants per year (P25-P75)*	23,2 (22,5-25,6)	7 (4,8-9,2)
Cancellation percentage (P25-P75)*	28,5 (24,9-33,5)	47,6 (40,6-50,5)
Mean flight time, min. (P25-P75)*	6,8 (5,3-7,8)	10 (7,1-13)
* mean; 25th and 75th percentile		

(Amsterdam, Rotterdam, Groningen and Nijmegen) on the one hand, and the 17 remaining MKA regions on the other hand.

DISCUSSION

The comparison of dispatch centre regions.

This study shows important differences between dispatch centre regions with respect to the deployment of HEMS in the years 2002-2005. However, the frequencies of HEMS callouts cannot be compared to each other without additional parameters, because the Dutch MKA regions differ in inhabitant numbers, surface area and urban or rural character. For this reason, the study first aimed to determine whether the inhabitant numbers allow for an adequate comparison of HEMS deployments. Traffic accidents resulting in physical injury, deaths caused by trauma and emergency runs by ambulances show a very strong correlation with the number of inhabitants in a region, with correlation coefficients of 0.94, 0.98 and 0.90 respectively. From this we conclude that the number of HEMS deployments (actual assistance provided) also relates to the number of inhabitants of the different MKA regions. The three indexes are a reflection of the number of situations per MKA region in which a HEMS could be deployed. After all, in many of these incidents a HEMS will be called out. It is true that in the majority of ambulance emergency runs there is no question of victims with serious traumatic injuries, but HEMS is also deployed in situations not involving trauma, such as the resuscitation of children. In view of the strong correlation between the three indexes and the number of inhabitants, the number of HEMS deployments per 100,000 inhabitants appears to be a useful measure for comparing the regions.

Deployment of HEMS.

If we use this measure the deployment frequency shows major variations (see Figure 2b). It is notable that the coordinating MKAs deploy HEMS more often (818 times versus 672 times), even though the combined number of inhabitants of these four regions is less than that of the other 17 regions (3.5 million versus 11 million) (see Table 3). The cancellation percentage in the four coordinating regions also proved to be significantly lower. Although these four regions cannot be compared to each other, it would seem unlikely that in these regions, in particular, the number of accidents was higher than in the other regions. After all, Table 1 shows that in this respect the coordinating MKA regions do not differ significantly from the other regions. It appears that the dispatch centre employees of the other MKA use a higher threshold for calling out a HEMS. In the 17 non-coordinating regions it happens more frequently that the ambulances, once they are at the scene, cancel a HEMS that is already airborne.

It has previously been demonstrated that some dispatch centre employees call out a HEMS less frequently than may be expected based on the deployment criteria. [10] It is also possible that the deployment of a HEMS is still not a sufficiently common part of the daily routine. The very low deployment frequency of certain MKA points to a high deployment threshold.

Under-utilisation or over-utilisation.

Dutch research has shown that somewhat less seriously injured patients benefit the most from treatment by a HEMS.[11] Therefore, a high deployment threshold combined with a high cancellation percentage could mean that HEMS is under-utilised. The pre-admission endotracheal intubation percentage may be a measure of over or under-utilisation. In view of the high intubation percentage of Dutch HEMS (more than 30%) there appears, on average, not to be any significant over-utilisation [12,13,14] The discrepancy with comparable facilities in Germany is very high; here the intubation percentage is around 6.8-9.3 and the

HEMS is deployed relatively more frequently .[15,16] A shorter flying time could be a reason for deploying a HEMS more often, because of the rapid availability. Conversely, a longer flying time to a more remote MKA region could be a reason for deploying a HEMS primarily in order to avoid losing time. After all, significant parts of these regions do not have access to a trauma centre. Transporting the victim to a trauma centre with the HEMS will then be the obvious solution in some cases, because this will have a positive effect on survival rates.[17] However, the differences observed between the deployment of different dispatch centre regions cannot be explained by shorter or longer flying times (see Table 2). Incidentally, there are major variations in flying times within the 17 non-HEMS-coordinating MKA regions, as a result of which the effect of a longer flying time to more remote regions cannot be excluded. It is not clear from this study whether the observed differences in deployment frequencies manifest themselves in survival or morbidity. The international literature is not unequivocal about the possible health benefits, and randomised controlled studies into this subject matter are unavailable.[17-23] The results of previous studies cannot be translated to the Dutch situation because of the differences in the organisation and realisation of pre-admission care, and the often incomparable geographical situations in various western countries. Two – non-randomised – studies in our country have shown that the deployment of a HEMS can halve the chances of serious trauma patients dying[24] or that the deployment of a HEMS would result in 12-17% fewer fatalities resulting from accidents in the Netherlands per year.[11,25]

Disadvantages of the comparison method.

The comparison of HEMS deployment per region with the aid of inhabitant numbers has a number of disadvantages. This method is based on assumptions and calculations from derived parameters; the results must be interpreted with caution. The strong correlations between the indexes, such as death resulting from trauma and the inhabitant numbers, do support our view that this method is usable. However, it remains to be seen whether the deployment pattern is the same every year.

For this reason, an analysis of HEMS deployment can only be made over a number of years. Our study did not show any trend changes, other than a gradual increase in call-outs and deployments. These inhabitant numbers must be high enough in order to be able to compare regions on the basis of inhabitant numbers. The inhabitant numbers of the current MKA regions (250,000 to 1.2 million) do appear to meet this condition. Smaller region classifications, such as those based on municipalities, would appear to us to be unsuitable for this purpose.

CONCLUSION

Our study shows that the number of HEMS deployments per 100,000 inhabitants is a useful measure for a comparison of different regions. The observed deployment frequencies per 100,000 inhabitants show significant differences between the various dispatch centre regions in the Netherlands in the years 2002-2005. Further research into the causes of the observed discrepancies is required.

REFERENCES

1. Acute zorg; brief minister met de Beleidsvisie traumazorg 2006-2010. Kamerstukken 2005-2006, 29.247 nr 37.
2. Langhelle A, Lossius HM, Silfvast T, Björnsson HM, Lippert FK, Ersson A, et al. International EMS systems: the Nordic countries. Resuscitation. 2004;61:9-21.
3. Albert J, Phillips H. Trauma care systems in the United Kingdom. Injury. 2003;34:728-734.
4. Masmejean EH, Faye A, Alnot JY, Mignon AF. Trauma care systems in France. Injury. 2003;34:669-673.
5. Westhoff J, Hildebrand F, Grotz M, Richter M, Pape HC, Krettek C. Trauma care in Germany. Injury. 2003;34:674-683.
6. Nijs SJ, Broos PL. Trauma care systems in Belgium. Injury. 2003; 34:652-657.
7. Voorbij 'het gouden uur' – Evaluatie beleidsvisie traumazorg 2004. Diemen: College voor zorgverzekeringen; 2005.
8. Kommer GJ, Veen AA van der, Botter WF, Tan I. Ambulances binnen bereik. Analyse van de spreiding en beschikbaarheid van de ambulancezorg in Nederland. RIVM-rapport 270556006/2003. Bilthoven: RIVM; 2003.
9. Veen AA van der, Zwakhals SLN, Hazelzet-Crans B, Manen JW van. Niet zonder zorg; een onderzoek naar de doelmatigheid en kwaliteit van de ambulancezorg. RIVM-rapport 270556002. Houten: Bohn Stafleu van Loghum; 2001.
10. Ringburg AN, Frissen IN, Spanjersberg WR, Jel G, Frankema SP, Schipper IB. Physician-staffed HEMS dispatch in the Netherlands:adequate deployment or minimal utilization? Air Med J. 2005;24:248-251.
11. Oppe S, de Charro FT. The effect of medical care by a helicopter trauma team on the probability of survival and the quality of life ofhospitalised victims. Accid Anal Prev. 2001;33:129-138.
12. Jaarverslag 2003 Helikopter Mobiel Medisch Team Traumacentrum Noord-West Nederland. Amsterdam: Traumacentrum Noord-West Nederland, locatie VU Medisch Centrum; 2004.
13. Trauma Regio Oost, Radboud Universiteit Nijmegen Medicsch Centrum. Jaarlijkse rapporten 2002-2005 MMT, https://www.tro.nl
14. Slagt C, Zondervan A, Patka P, Lange JJ de. A retrospective analysis of the intubations performed during 5 years of helicopter emergency medical service in Amsterdam. Air Med J. 2004;23:36-37.
15. Helm M, Hossfeld B, Schäfer S, Hoitz J, Lampl L. Factors influencing emergency intubation in the pre-hospital setting – a multicentre study in the German Helicopter Emergency Medical Service. Br J Anaesth. 2006;96:67-71.

16. Timmermann A, Eich C, Russo SG, Natge U, Bräuer A, Rosenblatt WH, et al. Prehospital airway management: a prospective evaluation of anaesthesia trained emergency physicians. Resuscitation. 2006; 70:179-185.
17. Biewener A, Aschenbrenner U, Rammelt S, Grass R, Zwipp H. Impact of helicopter transport and hospital level on mortality of polytrauma patients. J Trauma. 2004;56:94-98.
18. Davis DP, Peay J, Serrano JA, Buono C, Vilke GM, Sise MJ, et al. The impact of aeromedical response to patients with moderate to severe traumatic brain injury. Ann Emerg Med. 2005;46:115-122.
19. Di Bartolomeo S, Sanson G, Nardi G, Michelutto V, Scian F. HEMS vs. Ground-BLS care in traumatic cardiac arrest. Prehosp Emerg Care. 2005;9:79-84.
20. Osterwalder JJ. Mortality of blunt polytrauma: a comparison between emergency physicians and emergency medical technicians – prospective cohort study at a level I hospital in eastern Switzerland. J Trauma. 2003;55:355-361.
21. Lossius HM, Søreide E, Hotvedt R, Hapnes SA, Eielsen OV, Førde OH,et al. Prehospital advanced life support provided by specially trained physicians: is there a benefit in terms of life years gained? Acta Anaesthesiol Scand. 2002;46:771-778.
22. Biewener A, Aschenbrenner U, Sauerland S, Zwipp H, Rammelt S, Sturm J. Einfluss von Rettungsmittel und Zielklinik auf die Letalitat nach Polytrauma. Eine Standortbestimmung. AG Notfallmedizin der DGU. Unfallchirurg. 2005;108:370-377.
23. Klemen P, Grmec S. Effect of pre-hospital advanced life support with rapid sequence intubation on outcome of severe traumatic brain injury. Acta Anaesthesiol Scand. 2006;50:1250-1254.
24. Frankema SP, Ringburg AN, Steyerberg EW, Edwards MJ, Schipper IB, Vugt AB van. Beneficial effect of helicopter emergency medical services on survival of severely injured patients. Br J Surg. 2004;91:1520-1526.
25. Hübner BL. Evaluation of the immediate effects of preclinical treatment of severely injured trauma patients by Helicopter Trauma Team in the Netherlands [proefschrift]. Amsterdam: Vrije Universiteit; 1999.

Chapter 4

The deployment of a Helicopter Emergency Medical Service for vitally compromised children in the Netherlands

Bastiaan M Gerritse MD[1],
Jos MT Draaisma MD, PhD [2],
Ben J Pelzer PhD[3],
Gert Jan Scheffer MD, PhD[4]

Internet Journal of Aeromedical Transportation, 2010;2:1

1. Department of Anaesthesiology, Amphia Hospital Breda
2. Department of Paediatrics, Radboud University Hospital, Nijmegen, the Netherlands
3. Department of Social Science Research Methodology, Radboud University Nijmegen, the Netherlands
4. Department of Anaesthesiology, Radboud University Hospital, Nijmegen, the Netherlands

ABSTRACT

Objective: To evaluate the deployment of a Helicopter Medical Service (HEMS) for vitally compromised children in an HEMS region. A comparison is made between HEMS deployment for children and adults, with a subsequent evaluation of the current HEMS deployment criteria for vitally compromised children.

Methods: Prospective descriptive cohort analysis of all HEMS calls for paediatric emergencies (age 0-18 years) in the period 2001-2008. Data regarding type and location of incident, physiological parameters, Munich-modified NACA scores, treatment and 24-hour survival were collected and subsequently analysed.

Results: The HEMS had 891 calls for paediatric emergencies in the period from 2001-2008. Twenty-seven percent of these calls were cancelled before the arrival of the HEMS, while 48% of the calls for adults were cancelled. The cancel percentage of all HEMS calls increased significantly over the years; the cancel percentage of HEMS calls for children remained at a steady state. The HEMS coordinating dispatch region had a significant higher percentage of low NACA scores in comparison to the other dispatch regions. The non-trauma incidents had the lowest 24-hour survival rate, the highest 24-hour survival rate was in the incident group of HEMS calls based on mechanism of injury.

Conclusion: Dispatch criteria used for HEMS in the Netherlands appear not to be well suited to children and should be adjusted to contain a score of the neurological status. Dispatch criteria based on mechanism of injury are a poor triage tool, several types of severe illness should be explicitly included. Cancel criteria for HEMS calls in children are not applied in a consistent manner, and should be revised.

INTRODUCTION

A Helicopter Emergency Medical Service (HEMS), introduced in the Netherlands in 1996 to provide optimal pre-hospital care, consist of a physician (anaesthesiologist or trauma surgeon), a flight nurse and a pilot. HEMS physicians have received special training in adult and paediatric emergency care, pain management and extrication techniques. The HEMS leads to concentration of medical expertise with a high degree of diagnostic and therapeutic knowledge and skills. A similar system has been present and operational in many European countries for a long time.[1-5] The benefits of the HEMS have been substantiated by several studies.[6-8] The medical care provided by the HEMS has achieved a well accepted position in the full range of pre-clinical care in the Netherlands as described in a policy note on trauma by the Dutch Government in 2005.[9]

The Emergency Medical Service (EMS) is coordinated and supervised by 24 emergency dispatch regions in the Netherlands. The number of inhabitants per dispatch region ranges from 240,000 up to 1.2 million inhabitants. The dispatch regions receive the primary emergency call and decide if an EMS ambulance is sent, or an ambulance and a HEMS. The decision to activate a HEMS by the dispatcher is made in line with a strict list of criteria. The HEMS described in this study is funded by the Trauma Region Netherlands-East, which consists of a HEMS dispatch coordinating region and six adjacent dispatch regions.

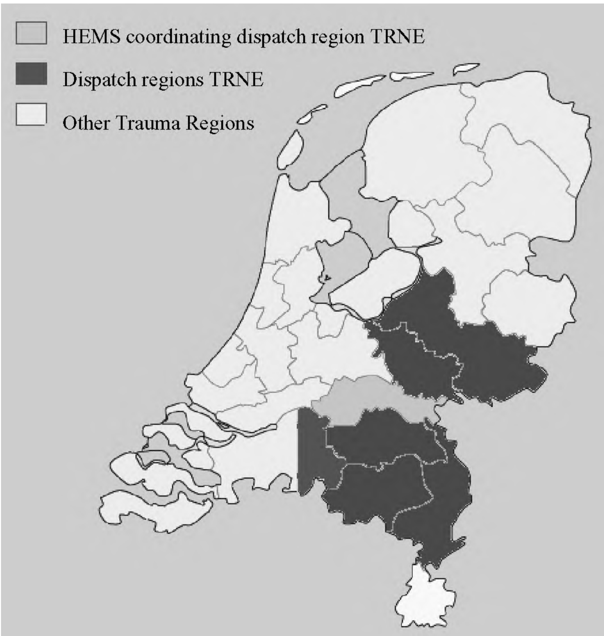

Figure 1. Trauma Region Netherlands-East (TRNE) consists of a HEMS coordinating dispatch region and six other dispatch regions

The only specific paediatric HEMS deployment criterion in the Netherlands is paediatric cardiopulmonary resuscitation, most of the triage criteria for HEMS in the Netherlands are based on trauma mechanism. As the EMS is generally less experienced in providing medical care for vitally compromised children, support from the HEMS is requested not only for trauma cases and paediatric CPR but also for vitally compromised children in general. The objective of this study was to evaluate the deployment of the HEMS Trauma Region Netherlands-East (TRNE) for vitally compromised children. A comparison is made between HEMS deployment for children and adults, with a subsequent evaluation of the current HEMS deployment criteria for vitally compromised children. The cancel percentages of HEMS deployments for adults and children were compared, in an effort to evaluate HEMS cancel percentages in call-outs for children.

METHODS

This study is a prospective descriptive cohort analysis of 891 HEMS calls for paediatric emergencies (age 0-18 years) for which the HEMS Trauma Region Netherlands-East was activated in the period 2001-2008. The primary dispatch area of the HEMS Trauma Region Netherlands-East comprises 7 emergency dispatch regions, but assistance can be requested by the other 17 emergency dispatch regions in the Netherlands. Registered data includes age, sex, type of emergency, physiological parameters (respiratory rate, heart rate, blood pressure, capnography), Glasgow Coma Scale (GCS), pre-clinical treatment given, diagnosis in the emergency ward and survival until 24 hours after hospital admission. All patients examined by the HEMS were assessed according to the NACA (National Advisory Committee on Aeronautics) score.[10]

Table 1. The National Committee on Aeronautics (NACA) developed a simple scoring system for patients receiving air transport during the Vietnam War. [10,11]

Patient Status	Intervention	Score Level
non-acute life-threatening disease or injury	acute intervention not necessary	1
further diagnostic studies needed	acute intervention not necessary	2
severe but not life threatening disease or injury	acute intervention necessary	3
development of vital danger possible	acute intervention necessary	4
acute vital (life threatening) danger	acute intervention necessary	5
acute cardiac or respiratory arrest	emergency resuscitation	6
dead		7

The worst clinical condition of the patient during pre-clinical management was the determining factor for classification, as described in the Munich modification of the NACA score.[11] A HEMS deployment was cancelled if the EMS-paramedic arrived on the scene first and diagnosed that either the child had no serious injury or illness, or the patient had succumbed. All data were recovered from the electronic patient data management system, custom made for the HEMS. The results were transferred into a data sheet (Excel ™, Microsoft Seattle, USA) and underwent statistical analysis and graphical depiction with SPSS Statistics 16.1 ™ (SPSS Inc., Chicago, IL, USA).

Pearson chi square was used for statistical comparisons, significance was defined as $p < 0.05$.

RESULTS

The HEMS had 891 calls involving children in the period 2001-2008. Of these child-related calls 245 (27%) were cancelled before the arrival of the HEMS, while 45% of all 6749 HEMS calls in this period (48% of the calls for adults) were cancelled. Table 2 demonstrates that while the cancel percentage of HEMS calls for adults increased significantly over the years, the cancel percentage of HEMS calls for children remained at a steady percentage. Reasons for the cancel of the 245 paediatric calls were: 199 calls normal physiological parameters, 27 calls patient died, 19 calls other reasons.

Table 2. Calls and Cancels Adults and Children

Year	All calls	Adults	Adult cancels*	Children	Child cancels
	(n)	(n)	(%)	(n)	(%)
2001	379	347	36	32	28
2002	549	469	35	80	36
2003	644	552	41	92	35
2004	584	491	45	93	35
2005	601	503	43	98	31
2006	1100	934	53	166	36
2007	1431	1277	53	154	9
2008	1461	1285	54	176	22

* Pearson chi-square $p<0.05$

The HEMS was called by 19 of the 24 dispatch regions in the Netherlands, with the most distant incident location situated 124 km from the helicopter base. There was no difference between the cancel percentages of the HEMS coordinating dispatch region and the other dispatchers, ninety percent (801/891) of the HEMS calls were in the TRNE. However, the patients in the HEMS coordinating dispatch regions had the highest percentage of NACA I-III patients (35%); the calls for NACA I-III patients from the other dispatch regions were significantly lower (8-19%). The number of calls, cancel percentage and NACA scores of the children examined on scene per dispatch region are shown in table 3.

Table 3. Trauma Region Netherlands-East (TRNE) HEMS calls for children

Dispatch Region	HEMS calls	Average Distance	Cancel	NACA I-III	NACA IV-VII
	n	km	%	n*	n*
Coordinating dispatch region TRNE	237	31.2	27	61	111
Dispatch regions TRNE	564	39.1	27	79	331
Other Trauma Regions	90	76.5	29	5	59
total	891	37.4	27	145	501

*Pearson chi square p<0.05

The HEMS examined and treated 646 children on scene, mean age 8.4 years (sd 5.9); 475 (74%) emergencies were trauma-related, 171 (26%) were non-trauma. Of the 646 children examined on scene 145 (22.5%) had NACA scores of I-III, and 501 (77.5%) had NACA scores of IV-VII (medical cases 11% versus 89%, trauma cases 26% versus 74% respectively). (Figure 2)

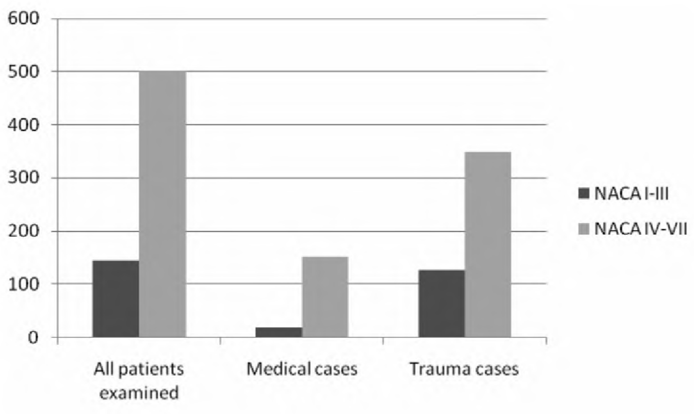

Figure 2. Patients examined on scene according to NACA score*
* Pearson chi square p<0.05

The incident type with an above-average mortality were all the non-trauma incidents, and near-drowning or burns. 'Passenger in motor vehicle' was the largest incident type, with a relatively low 24-hour mortality, 'congenital defect' is the incident type with the highest 24-hour mortality. Further details of the type of emergency are described in table 4. One hundred and five children died in the first 24 hours after the incident, of which 67 children died at the incident location.

DISCUSSION

Effective dispatch criteria define which vitally compromised children will benefit from HEMS deployment. The normal physiological range of the respiratory rate and blood pressure in

Table 4. HEMS incidents according to initial EMS call

Initial call	Incidents	Age range (mean age)	GCS (sd)	% 24-hour survival
	n	years		
Pre-clinical childbirth	29	0-0.25(0.1)	7 (5)	79
Congenital defect	14	0.25-15(4.9)	4 (2.4)	29
Infectious	28	0.25-16(2.5)	6 (3.7)	68
Convulsions	19	0.4-16(4.1)	7 (4.4)	95
Asphyxia	35	0.1-14(5.5)	10 (5.0)	71
CPR general (non-neonatal)	46	0.1-17(5.2)	5 (3.8)	52
Near-drowning	42	0.6-17(4.9)	7 (5.1)	81
Burns	12	0.2-11(4.5)	13 (4.6)	50
Pedestrian versus motor vehicle	67	0.2-17(9.0)	9 (4.9)	85
Cyclist versus motor vehicle	84	0.3-17(12.5)	9 (4.7)	92
Passenger in motor vehicle	108	0.3-17(9.9)	12 (4.5)	93
Moped	58	1-17(15.0)	9 (5.2)	91
Fall	62	0.3-17(7.99)	12(3.9)	92
Equestrian	16	4-17(11.5)	8 (4.8)	100
Other	26	0.4-17(8.3)	12 (5.1)	88
Total	646	0-17(8.4)	9 (5.1)	84

children is wide, and the hemodynamic parameters differ significantly from adults. Meaningful triage criteria based on patient parameters are difficult to establish in children.[12] Rhodes et al found level of consciousness to be the best single indicator for HEMS deployment in a predominantly adult population.[13] The Glasgow Coma Scale, however, also has a high sensitivity and specificity for appropriate HEMS dispatch criteria in children as demonstrated by Moront in a study of 3861 children.[12] HEMS deployment in the Netherlands is activated by a list of dispatch criteria approved by the Dutch Ministry of Health, this list is based almost entirely on mechanism of injury. The largest group of children examined by the HEMS were children who where a passenger in a motor vehicle collision. In these incidents adults were also involved as either the driver or passenger: they were the main victims for which the HEMS was called. Because the HEMS was present at the incident location the slightly injured children involved were also examined; these children had a relatively high 24-hour survival rate of 93%. This demonstrates that dispatch criteria based on mechanism of injury do not apply very well in children. (Table 4) Furthermore, there are differences between the interpretations of the HEMS criteria in the different dispatch regions as demonstrated by the respective percentage of NACA I-III patients. Dispatch regions called for HEMS in paediatric emergencies that could lead to paediatric CPR; pre-clinical childbirth, congenital heart disease, sepsis, convulsions and drowning. The deployment of HEMS is justified in hindsight by the remarkably low survival rate in these cases, although these types of emergencies were not specifically listed. In a comparable study, Mayer described 636 paediatric patients in Germany with an overall mortality of 7%, consisting of a 9% mortality in patients with trauma versus 6.3% in non-traumatic diseases.[14] As the mortality rate in this study is 16 percent, and considering this is only the 24-hour mortality, the children in our study consist of a severely vitally compromised patient population. In another comparable study in Germany, Eich described 2271 paediatric emergencies.[15] In this study, 72.7% of the children had an NACA score of I-III and 27.3% had a NACA score of IV-VII (versus 22.5% and 77.5% respectively in our study). (Chi square $p<0.05$). This difference may be caused by profound differences between the Netherlands and Germany in the pre-clinical emergency care for vitally compromised children, due to infrastructure, dispatching protocols, geography, training of EMS, etc. The actual deployment criteria for HEMS in the Netherlands are not suited for children. Based on the results of the aforementioned studies, the GCS should be applied in the future adjustment of the HEMS deployment criteria. It would seem worthwhile to include more potentially life-threatening events of medical origin in the future update of the dispatch criteria.

Did the dispatch of HEMS for adults and children follow the same profile since the introduction of this HEMS operation in 2001? A study by Lemson assessed whether a greater distance from the HEMS base to the incident entailed a greater cancel ratio of the HEMS deployment.[16] There was a strong correlation between the number of inhabitants per region and the number of deaths caused by trauma, the number of traffic accidents with injury, and emergency call-outs from ambulance services. Lemson et al also demonstrated that distance of the HEMS base to the emergency location was not correlated with the quantity of calls; several dispatch regions in the vicinity of a HEMS station had a lower number of HEMS calls than one would expect. Apparently, there are differences in the interpretation of HEMS criteria per dispatch region, caused by personal or institutional interpretation. In a study by Ringburg of a similar HEMS in the Netherlands was demonstrated that adherence to HEMS dispatch rates and dispatch criteria is low.[17] Better protocol adherence by emergency dispatchers could lead to a sevenfold increase of HEMS dispatching; the reasons for suboptimal protocol adherence were unclear. When extrapolating these results against the data in this article, it would seem probable that there are numerous emergencies in the field involving vitally compromised children for which a HEMS is not called.

Do the same cancel criteria apply for children and adults? A HEMS call could only be cancelled by the EMS paramedic if no serious illness of serious injury was present, or if the child had died on arrival of the EMS. As demonstrated in table 2, there is a sharp increase in all HEMS calls over the years (by the dispatcher) with a subsequent proportional increase of the cancel percentage (by the EMS paramedic on location). In the paediatric HEMS calls, the cancel percentage has not increased over the course of the years. The cause of this discrepancy cannot be specified by this study, but could be caused by the reluctance of the EMS-paramedic to cancel if children are involved.

There are several limitations to this study. Due to the nature of the health care provided, a blind prospective study was not possible. Follow-up after 24 hours of admission through the transportation of patients to hospitals out of the primary HEMS region was not feasible; therefore the survival until hospital discharge was unknown.

CONCLUSION

HEMS dispatches for children constitute a significant part of all dispatches. A substantial proportion of these dispatches involve vitally compromised children, as demonstrated by the 24-hour mortality of 16% of all children involved, and by the fact that 77.5% of all children had a NACA score of IV-VII. Dispatch criteria based on mechanism of injury are a poor triage tool. The present triage of vitally compromised children in the field is not sufficient, and needs to be addressed at the system or political level. Dispatch criteria used for HEMS in the Netherlands appear not to be well suited to children and should be adjusted to incorporate the GCS and specific types of severe illness

HEMS calls for children have not followed the same trends as HEMS calls for adults through the years. Contrary to HEMS calls for adults in the period 2001 until 2008, the cancel percentage of HEMS calls for children has not increased. This can be caused by an increase of the need for medical expertise in-the-field or by an growing reluctance of the EMS-paramedics to cancel the HEMS when children are involved. The data in this study cannot determine which cause, or combinations of causes is the dominant factor. Further research into HEMS deployment for children is necessary.

REFERENCES

1. Langhelle A, Lossius HM, Silfvast T, Bjornsson HM, Lippert FK, Ersson A, Soreide E: International EMS Systems; the Nordic countries. Resuscitation. 2004;61:9-21.
2. Albert J, Phillips H. Trauma care systems in the United Kingdom. Injury. 2003;34:728-734.
3. Masmejean EH, Faye A, Alnot JY, Mignon AF. Trauma care systems in France. Injury. 2003;34:669-673.
4. Nijs SJ, Broos PL. Trauma care systems in Belgium. Injury. 2003;34:652-657.
5. Westhoff J, Hildebrand F, Grotz M, Richter M, Pape HC, Krettek C. Trauma care in Germany. Injury. 2003;34:674-683.
6. Frankema SP, Ringburg AN, Steyerberg EW, Edwards MJ, Schipper IB, van Vugt AB. Beneficial effect of helicopter emergency medical services on survival of severely injured patients. Br. J. Surg. 2004;91:1520-1526.
7. Oppe S, De Charro FT: The effect of medical care by a helicopter trauma team on the probability of survival and the quality of life of hospitalised victims. Accid. Anal. Prev. 2001;33:129-138.
8. Ringburg AN. Helicopter Emergency Medical Services. Effects, costs and benefits. Thesis, Erasmus University Rotterdam, 2009
9. Anonymous, Policy note on trauma care 2006-2010, Dutch House of Parliament 29 247, nr 37
10. Veldman A, Fischer D, et al. Proposal for a new scoring system in international interhospital air transport. J Travel Med. 2001; 8: 154-157. (Table 1, page 154)
11. Lackner, CK, Schlechtriemen T, Burghofer K, Stolpe E, Altemeyer KH. NACA score: Modification of the NACA score for preclinical emergency medicine. Notfall und Rettungsmedizin, 2005; 8 (2): 109-111
12. Moront ML, Gotschall CS, Eichelberger MR. Helicopter transport of injured children: system effectiveness and triage criteria. J Pediatr Surg 1996;31(8):1183-1186
13. Rhodes M, Perline R, Aronson J, et al. Field triage for on-scene helicopter transport. J Trauma 1986;26:963-969
14. Mayer TA, Walker ML. Severity of illness and injury in pediatric air transport. Ann Emerg Med 1984;13:108-111
15. Eich C, Russo SG, Heuer JF, Timmermann A, Gentkow U, Quintel M, Roessler M. Characteristics of out-of-hospital paediatric emergencies attended by ambulance- and helicopter-based emergency physicians. Resuscitation 2009;80 (8):888-892
16. Lemson J, PM van Grunsven, IB Schipper, JP Valk, HMT Christiaans, BM Gerritse, GJ Scheffer. Helicopter-Mobile Medical Teams in The Netherlands: significant differences in deployment frequencies between different emergency room regions Ned Tijdschr Geneeskd. 2008 May 10;152 (19):1106-1112 [My paper]
17. Ringburg AN, Frissen IN, Spanjersberg WR, Jel G de, Frankema SPG, Schipper IB. Physician-staffed HEMS dispatch in the Netherlands: Adequate deployment or minimal utilization? Air Med J 2005;24(6):248-251

Chapter 5

Advanced medical life support procedures in vitally compromised children by a Helicopter Emergency Medical Service

Bastiaan M Gerritse MD[1],
Annelies Schalkwijk M Sc[2],
Ben J Pelzer PhD[3],
Gert Jan Scheffer MD, PhD[4],
Jos MT Draaisma MD, PhD[5]

BMC Emergency Medicine 2010;10:6

1. Department of Anaesthesiology, Amphia Hospital, Breda, the Netherlands
2. Department of Epidemiology, Biostatistics and Health Technology Assessment, Radboud University Medical Centre, Nijmegen, the Netherlands
3. Department of Social Science Research Methodology, Radboud University Medical Centre, Nijmegen, the Netherlands
4. Department Anesthesiology, Pain and Palliative Medicine, Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands
5. Department of Paediatrics, Radboud University Medical Centre, Nijmegen, the Netherlands

ABSTRACT

Objective: To determine the advanced life support procedures provided by an Emergency Medical Service (EMS) and a Helicopter Emergency Medical Service (HEMS) for vitally compromised children. Incidence and success rate of several procedures were studied, with a distinction made between procedures: procedures which are restricted to the HEMS (physician) and procedures for which the HEMS is more experienced than the EMS.

Methods: Prospective study of a consecutive group of children examined and treated by the HEMS of the eastern region of the Netherlands. Data regarding type of emergency, physiological parameters, NACA scores, treatment, and 24-hour survival were collected and subsequently analysed.

Results: Of the 646 children examined and treated by the HEMS on scene, 77.5% had a NACA score of IV-VII. 65% of the children had one or more advanced life support procedures restricted to the HEMS and 80% of the children had one or more procedures for which the HEMS is more experienced than the EMS. The HEMS intubated 38% of all children, and 21% of the children intubated and ventilated by the EMS needed emergency correction because of potentially lethal complications. The HEMS provided the greater part of intra-osseous access, as the EMS paramedics almost exclusively reserved this procedure for children in cardiopulmonary resuscitation. The EMS provided pain management only to children older than four years of age, but a larger group was in need of analgesia upon arrival of the HEMS, and was therefore subsequently cared for by the HEMS.

Conclusion: The Helicopter Emergency Medical Service of the eastern region of the Netherlands brings essential medical expertise in the field not provided by the emergency medical service. The Emergency Medical Service does not provide a significant quantity of procedures needed by the paediatric patient.

INTRODUCTION

Advanced Life Support (ALS) for the pre-clinical management of vitally compromised children consists of endotracheal intubation and ventilation, intravenous or intra-osseous access with fluid replacement and administration of medication. The purpose of on-site advanced interventions is to stabilise the patient before transport to the hospital. These procedures are expected to reduce physiological deterioration, and thus to reduce mortality. However, this has never been proven on the basis of evidence. One of the confounding factors could be the (lack of) experience and the training required to perform the advanced interventions in a pre-clinical setting.[1]

The Helicopter Emergency Medical Service (HEMS) was introduced in the Netherlands to provide optimal pre-clinical care, and consists of a physician (anaesthesiologist or trauma surgeon), a flight nurse and a pilot/driver. When the HEMS became operational, the Emergency Medical Service (EMS) frequently asked for assistance in stabilizing vitally compromised children. There were no paediatric HEMS data available in the Netherlands, research in other countries could not be easily extrapolated due to the international differences in HEMS and EMS organisations. However, there was a necessity to characterize the children involved to ameliorate HEMS and EMS care. The objective of this study was to evaluate the advanced medical interventions performed by the EMS and the HEMS in vitally compromised children, and to examine how often the HEMS provided additional care which was not or could not be provided by the EMS.

METHODS

Prospective cohort analysis of all HEMS calls for paediatric (under 18 years of age) emergencies for which the HEMS in the eastern part of the Netherlands (HEMS Netherlands-East) was called out, in the years 2001 to 2009. The HEMS Trauma Region Netherlands-East is one of the four HEMS regions in the Netherlands, and covers an area of about 10,088 square kilometres in the eastern part of the Netherlands, totalling approximately 4.5 million inhabitants. Approximately 19.5% of the population in this area is under 16 years of age.

The HEMS is called out either by the EMS dispatch centre (primary call) or by the EMS at the incident location (secondary call). The helicopter was active from January 2001 until September 2006 in daylight, and a physicians car was available during night and adverse weather. From September 2006 until today the helicopter crew is equipped with night vision goggles and fully operational 24 hours each day by helicopter. The physicians car is still available for foggy weather, and incidents close to the HEMS base (<10 kilometres).

HEMS physicians have received additional, extensive training (more than six months) in adult and paediatric emergency care, pain management and extrication techniques. HEMS physicians are authorised to perform advanced interventions that the paramedics of the EMS are not legally allowed to perform in the Netherlands. The paramedics of the EMS in the Netherlands are registered nurses with an additional training consisting of 175 hours of lectures concluded by exams. The EMS protocol in the Netherlands is a national protocol with precise description of procedures to follow. The paramedics of the EMS have only limited training and experience in vitally compromised children. However, the EMS-ambulance will be at the incident location in 15 minutes, due to the geographical distribution of EMS stations and time limits set by the government.

The HEMS is called out according to a structured list of injury mechanisms or suspected morbidity. The HEMS can be cancelled before arrival if the vital signs of the patient are (almost) normal or if the patient has died. All medical procedures are applied in accordance with the appropriate advanced life support protocols (National EMS protocol for the EMS, guidelines of the Advanced Paediatric Life Support for the HEMS)

The registered data includes age, sex, type of incident, physiological parameters (respiratory rate, heart rate, blood pressure, capnography), Glasgow Coma Scale (GCS), the pre-hospital treatment given, diagnosis in the emergency ward and survival until 24 hours after hospital admission. All patients examined by the HEMS were assessed according to the NACA (National Advisory Committee for Aeronautics) score.[2] (Table 1).

Table 1. The National Advisory Committee for Aeronautics (NACA) developed a simple scoring system for patients receiving air transport during the Vietnam War.[2]

Patient Status	Intervention	Score Level
non-acute life-threatening disease or injury	Acute intervention not necessary	1
further diagnostic studies needed	Acute intervention not necessary	2
severe but not life threatening disease or injury	Acute intervention necessary	3
development of vital danger possible	Acute intervention necessary	4
acute vital (life threatening) danger	Acute intervention necessary	5
acute cardiac or respiratory arrest	emergency resuscitation	6
Dead		7

The NACA score is a simple and both internationally and nationally established scoring system for grading disease or injury severity of patients in the preclinical setting. The worst clinical condition of the patient during pre-clinical management was the determining factor for classification, as described by the Munich modification of the NACA score.[3] It was also documented which of the pre-clinical advanced procedures were performed by the EMS or the HEMS. Advanced medical procedures were classified in three groups: procedures which are restricted to physicians under Dutch law (and thus restricted to the HEMS), procedures for which the HEMS is more experienced than the EMS and procedures for which the HEMS and EMS are equally experienced. This classification was created after a structured discussion between the HEMS and EMS management teams.

All data was recorded in an electronic patient data management system, custom made for the HEMS. The results were transferred into a data sheet (Excel TM, Microsoft Seattle, USA), after which all data underwent statistical analysis and graphical depiction with SPSS Statistics 16.1 TM (SPSS Inc., Chicago, IL, USA). Pearson chi square was used for statistical comparisons, significance was defined as $p < 0.05$. Since the tables contain one or more cells with zero frequency, the exact significance of the obtained Chi square value was used instead of the asymptotic approximation. Approval from the ethical board of the Radboud University Nijmegen Medical Centre was obtained prior the onset of the study, informed consent was not required due to the study design.

RESULTS

The HEMS had 891 calls involving children. In all cases the EMS was the first to arrive at the incident location. The average flight time of the HEMS was 9,6 minutes, ranging from 1 to 31 minutes. The time from HEMS alert to take-off or departure of the vehicle was an additional 2-5 minutes. Of these 891 calls, 245 (27%) were cancelled by the EMS before the arrival of the HEMS (199 children had normal physiological parameters, 27 children died and 19 calls other reasons). The HEMS examined and treated 646 children on scene with a mean age of 8.4 years (SD 5.9). Of these 646 children, 475 (74%) children had a trauma-related emergency and 171 (26%) children a non-trauma-related emergency. Of the children involved 145 (22.5%) had NACA scores of I-III, and 501 (77.5%) had NACA scores of IV-VII (medical cases 11% versus 89%, trauma cases 26% versus 74% respec-

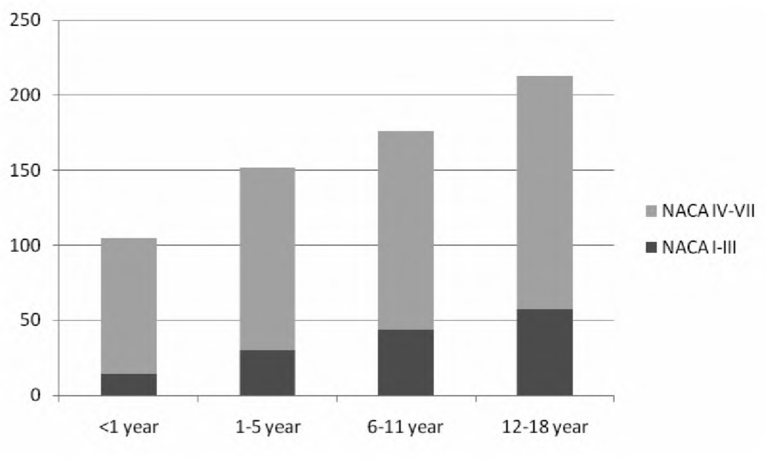

Figure 1. Age-dependent distribution of NACA scores, differentiated according to numbers of infants (<1 years) toddlers (1-5 years), schoolchildren (6-11 years), adolescents (12-18 years). Pearson chi square p< 0.05

tively). (Chi square $p < 0.05$). The youngest group of children (< 1 year) had the relatively highest percentage of NACA scores IV to VII. (Figure 1).

Eight percent of all children were given cardio respiratory resuscitation in the field (with a 24-hour survival rate of 26%). One hundred and five (16%) children died in the first 24 hours after the incident, of which 67 at the incident location. The emergency types with above-average mortality were all the non-trauma emergencies (except convulsions), near-drowning and burns. The emergency type 'congenital' includes all congenital disorders: cardiac, pulmonary or metabolic in a group of children with a wide variety of ages (Table 2).

Table 2. Paediatric HEMS incident according to initial EMS call

Initial HEMS call	Incidents	Mean age (age range)	GCS (SD)	% 24-hour survival
	n	years		
1. preclinical childbirth	29	0.1 (0-0,1)	7 (5)	79
2. congenital	14	4.9 (0,25-15)	4 (2.4)	29
3. infectious	28	2.5 (0,25-15)	6 (3.7)	68
4. convulsions	19	4.1 (0,4-15)	7 (4.4)	95
5. asphyxia	35	5.5 (0,1-14)	10 (5.0)	71
6. CPR general (non-neonatal)	46	5.2 (0,1-16)	5 (3.8)	52
7. Near-drowning	42	4.9 (0,6-15)	7 (5.1)	81
8. Burns	12	4.5 (0,2-11)	13 (4.6)	50
9. Pedestrian versus motor vehicle	67	9.0 (0,2-17)	9 (4.9)	85
10. Cyclist versus motor vehicle	84	12.5 (0,3-17)	9 (4.7)	92
11. Passenger in motor vehicle	108	9.9 (0,3-17)	12 (4.5)	93
12. Moped	58	15.0 (1-17)	9 (5.2)	91
13. Fall	62	7.99 (0,3-17)	12(3.9)	92
14. Equestrian	16	11.5 (4-17)	8 (4.8)	100
15. Other	26	8.3 (0,4-17)	12 (5.1)	88
Total	646	8.4 (0-17)	9 (5.1)	84

Of the 579 children who were transported from the incident location, 110 children (19%) were transported by helicopter. Children transported by ambulance without the HEMS physician had a significantly lower NACA score (Table 3).

A total of 1795 advanced medical procedures were provided by the HEMS to the 646 children, an average of 2.8 procedures per child (table 4). Advanced medical procedures (n=859) restricted to the HEMS were given to 65% (n=422) of the children. Medical procedures (n=936) for which the HEMS is more experienced than the EMS were provided to 80% (n=518) of the children (Table 4). In 563 children (87%) a medical procedure from one or both of these groups was performed by the HEMS.

Table 3. Transportation of patients

	n	NACA I-III@	NACA IV-VII@
No transportation, dead on scene	67	0	67
Ambulance, with HEMS physician	315	20	295
Ambulance, without HEMS physician	154	124	30
Helicopter transport because of distance to receiving hospital	26	1	25
Helicopter transport because of condition of patient	82	0	82
Interhospital transfer	2	0	2

@NACA groups: Pearson chi square p< 0.05

Table 4. Pre-hospital medical procedures

Restricted to HEMS		HEMS more experienced	HEMS	EMS
	n		n	n
Hypnotics*	180	Unsuccessful intubation®	0	20
Muscle relaxants#	171	Successful intubation®	248	93
Chest tube	12	Peripheral venous canula	315	359
Central venous line	13	Intra-osseous access	72	31
Hypertonic fluid&	137	Intra-osseous access + CPR	19	27
Antibiotics∀	28	Pain Management**	188	54
Physician transfer	315	Medication for ALS⊥	113	32
Venous cut down	3			
Total	859		936	569

*Hypnomidate, midazolam, propofol, s-ketamine (hypnotic dose)
#Suxamethonium, rocuronium
&Mannitol, hyperhaes
∀Cefazolin, ceftriaxon
⊥Amiodarone, atropine, dobutamine, epinephrine,
**Fentanyl, Alfentanyl, locoregional anaesthesia, s-ketamine (analgetic dose)
@ Successful versus unsuccessful endotracheal intubation: Pearson chi square p< 0.05

A medical procedure in which the HEMS is more experienced than the EMS is endotracheal intubation. EMS paramedics arriving at the incident location before the arrival of the HEMS intubated 93 children, with a success rate of 78% (n=73). A part of these children have been further described in a previous publication by these authors.[4] In twenty of these 93 children an emergency correction of the endotracheal tube or ventilator settings was performed by the HEMS upon arrival: oesophageal intubation (n=13), inappropriately sized uncuffed endotracheal tube making positive pressure ventilation impossible (n=5) and potentially lethal ventilator settings (n=2) (>300% of recommended ventilator settings). The HEMS intubated 248 children with 100% success. Successful intubation was defined as symmetrical breath sounds by auscultation, and a positive mainstream capnography, followed by mechanical ventilation with normal airway pressures. These measures only partially eliminate the presence of bronchial intubation, but would make it more rare. An acknowledged and corrected primary oesophageal intubation by HEMS was registered as a success. Oxygen saturation was often difficult to register during the medical intervention, and the fall of oxygen saturation was not registered during the endotracheal intubation. In cardiopulmonary resuscitation without any capnography reading, the endotracheal intubation was confirmed by repeat laryngoscopy. The difference in the number of successful endotracheal intubations by the EMS and the HEMS is significant (Chi square $p < 0.05$). Fourteen percent (n=47) of the children with a GCS > 7 were intubated by the HEMS (compromised airway, pain management or to facilitate transportation by helicopter).

Intra-osseous access was obtained in 103 children, 72 by the HEMS and 31 by the EMS. Eighty-seven percent (n=27) of all children provided with intra-osseous access by the EMS were in cardio respiratory arrest, versus 26% (n=19) in the HEMS group.

Pain management was given to 29% (188/646) of the children. The medication of choice was fentanyl or alfentanyl, occasionally lidocaine for infiltration anaesthesia and levobupivacaine for peripheral nerve blocks. The youngest child provided with pain management by an EMS paramedic was four years old; by the HEMS only two months old. No detrimental effects of the pre-clinical application of analgesics were recorded.

DISCUSSION

There are no studies that show convincingly that a physician-based EMS leads to a decrease in overall mortality or morbidity of pre-clinically treated patients.[5] However, in those patients requiring advanced airway management or other invasive procedures, as well as fluid management and pharmacotherapy, adding a specialist physician to the pre-hospital emergency care can increase survival and improve outcome.[5]

The children in this study who were examined and treated by the HEMS constitute a particularly compromised group. Eight percent of all children were given cardio respiratory resuscitation in the field (with a 24-hour survival rate of 26%). Eich described 2271 paediatric emergencies in a comparable study on EMS and HEMS in Germany.[6] In the study by Eich, 72.7% of the children had a NACA score of I-III and 27.3% had a NACA score of IV-VII (versus 22.5% and 77.5% respectively in our study). (Pearson chi square p<

0.05). This discrepancy may be caused by profound differences between the Netherlands and Germany in the pre-clinical emergency care for vitally compromised children, due to differences in infrastructure, dispatching protocols, geography or training of EMS. Still, the conclusions stated in the study of Eich are even more valid to the HEMS in the Netherlands. The HEMS in our study encounters a high incidence of paediatric emergencies in children, therefore "... skills in paediatric airway management, cardio respiratory resuscitation and intraosseous canulation in all age groups are essential.."[6]

The youngest patients have the highest NACA scores. Certain causes of a pre-clinical vital threat occur only in early childhood, like unexpected childbirth and duct-dependent congenital heart disease. Other causes of life-threatening events, like sepsis, convulsions and near-drowning, occur especially in toddlers and younger children.[6] These life-threatening events have a low rate of survival in this study. As advanced life support procedures are considered to be more difficult in younger children, special training in these cases should be provided for optimal performance of the HEMS. As shown in the age range variation in table 2, young children can be involved in any kind of trauma incident.

Zautcke e.a. studied the amount of skill deterioration in 40 paramedics after graduation.[7] Examination consisted of the practical aspects of airway management, spinal immobilization and intravenous fluid therapy in relation to their final school examination. As a group, the study scores were significantly lower than the graduation scores except in spinal immobilization and extremity immobilization. A continuing education and recertification process is necessary to identify and correct deficiencies in performance.

The number of 20 failed intubations or lethal ventilator settings is unacceptably high. The rate of failed endotracheal intubations by the EMS-paramedics has relatively diminished in the last years of this study in comparison to our previous publication on this subject.[4] The reasons for this trend are unknown, still any not-recognised oesophageal intubation can have catastrophic consequences.

It has been clearly shown that experience is crucial for successful preclinical endotracheal intubation.[8,9] A far better option for the paramedics in the EMS would be the maintenance of oxygenation by bag-valve-mask ventilation until the arrival of an HEMS or arrival in the emergency ward.[4,10,11] Theoretically, there are clear advantages to preclinical endotracheal intubation: facilitation of artificial ventilation, protection against aspiration, facilitation of transport by helicopter. This should, however, never compromise the application of supplemental oxygen and adequate ventilation.

Intra-osseous access is recommended in vitally compromised children if intravenous access is difficult or impossible, and can also be effective in adults. As intra-osseous access by EMS-paramedics is predominantly used in children in cardiac arrest, a potentially large group of vitally compromised children go without this useful device. The HEMS in this study did provide intra-osseous access to children outside the CPR group. Although the EMS paramedics are trained in intra-osseous access, it is not widely applied: only 30%

of all intra-osseous access was provided by the EMS paramedics. The infrequent use of intra-osseous infusion compared to other advanced life support skills in hospital and by paramedics and HEMS has been described.[12,13] Still, several studies have shown that the placement of an intra-osseous line is easy, fast and has a high success rate.[14-16]

The number of children who needed pain medication but did not receive it from the EMS is high: 78%. No child under the age of four years (e.g. the burn victims) received any pain medication from the EMS. The safe delivery of adequate analgesia is a priority in pre-hospital care; ketamine is relatively safe when used by physicians.[17] In a review by Thomas, clear evidence supporting the safety of pre-hospital analgesia was provided. Pain relief can be improved in an EMS or HEMS by balancing the desire to do no harm, and the unacceptable fact of allowing needless suffering.[18] This clearly calls for additional education and standards to improve pre-clinical pain management. The potential fear of the EMS of causing ventilatory depression has to be addressed.

There are several limitations to this study. Due to the nature of the health care provided, a blind prospective study was not feasible. The added value of adding an HEMS to the EMS was quantified by the number of medical procedures, with special attention for the procedures for which the EMS is neither certified nor experienced. There was no follow-up after 24 hours of admission, so actual survival until hospital discharge was unknown. The reason for this was the transportation of patients to hospitals out of the primary HEMS region.

CONCLUSION

The HEMS of the eastern part of the Netherlands provides essential additional medical expertise not provided by the EMS. The only formal paediatric indication for HEMS at this moment is the paediatric cardiopulmonary resuscitation. This study calls for a lower threshold for HEMS activation in any serious incident involving children, preferably based on the type of primary emergency call.

Sixty-five percent of the vitally compromised children received a preclinical medical procedure restricted to a physician, 78% received a medical procedure for which a physician was more experienced. The majority of all patients encountered by the HEMS had a NACA score of IV-VII. As the younger patients had a higher NACA score, special attention should be given to training and the provision of advanced life support procedures for these patients.

Successful endotracheal intubation and subsequent appropriate ventilation in children is a difficult task for EMS paramedics; preclinical endotracheal intubation of children calls for an experienced physician. The use of intra-osseous access devices and the use of analgesics by EMS paramedics could be improved. Further investigation into the pre-hospital care for vitally compromised children is necessary.

REFERENCES

1. Ummenhofer W, Scheidegger D. Role of the physician in prehospital management of trauma: European perspective. Current Opinion in Critical Care 2002;8:559-565.
2. Veldman A, Fischer D, et al. Proposal for a new scoring system in international interhospital air transport. J Travel Med. 2001; 8: 154-157. (Table 1, page 154)
3. Lackner, CK, Schlechtriemen T, Burghofer K, Stolpe E, Altemeyer KH. NACA score: Modification of the NACA score for preclinical emergency medicine. Notfall und Rettungsmedizin, 2005; 8 (2): 109-111
4. Gerritse BM, Draaisma JMT, Schalkwijk A, Grunsven PM van, Scheffer GJ. Should EMS-paramedics perform paediatric tracheal intubation in the field? Resuscitation 2008;79:225-229
5. Timmermann A, Russo SG, Hollmann MW. Paramedic versus emergency physician emergency medical service: role of the anaesthesiologist and the European versus the Anglo-American concept. Curr Opin Anaesthesiol 2008;21:222-227
6. Eich C, Russo SG, Heuer JF, Timmermann A, Gentkow U, Quintel M, Roessler M. Characteristics of out-of-hospital paediatric emergencies attended by ambulance- and helicopter-based emergency physicians. Resuscitation 2009; 80 (8): 888-892
7. Zautcke JL, Lee RW, Ethington NA. Paramedic skill decay. Journ Emerg Med 1987;5:505-512
8. Boswell WC, McElveen N, Sharp M, Boyd CR, Frantz EI. Analysis of prehospital pediatric and adult intubation, Air Med J. 1995; 14: 125-128
9. Pepe PE, Copass MK, Joyce H. Prehospital endotracheal intubation: rationale for training emergency medical personnel. Ann Emergency Medicine. 1985;14(11): 1085-1092
10. Cooper A, DiScala C, et al. Prehospital endotracheal intubation for severe head injury in children: a reappraisal. Sem in Pediatric Surgery. 2001; 10(1):3-6
11. Gausche M, Lewis RJ, Stratton SJ, Haynes BE et al. Effect of Out-of-hospital pediatric endotracheal intubation on survival and neurological outcome, JAMA 283 (2000) p.783-790
12. Glaeser PW, Helmich TR, Szewczuga D, Losek JD, Smith DS. Five-year experience in prehospital intraosseous infusions in children and adults. Ann Emerg Med 1993;22:1119-1124.
13. Helm M, Hauke J, Bippus N, Lampl L. Die intraossäre Punction in der präklinischen Notfallmedicin. Der Anaesthesist 2007;56:18-24.
14. Curran A, Sen A. Best evidence topic report. Bone injection gun placement of intraosseous needles. Emerg Med J. 2005 May;22(5):366. Review.
15. Calkins MD, Fitzgerald GF, Bentley TB, Burris D. Intraosseous infusion devices: a comparison for potential use in special operations. J Trauma 2000;48:1068-1074.
16. Gerritse BM, Draaisma JMT, Prehospital intraosseous access with the bone injection gun by a Helicopter Emergency Medical Service. J Trauma 2009; 66 (6): 1739-1741
17. Bredmose PP, Lockey DJ, Grier G, Watts B, Davies G. Pre-hospital use of ketamine for analgesia and procedural sedation. Emerg Med J. 2009;26:62-64
18. Thomas SH, Shewakramani S. Prehospital trauma analgesia. Journal of Emerg Med 2008;35:45-57

Chapter 6

Should EMS-paramedics perform paediatric tracheal intubation in the field?

Bastiaan M Gerritse MD[1], Jos MTh Draaisma MD, PhD [2], Annelies Schalkwijk MSc [3], Pierre M van Grunsven MD, PhD[4], Gert Jan Scheffer MD, PhD[5]

Resuscitation 2008;79(2):225-9

1. Department of Anaesthesiology, Amphia Hospital, Breda, the Netherlands
2. Department of Paediatrics, Radboud University Nijmegen Medical Centre, the Netherlands
3. Department of Biomedical Sciences, Radboud University Nijmegen Medical Centre, the Netherlands
4. Medical Director Regional Ambulance Service Gelderland Zuid, the Netherlands
5. Department of Anaesthesiology, Radboud University Nijmegen Medical Centre, the Netherlands

ABSTRACT

Objective: To determine the incidence and success rate of out-of-hospital tracheal intubation (TI) and ventilation of children, and the association between type of healthcare provider and patient survival until hospital discharge.

Methods: A prospective study to analyse a consecutive group of children for which a Helicopter Emergency Medical Service (HEMS) was called. In all cases, the Emergency Medical Service (EMS)-paramedics arrived at the scene first. Data regarding type of incident, physiological parameters, treatment, and survival until hospital discharge were collected and subsequently analysed.

Results: Of the 300 children examined and treated by the HEMS on scene, 155 (52%) children required out-of-hospital tracheal intubation. 95 children had an initial Glasgow Coma Scale (GCS) of 3-4: the EMS-paramedics performed bag-valve-mask-ventilation (BVMV) until arrival and subsequent TI by the HEMS (54 children, survival 63%), or the EMS-paramedics performed TI themselves (41 children, survival 5%, subsequent correction of tube/ventilation by HEMS 37%). 205 children had an initial GCS of 5-15, 60 required TI (survival 67%), and 145 children required no TI (survival 100%).

Conclusion: We do not recommend early TI by EMS-paramedics in children with a GCS of 3-4. The rate of complications of this procedure is unacceptably high; BVMV is to be preferred. An association between healthcare provider in the field and patient survival until discharge could not be proven. Out-of-hospital TI performed by HEMS is safe and effective. The HEMS has skills in advanced airway management not provided by the EMS.

INTRODUCTION

An important goal of prehospital advanced life support is optimization of the physiological status of the patient before arrival in the emergency department. During advanced life support adequate airway management, oxygenation and ventilation are of crucial importance. Although bag-valve-mask ventilation (BVMV) and tracheal intubation (TI) are both widely used in the prehospital setting in vitally compromised children, there is no consensus about its indications for use. There is evidence that successful prehospital TI is likely to require specialized training and experience.[1] Doubts have been expressed whether prehospital TI in vitally compromised children is both safe and efficient.[2,3,4]

The view has been expressed that: "...personnel who are well experienced in the everyday clinical routines of assessing and managing difficult airway scenarios are the only individuals who should perform tracheal intubations in the out-of-hospital environment..."[1]

A Helicopter Emergency Medical Service (HEMS) was introduced in 2001 in the eastern part of the Netherlands to facilitate and support out-of-hospital medical interventions. The Emergency Medical Service (EMS)-paramedics are also allowed to perform TI and mechanical ventilation in children, but not to administer sedation or muscle relaxation.

The primary objective of this study was to compare TI success and survival rates of children with a Glasgow Coma Scale (GCS) of 3-4, when EMS-paramedics have a choice between performing TI themselves or giving BVMV until HEMS arrival. The secondary objective was to document and evaluate the out-of-hospital performance of TI by the HEMS.

MATERIAL AND METHODS

Settings

The HEMS-Netherlands-East covers an area of about 10.088 square kilometers area in the eastern part of the Netherlands, counting 4.5 million inhabitants. Approximately 19.5% of the Dutch population in this area is younger than 16 years of age. Critically ill or injured paediatric patients are resuscitated in the field and transported by the HEMS to an academic paediatric (trauma) centre. The HEMS consists of a physician (consultant in anesthesiology or trauma surgery), nurse and a pilot. The HEMS-crew has received special education and training in out-of-hospital paediatric and adult emergency care and is well experienced in everyday clinical routines of the care of vitally compromised children and adults. The trauma surgeons involved in the HEMS program have received an extensive (>6 months) in-hospital training in adult and paediatric intubation using rapid sequence induction.

The HEMS is activated either by the Emergency Medical Services (EMS)-dispatch centre or by the EMS-paramedics at the scene of the incident. Activation of the HEMS is according to a list of injury mechanisms or suspected morbidity. The HEMS can be cancelled before arrival if the vital signs of the patient are stable or if the patient is deceased.

Although adult TI is within the scope of paramedical practice, Dutch EMS-paramedics have only received a total of 24-days formal training, besides the training on the job. The structured education for EMS-paramedics on paediatric airway management is a 4-hour session combining theory and practice on an intubation dummy. There is no formal teaching program of advanced airway management by EMS-paramedics on live patients

Data collection

A prospective analysis of the standardized HEMS-forms was performed of 463 HEMS-calls involving pediatric patients (age up to 16 years) for whom the HEMS-Netherlands-East was activated from January 2001 to September 2006. These data include age, sex, type of incident, physiological parameters (respiratory rate, heart rate, blood pressure, capnography), GCS, Revised Trauma Score (RTS), out-of-hospital treatment given, diagnosis in the emergency department and survival until hospital discharge. TI was confirmed in the field by continuous end-tidal carbon dioxide monitoring and auscultation, and a chest X-ray on arrival in the emergency ward. It was specified whether the tracheal intubation was performed by the EMS-paramedics or the HEMS-physician.

Statistical analysis

The data were analysed with SPSS 12.0.1. Descriptive statistics (frequency tables and cross tables) were used to summarize the information. Inferential statistics (student's t-test, Fisher exact) were used to show relation between variables with a significance threshold of $p \leq 0.05$.

RESULTS

General

During the specified time period, the HEMS received 463 calls involving children. A total of 163 calls (35%) were cancelled by the EMS-paramedics before the arrival of the HEMS (131 calls normal physiological parameters, 21 calls patient deceased, 11 calls other reasons).

The HEMS examined and treated 300 children on the scene of the incident (mean age 6.8 years, SD 5.4); 249 (83%) incidents were trauma related, 51 (17%) incidents were non-trauma. Injury mechanisms or type of illness are specified in table 1.

In all cases the EMS-paramedics arrived at the incident location before the arrival of the HEMS. Seventy-nine children died after the arrival of the HEMS; 23 on location, 12 during transport or in the emergency ward, 44 in the intensive care.

Table 1. Out-of-hospital paediatric tracheal intubations according to injury mechanism/illness, GCS on scene and survival until hospital discharge.

Initial call	n (% of total)	Age in years (SD)	GCS (SD)	Survival until hospital discharge %
All	155 (100)	7.3 (5.3)	5.3 (3.4)	49
Prehospital childbirth	6 (4)	0 (0)	4 (2)	33
Congenital heart defect	6 (5)	8.3 (6.6)	3.1 (0.4)	17
Sepsis	8 (6)	3.3 (4.6)	3.4 (6.7)	37
Convulsions	5 (3)	4.0 (5.0)	5.8 (2.6)	100
Asphyxia	4 (2)	5.8 (3.0)	3.0 (0)	0
CPR (non-specified causes)	10 (7)	2.6 (3.3)	3.0 (0)	0
Near-drowning	16 (10)	3.1 (3.5)	3.5 (2)	16
Burns	5 (3)	2.8 (2.0)	7.8 (5.8)	40
Pedestrian vs. motor vehicle	20 (13)	6.3 (3.9)	6.7 (4.3)	60
Cyclist vs. motor vehicle	42 (27)	11.6 (3.7)	5.7 (3.3)	64
Passenger in motor vehicle	18 (12)	10.2 (4.3)	6.8 (4.0)	61
Fall	12 (8)	9.1 (3.2)	5.7 (3.0)	66
Other	3 (2)	2.3 (1.3)	4.5 (7.1)	66

Tracheal intubation

Of the 300 children examined and treated by the HEMS, 155 (52%) underwent out-of-hospital TI. All TI by HEMS-physicians were successful. There was no difference in management or outcome if the TI was performed by an anaesthesiologist or a trauma surgeon. Ninety-five children had an initial GCS of 3-4 at arrival of the EMS-paramedic (table 2). The EMS-paramedics on the scene made the choice to either apply BVMV and wait until arrival of the HEMS, or to perform TI themselves . In the standard of Dutch EMS procedures is stated that TI in children should only be performed if BVMV is not adequate.

Table 2. BVMV or TI by EMS-paramedics in children with an initial GCS of 3 or 4

	BVMV by EMS until TI by HEMS	TI by EMS	p-value
n	54	41	
Age in years (SD)	6.7 (5.5)	5.9 (5.3)	ns
Revised Trauma Score (SD)	1.1 (2.6)	3.2 (3.5)	ns
Trauma versus non-trauma (n)	32/22	29/12	ns
Prehospital CPR (n)	24	27	ns
Successful TI and ventilation (n)	54	26	p<0.001
Survival until hospital discharge (n)	37	2	P<0.001

EMS-paramedics intubated and ventilated 41 children with an initial GCS of 3-4 before the arrival of the HEMS. Fifteen of these 41 children had an emergency correction of the tracheal tube or ventilator settings by the HEMS-physician at arrival. An emergency correction was applied after auscultation, direct laryngoscopy, continuous end-tidal carbon

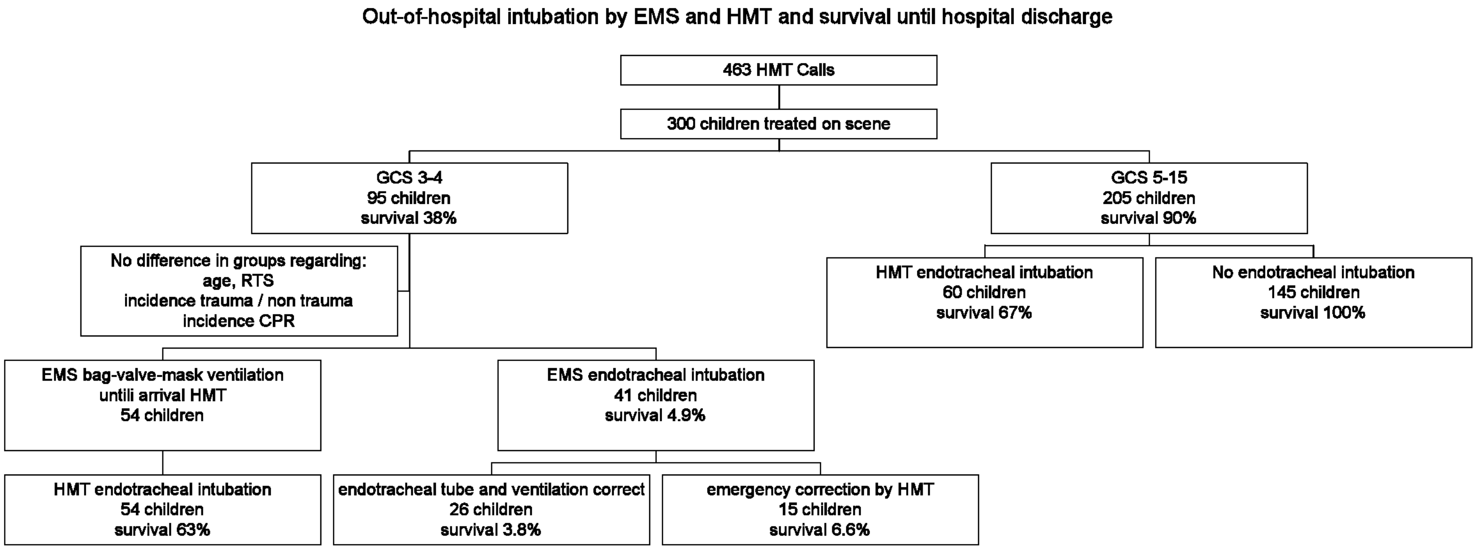
Out-of-hospital intubation by EMS and HMT and survival until hospital discharge
463 HMT Calls
300 children treated on scene
GCS 3-4
95 children
survival 38%
GCS 5-15
205 children
survival 90%
No difference in groups regarding:
age, RTS
incidence trauma / non trauma
incidence CPR
HMT endotracheal intubation
60 children
survival 67%
No endotracheal intubation
145 children
survival 100%
EMS bag-valve-mask ventilation
untili arrival HMT
54 children
EMS endotracheal intubation
41 children
survival 4.9%
HMT endotracheal intubation
54 children
survival 63%
endotracheal tube and ventilation correct
26 children
survival 3.8%
emergency correction by HMT
15 children
survival 6.6%

Figure 1.

dioxide monitoring and inspection of materials and settings. It appeared that 6 children were intubated in the esophagus by the EMS-paramedics, 7 children had an inappropriate size uncuffed tracheal tube making positive pressure ventilation impossible and 2 children had potentially lethal ventilator settings (administered ventilator settings > 300% of recommended ventilator settings). Other factors influencing survival were compared in the groups BVMV or TI by the EMS-paramedic. There were no statistical significant differences in prehospital cardiopulmonary resuscitation, revised trauma score or incidence of non-trauma in the BVMV and TI group. There was however a significant difference ($p< 0.05$) between these groups regarding the percentage of successful tracheal intubation and survival until hospital discharge.

Sixty children with an initial GCS of 5-15 required TI. The indications for TI in this group were: a GCS of 5-7 (33 children), compromised airway (16 children), to facilitate pain management or transportation by helicopter (11 children). Forty children (67%) of this group survived until hospital discharge. The 145 children that were examined and treated by the HEMS, but were no TI was performed, all survived. (figure 1)

DISCUSSION

Vitally compromised children are generally identified as a distinct group in emergency care and are considered more difficult to treat. Children sustain different kinds of injury than adults, and body proportions and tissue properties are different. Normal physiological variables and appropriately sized airway devices differ according to age and size of the patient.[5] All this leads to the perception that TI is more difficult in children than in adults. Still, out-of-hospital TI could be beneficial, as it facilitates artificial ventilation and protects against aspiration of gastric content.

This study shows that 52% of the children for which a HEMS was called, required advanced airway management. The group 41 deeply comatose children where the EMS-paramedics performed BVMV and subsequent TI had a worse survival than the BVMV-only group. The amount of 15 failed intubations or ventilations in this group of 41 children is in the opinion of the authors an unacceptable quantity: only 2 out of this group survived until hospital discharge. However, we cannot conclude, due to the study design, that intubation is causative in increased mortality. In table 2 is shown that the trauma score of initially intubated patients is 3-times higher than patients non-intubated by the EMS. Differences in the illness severity between the two groups (not detected by our analysis) or other aspects of care may have lead the EMS staff more frequently to intubate those less likely to survive or adversely affected survival.

The added value of the experience of a HEMS-physician compared to the standard EMS-paramedic was quantified in our study by the success rate of HEMS-performed out-of-hospital TI. HEMS-physicians are either an anaesthesiologist or a trauma-surgeon extensively trained in pediatric airway skills in a level one trauma centre. There is no official data concerning the number of intubations performed per year by Dutch EMS-paramedics. This number is, by personal communication, not more than an average of three adult intubations per year for one EMS-paramedic; a paediatric intubation is even more rare.

The out-of-hospital paediatric TI by EMS-paramedics has been described in other countries.[6] Brownstein studied 355 children intubated at the scene of the incident, in half of the cases with the use of suxamethonium. Serious complications of TI were found in 10% of the patients. In comparable studies, a major complication incidence of 25% of all out-of-hospital TI has been described.[4]

Medical literature clearly shows that experience is crucial for successful out-of-hospital TI.[7,8] The incidence of failed out-of-hospital TI (0.8 – 2.6%) for emergency physicians is lower than for paramedics (1.6 – 15.8%).[9] It has been demonstrated that out-of-hospital TI in adult trauma does not improve survival compared to bag-mask ventilation.[10] Ehrlich described that in the field 91% of the paediatric patients can be successfully oxygenated by bag-valve ventilation by paramedics, and that multiple attempts for tracheal intubation in children are associated with significant complications.[11]

Studies have been published where airway devices other than endotracheal tubes were successfully applied in the pre-hospital setting.[12,13] However, there are no data regarding the prehospital use of alternative airway devices in children. At this moment supraglottic airway devices (SAD) are not included in the Dutch EMS protocols. Considering the paucity of studies, the training required, the number of EMS-paramedics in the Netherlands and the small number of children in need of advanced airway management, the authors do not recommend the introduction of SAD in the Dutch EMS protocols.[14]

There are several limitations to our study. Due to the nature of the health care provided, a prospective randomized or blinded study was not feasible, and although all subsequent patients in a 5 year period were included, the numbers are still small. Another limitation was the fact that beyond the qualification 'survival until hospital discharge', there was no knowledge concerning the physical or psychological condition of the children at discharge or the long term outcome. An additional limitation was the fact that the injury mechanisms and illness of the 155 children that were intubated were diverse.

CONCLUSION

Based on our experience, successful tracheal intubation and subsequent appropriate ventilation in children appears to be a difficult task for EMS-paramedics. Due to the amount of serious complications, the authors recommend that out-of-hospital pediatric TI is restricted to HEMS. Bag-mask ventilation is to be preferred to a failed intubation effort, even if bag-mask ventilation is suboptimal. Out-of-hospital tracheal intubation of children calls for an experienced physician. The HEMS provides additional medical expertise not provided by the EMS-paramedics concerning advanced airway management in children. A new prospective trial of TI versus BVMV should be performed in the Netherlands to provide definitive data regarding the effect of advanced airway skills on survival, no such relation was evident in this study.

REFERENCES

1. Ummenhofer W, Scheidegger D. Role of the physician in prehospital management of trauma: European perspective. Current Opinion in Critical Care 2002;8:559-565.
2. Brooke Lerner E, Moscati RM. The golden hour: scientific fact or medical urban legend? Academic Emergency Medicine. 2001;8:758-760
3. Gausche M, Lewis RJ, Stratton SJ, Haynes BE e.a. Effect of Out-of-hospital pediatric tracheal intubation on survival and neurological outcome, JAMA 2000;283:783-790
4. Nakayama DK, Gardner MJ, Rowe MI. Emergency tracheal intubation in pediatric trauma. Ann of Surg 1990;211:218-223
5. Turner NM, van Vught AJ (ed). Advanced Paediatric Life Support, de Nederlandse editie (tweede druk). Elsevier Gezondheidszorg,Maarssen 2006 (in dutch)
6. Brownstein D, Shugerman R, Cummings P, Rivera F e.a. Prehospital tracheal intubation of children by paramedics, Ann Emerg Med 1996;28:34-39.
7. Boswell WC, McElveen N, Sharp M, Boyd CR, Frantz EI. Analysis of prehospital pediatric and adult intubation, Air Med J 1995;14:125-128.
8. Pepe PE, Copass MK, Joyce H. Prehospital tracheal intubation: rationale for training emergency medical personnel. Ann Emergency Medicine. 1985;14(11): 1085-1092.
9. Timmermann A, Eich C, Russo SG, Natge U, Bräuer A, Rosenblatt WH, Braun U. Prehospital airway management: a prospective evaluation of anaesthesia trained emergency physicians. Resuscitation 2006;70:179-185.
10. Stockinger ZT, McSwain NE. Prehospital tracheal intubation for trauma does not improve survival over bag-valve-mask ventilation. J Trauma. 2004;56:531-536.
11. Ehrlich PF, Seidman PS, Atallah O, Haque A, Helmkamp J. Tracheal intubations in rural pediatric trauma patients**.** J Pediatr Surg. 2004;39(9):1376-1380
12. Rumball CJ, MacDonald D. The PTL, Combitube, laryngeal mask, and oral airway: a randomized prehospital comparative study of ventilatory device effectiveness and cost-effectiveness in 470 cases of cardiorespiratory arrest. Prehosp Emerg Care. 1997;1:1-10
13. Rabitsch W, Schellongowski P, Staudinger T, Hofbauer R, e.a. Comparison of a conventional tracheal airway with the Combitube in an urban emergency medical services system run by physicians. Resuscitation. 2003;57(1):27-32
14. Youngquist S, Gausche-Hill M, Burbulys D. Alternative airway devices for use in children requiring prehospital airway management: update and case discussion. Pediatr Emerg Care. 2007;23(4):250-258

Chapter 7

Endotracheal cuff pressure: An important risk factor for iatrogenic tracheal stenosis in emergency medicine

Bastiaan M Gerritse MD[1],
Jos M.Th. Draaisma MD, PhD[2] ,
Anna Besselink-Lobanova MD[3],
Ben J Pelzer PhD[4],
Henri A. M.Marres MD, PhD[5],
Gert Jan Scheffer MD, PhD[6]

1. Department of Anesthesiology, Amphia Hospital, Breda, the Netherlands
2. Department of Paediatrics, Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands.
3. Department of Anesthesiology, Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands.
4. Department of Social Science Research Methods, Radboud University Nijmegen, the Netherlands.
5. Department of Otorhinolaryngology, Head and Neck Surgery, Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands.
6. Department of Anesthesiology, Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands.

Resuscitation 2009;80(8):962

ABSTRACT

Background: To evaluate risk factors for iatrogenic tracheal stenosis after endotracheal intubation in the field. The risk factors according to medical literature are cuff pressure, use of alpha-agonists, occurrence of shock, or combinations of these factors. In the period of a year, three incidents were reported in our hospital where a patient developed severe stridor after detubation. All three patients were intubated in the field after rapid sequence induction by a Helicopter Emergency Medical Service.

Methods: Prospective descriptive study regarding all patients intubated in the field were prospectively collected. Patient data included: prevalence of shock, use of alpha-agonists, endotracheal cuff pressure. The endotracheal cuff pressure was measured only after the standard prehospital routine of intubation and insufflation as mandated by the national procedure board of the emergency medical service, had been performed. Medical personnel charged with the insufflation of the cuff were not informed regarding the purpose of the study.

Results: 241 patients were included in the study, indications for prehospital intubation were brain injury, major trauma, and cardiac resuscitation. One or several risk factors of iatrogenic tracheal stenosis could be identified in 89% of all patients. Cuff pressure was elevated above 25 cm H_2O in 214 patients, the mean cuff pressure was 69± 31cm H_2O . 41 patients were in shock, 14 patients were administered alpha-agonists.

Conclusions: Inappropriately high cuff pressures are frequently measured after prehospital intubation in the Netherlands.

INTRODUCTION

A Helicopter Emergency Medical Service (HEMS) was introduced in 2001 in the eastern part of the Netherlands to provide advanced pre-hospital care. The HEMS consists of a doctor (anaesthesiologist or trauma-surgeon), nurse and a pilot. The HEMS-crew has received special education and training in pre-hospital paediatric and adult emergency care and is well experienced in everyday clinical care of vitally compromised children and adults. The HEMS is activated either by the Emergency Medical Services (EMS)-dispatch centre or by EMS-paramedics at the scene of the incident.

In a short period of time, three patients admitted in our hospital, developed a severe inspiratory stridor during recovery after a period of intubation. All three were admitted to our hospital after requiring endotracheal intubation in the field by the HEMS. These three patients (age 14, 12 and 14 years) were treated for major blunt force trauma and have been ventilated in the intensive care ward (for 3, 14 and 5 ventilator days respectively). No evident in-hospital risk factors for iatrogenic tracheal stenosis could be found in the patients charts during multidisciplinary evaluation. Because of the resemblance in pre-hospital intervention, the suspected relation with local tracheal cuff trauma and the lack of obvious in-hospital risk factors, a pre-hospital cause was suspected. Known risk factors for iatrogenic tracheal stenosis are the appropriateness of the diameter of the endotracheal tube [1,2], the given cuff pressure [3,4], or the presence of hypovolemic shock and the use of alpha-agonists [5].

The aim of this prospective descriptive study was to determine the incidence of risk factors for iatrogenic tracheal stenosis in the patient population treated by our HEMS.

METHODS

The study had an open prospective cohort design. All consecutive patients intubated in the field by the HEMS over a two year period (July 2005-august 2007) with a cuffed endotracheal tube (Lo-Contour tm Murphy tube, Mallinckrodt®) were included in the study. Patients were intubated after induction of anaesthesia by administrating hypnotics and muscle relaxants. The appropriate size of the endotracheal tube for children was determined by using the guidelines of the Advanced Paediatric Life Support Course.[6] The adult patients were intubated with an endotracheal tube size 7 (females) or size 8 (males).

The cuff of the endotracheal tube was inflated by the EMS-paramedic or HEMS-member according to standard EMS procedures, as described in the national EMS guidelines.[7] First the cuff of the endotracheal tube is filled with 10 ml of air to test for leakage, subsequently the cuff is deflated. After appropriate endotracheal intubation, the cuff is inflated with air using the same syringe. In the national guidelines no specified instructions are given to the proper volume of air required to seal the cuff, or methods to avoid over inflation.

In our study the measurement of the cuff pressure was taken by the HEMS-physician with a calibrated cuff manometer (Rusch®, Endotest Measuring Device) immediately after insufflation of the endotracheal cuff by the paramedic. The endotracheal cuff pressure was noted and eventually readjusted to a maximum cuff pressure of 25 cm H_2O. With this amount of pressure the cuff of the tracheal tube is unlikely to exceed the capillary perfusion pressure of the tracheal wall (arbitrarily defined as 25 mm Hg or 34 cm H_2O). [8]

The following data were collected: age, sex, type of injury, initial heart frequency, systolic blood pressure, diastolic blood pressure, Glasgow Coma Score, endotracheal tube size, presence of shock, use of alpha-agonists (norepinephrine or epinephrine) and stored in a database designed for this study.

The data were analyzed with SPSS (version 15). Descriptive statistics were used to summarise the information. Inferential statistics (Student's *t*-test, Fisher exact) were used to show the relationship between variables with a significance threshold of $p \leq 0.05$.

RESULTS

In the study period 241 patients in the field were intubated by the HEMS, all patients were included in this study. Indications for endotracheal intubation were: severe neurotrauma with loss of consciousness (63%), major trauma (34%) or cardiopulmonary resuscitation (3%). The study population consisted of 174 males and 67 females, with an age ranging from 3-81 years. Of these, 45 (19%) were children aged 3 - 17 years.

The endotracheal tubes used ranged from size 5 – 8 mm and the cuff pressures measured ranged from 5- 140 cm H_2O. The mean cuff pressure in all patients was 64± 37 cm H_2O. The cuff pressure was above 25 cm H_2O in 214 patients (89%). Cuff pressure was higher than the diastolic blood pressure in 65 patients. The tube sizes used were according to the guidelines stated in methods in all patients. The cuff pressure of patients with a tube size 6 or 7 had a significant ($p<0.05$) higher cuff pressure than patients with a tube size 5 or 8. As stated in methods, all cuff pressure was optimised after measurement.

All patients that were administered α-agonists had concurring hypovolemic shock. Subsequently, 7 patients (3%) had all three risk factors for iatrogenic tracheal stenosis.

As of this day (a year after completion of the study), none of these 241 patients developed a tracheal stenosis. Further results of the population are described in table 1.

Table 1. All patients

Cuff pressure (cmH_2O)	all	≤ 25	>25 and ≤ 50	>50
No. of patients	241	27	93	121
Hypovolemic shock	41	4	14	23
α-agonists	14	1	6	7

Children could possibly be more susceptible for iatrogenic tracheal stenosis so the paediatric data are represented separately in table 2. [3]

Table 2. Children (3-17 years)

Cuff pressure (cmH_2O)	all	≤ 25	>25 and ≤ 50	>50
No. of patients	45	4	22	19
Hypovolemic shock	7	1	3	3
α-agonists	4	0	2	2

Of the 45 children intubated in the field, 41 (91%) had a cuff pressure above 25 cm H_2O. The cuff pressure measured in children ranged from 5-140 cm H_2O (mean 61 cm H_2O). As 91% of the children had an elevated cuff pressure, versus 88% of the adults, there is no bias towards children for an elevated cuff pressure.

DISCUSSION

Our data demonstrate that the endotracheal cuff pressure in this patient group is significantly above the pressure recommended in medical literature. As in part of the population described multiple risk factors for iatrogenic tracheal stenosis are present, it seems even more important to avoid the unnecessarily high cuff pressures. The pressure limit of 25 cm H_2O is quite arbitrary, because no definite data regarding the capillary flow pressure in the tracheal mucosa in patients is known. However, if the cuff pressure of the endotracheal tube is higher than the diastolic pressure, subsequent damage to the tracheal wall can be expected resulting in necrotic mucositis, perichondritis and even in chondritis, on the long term fibrosis will lead to invalidating stenosis.

The current standard Dutch ambulance protocol was used for the procedure of inflating the endotracheal cuff.[7] As of this moment, no specified instructions are stated regarding the proper volume of air required to seal the cuff, or to how avoid over inflation. This ambulance protocol should be evaluated, and changed accordingly.

The cuff pressure is best measured by a mechanical aid, as literature shows that a manual estimate is not effective, even for experienced anaesthesiologists or anaesthesia nurses.[5] The authors recommend that this measurement should take place at the scene of intubation, in the emergency room and on admission in intensive care ward.

Measurement of the cuff pressure is a standard procedure in the operating theatres in the Netherlands, but not in the EMS or emergency ward. If the cuff is overinflated during the endotracheal intubation in the field and not corrected in the hospital, elevated pressure can persist and resulting in damage to the tracheal wall.

CONCLUSION

Inappropriately high endotracheal cuff pressures are frequently measured after prehospital intubation in the Netherlands. A high cuff pressure is by far the most frequent risk factor for iatrogenic tracheal stenosis in this study. It is an avoidable risk factor as it can easily be measured and corrected. A change of the EMS-protocol in the Netherlands is necessary; training of all personnel concerned should include instruction on proper cuff insufflation. The measurement of the cuff pressure involves little investment regarding time, material or training, but could possibly avoid severe sequelae. As such, the authors recommend measurement of the cuff pressure directly after endotracheal intubation, and at every subsequent location the patient is transferred to.

REFERENCES

1. Stamm D, Floret D, Stamm C, Cochat P, Truy E, Morgon A. Subglottal stenosis following intubation in children, Arch Fr Pediatr 1993;50(1):21-25
2. Meneghini L, Zadra N, Metrangolo S, Narne S, Giusti F. Post-intubation subglottal stenosis in children: risk factors and prevention in pediatric intensive care. Minerva Anesthesiol. 2000;66(6):467-471
3. Wiel E, Vilette B, Darras JA, Scherpereel P, Leclerc F. Laryngotracheal stenosis in children after intubation. Report of five cases. Paediatr Anaesth. 1997;7(5):415-419
4. Newth CJL, Rachman B, Patel N, Hammer J. The use of cuffed versus uncuffed endotracheal tubes in pediatric intensive care. The Journal of Pediatrics 2004, 333-337
5. Sengupta P, Sessler DI, Maglinger P, Wells S, Vogt A, Durrani J, Wadhwa A. Endotracheal tube cuff pressure in three hospitals and the volume required to produce an appropiate cuff pressure. BMC Anesthesiology 2004;4:8
6. Turner NM, van Vught AJ. Advanced Paediatric Life Support. (in dutch). Elsevier, Maarssen 2006
7. Landelijk Protocol Ambulancezorg, versie 7.0. Stichting Lamp, Zwolle 2008 (in Dutch)
8. Inada T, Uesugi F, Kawachi S, Inada K. The tracheal tube with a high-volume, low-pressure cuff at various airway inflation pressures. Eur J Anaesthesiolo. 1998;15:629-632

Chapter 8

Potential cervical spine injury in children: should we use the adult trauma protocols?

Bastiaan M. Gerritse[1] MD, Jos M. Th. Draaisma[2] MD, PhD

1. Department of Anaesthesiology, Amphia Hospital, Breda, The Netherlands.
2. Department of Paediatrics, Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands.

Intensive Care Capita Selecta. Utrecht, 2005

ABSTRACT:

Background: Cervical spine injury (CSI) in children is very rare, but may be catastrophic when present. As experience with CSI in children is often lacking, most health care providers will depend on scientific data and validated protocols for optimal treatment.

Methods: To examine all studies regarding CSI in children, with an emphasis on prevalence, examination, immobilisation and removal of immobilisation. Search strategy: The authors searched the Pubmed database with an extensive list of relevant search terms.

Results: No randomised controlled trials of spinal immobilisation strategies in children were found. Although adult trauma protocols are applied to children, validated studies are lacking. The type and location of an eventual CSI depends on the age and development of the child. The detrimental effects of spinal immobilisation on children are well documented, especially regarding the interaction with the anatomy of the airway and the physiology of the ventilation.

Conclusions: Adult immobilisation protocols should only be applied in children with special care; the necessity of immobilisation should be evaluated continuously. Local protocols should be developed to remove the spinal immobilisation of children as soon as possible.

INTRODUCTION

Cervical spine injury is very rare in children, but may be catastrophic when present. Cervical Spine Injury (CSI) occurs in 1,6% of all severe trauma in children.[1] As most providers of prehospital care will only rarely treat a child with a severe trauma, this implies that the experience with CSI in children will be even less. [2-4]

In general, trauma care is too often specified for adults and most protocols and technical aides are not optimised for children. We wondered what the state of the art scientific evidence is for immobilisation of the cervical spine in children.

For this reason we reviewed the literature to identify the current scientific knowledge on prevalence and prevention of CSI in children of all ages. This review includes the initial medical examination, need for immobilisation of the cervical spine in children and guidelines for the removal of the immobilisation devices. In this context, the possibly adverse effects of cervical spinal immobilisation in children will also be discussed.

METHODS

We searched MEDLINE using the search terms: spinal cord injury, immobilisation or mobility, stabilisation or collar, backboard or vacuum splint, strapping or spine board, infant (MeSH), child (MeSH), adolescent (MeSH), trauma. These search terms were based on a comparable search performed by Kwan et al.[5] In this review article, the authors tried to quantify the effect of different methods of spinal immobilisation on mortality, neurological disability, spinal stability and adverse effects in trauma patients. The database was searched from the onset of the database throughout January 2009.

All studies that had been retrieved were reviewed independently by both authors. To be eligible for inclusion in this review, a study had to meet the following criteria: it had to have studied the subject of cervical spine injury in patients or healthy volunteers under 18 years of age.

RESULTS

Seventy-two articles were identified as potentially relevant and thus retrieved.

Forty-seven articles were excluded. Seven of these 47 papers had only a relevancy on the subject of cervical spine injury in adults, 40 articles did not study cervical spine injury at all. Therefore, 25 articles were included. Four of these 25 articles were review articles. (all articles can be found as a reference in this article). None of these 25 articles was a randomised controlled study on either patients or healthy volunteers.

Prevalence

Analysis of 5 years of data collection of the National Paediatric Trauma Registry in the United States showed that CSI was diagnosed in 1,6% of all severe trauma in children.[1] CSI was defined as a blunt force trauma with at least one of the following injuries: cervical spine fracture, cervical spine dislocation or spinal cord injury without a fracture (also described as SCIWORA: spinal cord injury without radiographic abnormality).

The mean age of a child with CSI was 10.5 years, 59% of the children being male. Mortality of children with (also) a CSI varied from 7 to 30% (depending on age: less in older children), death was in 93% associated with concurring severe brain injury.[1] Remarkably, in 83% of the children with a cervical spine fracture, no neurological defects were diagnosed.

CSI in younger children (<10 year) occurred by a blunt trauma as occupant of a motor vehicle or a pedestrian in a collision. In older (>10 year) children CSI was more often caused by sports or a fall from height. [6,7,8]

Despite the devastating consequences of cervical spine injury in children after motor vehicle collisions, the factors leading to the injury and the appropriateness of protective restraints remain undefined. Zuckerbraun et al. hypothesized that age-related anatomic factors contribute to inadequate restraints and therefore increase injury severity after motor vehicle collisions. [8]

A high CSI (C1-C4) occurred more often in younger children, a CSI in the lower part of the spine (C5-C7) was more prevalent in older children.[1] There was also a difference in the type of injury. In younger children a displacement of the vertebrae or spinal cord injury without fracture was more common, versus cervical spine fracture in older children.[1] These differences can be due to the biomechanical and anatomical differences caused different development phases of growth. The head of younger children is proportionally larger, with a relative underdevelopment of the muscles of the neck. For this reason, younger children may be more susceptible to flexion-extension injury. Because of the relative higher weight of the head, the energy of the injury will be transferred to higher part of the cervical spine. This point of energy transfer is lower in adolescents: C5-C6. The cervical spine in the younger child has more anterior curvature, and the facet joint is in a more horizontal position. The interspinal ligaments, the cartilage and joint ligaments are more elastic, so less resistance to displacement is applied.[1]

All these factors subsequently facilitate injury of the spinal cord in an acceleration / deceleration trauma without damage or displacement of the bone structures in the neck.

Physical and radiological examination in children with CSI

The classical symptoms of CSI are localised pain by pressing, muscle spasm and impaired movement of the neck. Other presenting symptoms are paraesthesia and muscle weakness.[9] A characteristic symptom is a burning feeling in the palm of the hand: the cervical nerve plexus is damaged. Injury of the chin or jawbone should always remind the health care provider that kinetic energy could be transferred to the cervical spine. Injury of the spinal cord can cause apnoea or hypoventilation, but spinal shock can also cause hypotension and bradycardia.

When the spine has been immobilised in the field by a stiff-neck, this should be removed to obtain the optimum condition for physical examination of neck. Muscle tone, muscle strength, sensibility and reflexes should also be examined. It can be difficult to exclude CSI in children with a blunt force trauma; this is caused by differences in development and anatomy. Previous reports, all retrospective in nature, have not identified any cases of CSI in either children or adults in the absence of neck pain, neurologic symptoms, distracting injury or altered mental status.[10] X-rays of the cervical spine in children are difficult to use as a diagnostic tool. [11] This requires much experience, especially regarding the physiological maturation of bones, normal anatomic variables and pseudo-dislocations.

Hoffman et al. defined a simple decision instrument based on clinical criteria to identify patients in need of radiography of the cervical spine after blunt trauma.[12] These findings were confirmed in a prospective study in children with blunt force trauma where a full physical exam was performed before the radiological examination.[10] The presence or absence of the following factors was noted in the Hoffman criteria:

1. Midline cervical tenderness
2. Focal neurological deficit
3. Intoxication
4. Alertness
5. Presence of a distracting injury

A full radiological examination (X-cervical spine, CAT-scan and MRI) was performed subsequently. CSI was diagnosed in 30 out of 3065 children (1%): at least one of the above mentioned factors was found in each of these patients. None of the 603 patients without one of these five factors had any sign of CSI in the radiologic images. Only 4 out of the 30 patients with CSI in this study were under ten years of age. The author of this study noted the limitations of this study: a population of 80000 children with serious blunt force trauma would be needed to be statistically significant. Still, this is the largest prospective study on CSI in children. The Hoffman criteria are the diagnostic guidelines as noted in the management of paediatric cervical spine and spinal cord injuries by the congress of neurological surgeons. [13]

Sharma demonstrated in a review that assessment of the entire spinal column should be done in patients with a CSI. [14] A multi-detector row computed tomography of the cervical spine excludes the need for MR imaging, although the full spectrum of Chance-types injuries is only discernible with MR imaging. [15,16]

Immobilisation

Injury of the spinal cord can cause very serious and definite invalidity, with catastrophic consequences for the quality of life. Several strategies for spinal immobilisation can be applied to prevent further deterioration of the function of the spinal cord. The purpose of prehospital stabilisation of the cervical spine is to prevent any further movement of the vertebrae, and to prevent secondary injury during extrication, stabilisation and transport to the hospital. Immobilisation of the cervical spine is applied worldwide and recommended in several guidelines.[17,18] Despite the massive application of cervical spine immobilisation of all sort of devices, serious doubts have been cast regarding the positive effect in preventing any CSI by immobilisation. Probably, most damage to the spinal cord is inflicted during trauma and not afterwards.[19] The amount of force required to cause CSI is of a far greater magnitude than any force that could be applied by a medical provider. Most patients with blunt force trauma will not have CSI, so they do not benefit of spinal immobilisation. Still, five million persons are immobilised yearly in the United States.[5] A major review was published by request of the World Health Organisation Prehospital Trauma Care Steering committee on all scientific studies regarding immobilisation of the cervical spine in adults.[5] In a proper study different treatment modalities would be compared in a randomised fashion, with a standardised control group. However, of the 4453 studies found in the electronic search engines by Kwan et al., none stood up to these qualifications. Some studies were found that compared different immobilisation techniques in healthy volunteers. All published patient studies were done retrospectively.

Kwan stated in conclusion that there is absolutely no proof that the prehospital immobilisation of the cervical spine diminishes the incidence or severity of CSI in patients with blunt force trauma in any way. [5] Most immobilisation in the USA is performed in response to fear of litigation. Kwan also stated that in contrast to the absence of scientific evidence of the positive effect on preventing CSI injury in adults, cervical spine immobilisation has been proven to have detrimental side effects. Patients in cervical spine immobilisation are in more pain, and are more prone to get bedsores, increased intracranial pressure, pulmonary aspiration and respiratory failure.[20] Kwan also published a comprehensive review on the effects of prehospital spinal immobilization in randomized trials on healthy subjects. [21] This review supported the previous findings that spinal immobilization is associated with improved reduction of spinal mobility as well as adverse outcomes such as ventilator restriction, ischemic pain and discomfort in healthy volunteers. The hard spine boards are designed for extrication at trauma scenes, not for transportation or immobilization in emergency wards [22] Different devices are available for spinal immobilization, but none has given a proven reduction of morbidity or mortality in patients. [23,24]

Cervical spine stabilization manoeuvres limit the laryngeal view during laryngoscopy therefore airway management by endotracheal intubation could be more difficult. [25]

Finally, a recent retrospective study made a comparison between CSI prevention in Malaysia and the United States. Two similar hospitals were compared for c-spine injuries in trauma patients. All of the United States patients were transported to the emergency department with standard ATLS level spinal immobilization, none of the patients in Malaysia was immobilised. The researchers found less disability (even in the patients with fractures) in the non-immobilised patients than the immobilised patients.[26]

In children, the scientific basis for spinal immobilisation is even smaller. Immobilizing a child is an unique challenge for emergency medical services, and most equipment carried by EMS personnel is sized for adult use.[27] The Kendrick extrication device has been described as an ideal paediatric immobilization device as it is routinely used by EMS personnel and can easily be modified for children, but no patient data are available.[27,28] In an evaluation of the different techniques on healthy children was demonstrated that a rigid-type cervical collar should be used in combination of a supplemental device (Kendrick Extrication Device, half-spine board) to obtain optimal cervical spine stabilization.[29]

It is very difficult to obtain the proper anatomical position of the cervical spine while using an immobilisation device.[30] As the head has a logarithmic growth versus the linear growth of the chest, the ideal position of the head will change according to age.[31] If a younger child will be fixated on a spine board, the upper part of the cervical spine will be displaced forwards. The optimal position of the cervical spine has to be obtained by placing enhancement under the chest. In an article by Herzenberg describing 10 children under 7 years of age with CSI, none were properly positioned on the spine board.[31]Another study described that 71 out of 118 children in spinal immobilisation were not correctly positioned in spinal immobilisation, but fortunately no CSI was diagnosed.[32] Spinal immobilisation has a negative effect on the respiratory function in children, especially while breathing spontaneously. It appeared that the forced vital capacity of healthy volunteer children diminishes 41-90% while in spinal immobilisation.[33] A vacuum mattress-splint is associated with less pain than a standard backboard, but is comparable in quality of immobilisation.[34,35] Positioning of the patient on a spine board produces tissue-interface pressure high enough to result in the development of pressure necrosis.[36]

Removal of cervical spine immobilisation

Several medical disciplines are involved in advanced trauma care and their participation is necessary at all stages. A protocol, adjusted to local circumstances and support by all relevant medical disciplines, is required for the removal of the cervical spine immobilisation in the hospital. Medical disciplines that could be involved are orthopaedic surgeons, trauma surgeons, paediatricians, radiologists, anaesthesiologists, nurses of the emergency ward and emergency medical service. All have to participate to obtain a fast and unequivocal decision to remove the spinal immobilisation. A large reduction of the duration of spinal immobilisation can be obtained if all providers adhere to a well-planned protocol.[37,38] A modified adult protocol can offer guidance in managing the majority of older children with blunt trauma. [39]

An evidence-based imaging protocol to avoid unnecessary imaging studies and to minimize radiation exposure in children was proposed by Khanna.[40] The radiologic evaluation of suspected cervical spine injuries consists of three standard views: the AP, lateral and open-mouth-view. A single lateral view is not sufficient to clear the cervical spine in children, the sensitivity being only 85%. The open-mouth view can be a challenge to obtain in children, and is therefore not recommended. The positive yield of new trauma-induced findings on a CT-scan in younger children is low.[41] In a study of 606 patients under 5 years of age, Hernandez noted only four patients with significant injury on the CT-scan, but all four of these patients had positive radiologic evaluations as well. MRI is an effective imaging tool in all patients suspected of SCIWORA, but also in all unconscious paediatric trauma patients. MRI within 72 hours of admission has been shown to be cost effective, resulting in a significant decrease of hospitalization days and costs.[42]

CONCLUSION

Few scientific data can be found in medical literature that validates the application of cervical spine immobilisation in patients. Adult patients are immobilised on a large scale after blunt force trauma, without differentiation regarding physical complaints or trauma mechanism. Trauma protocols and techniques for adults are also used for emergency care in children, without any scientific validation. The type and location of injury of the cervical spine will depend on the age and developmental stage of the child. It is paramount to take a full history and physical examination, as these could give valuable information. There has to be a strict time management at the arrival of an immobilised child at the emergency ward; physical and radiological examination has to be performed as soon as possible. Any unnecessary delay in removal of the immobilisation devices can induce anxiety and can cause bodily harm.

REFERENCES

1. Kokoska E, Keller MS, Rallo MC, et al. Characteristics of pediatric spine injuries. Journal of Pediatric Surgery 2001;36:100-105
2. Richard J, Osmond MH, Nesbitt L, et al. Management and outcomes of pediatric patients transported by emergency medical services in a Canadian prehospital system. CJEM 2006;8(1):6-12
3. Brolin K, von Holst H. Cervical injuries in Sweden, a national survey of patient data from 1987 to 1999. Inj Control Saf Promot 2002;9(1):40-52
4. Lallier M, Bouchard S, St-Vil D, et al. M. Falls from heights among children: a retrospective review. J Pediatr Surg 1999;34(7):1060-1063
5. Kwan I, Bunn F, Roberts I. Spinal immobilisation for trauma patients. Cochrane database of Systematic Reviews 2001, issue 2
6. Cirak B, Ziegfeld S, Knight VM, et al. Spinal injuries in children. Journal of pediatric surgery 2004;39:607-612
7. Fashing G, Schippinger G, Pretscher R. Paragliding accidents in remote areas. Wilderness Environ Med 1997;8(3):129-133
8. Zuckerbraun BS, Morrison K, Gaines B, et al. Effect of age on cervical spine injuries in children after motor vehicle collisions: effectiveness of restraint devices. Journal of Pediatric Surgery.2004;39:483-486
9. Caviness AC. Evaluation of cervical spine injuries in children. UpToDate; 2003:12.1
10. Viccellio P, Simon H, Pressman BD, et al. A prospective multicenter study of cervical spine injury in children. Pediatrics 2001;108:1-6
11. Lustrin ES, Karakas SP, Ortiz AO, et al. Pediatric cervical spine: normal anatomy, variants, and trauma. Radiographics 2003;23:539-560
12. Hoffman JR, Mower WR, Wolfson AB, et al. Validity of a set of clinical criteria to rule out injury to the cervical spine in patients with blunt trauma. N Engl J Med 2000;343(2):94-99
13. Anonymous. Management of pediatric cervical spine and spinal cord injuries. Neurosurgery, 2002;50(3 suppl):S85-99
14. Sharma OP, Oswanski MF, Yazdi JS, et al. Assessment for additional spinal trauma in patients with cervical spine injury. Am Surg 2007;73(1):70-74
15. Hogan GJ, Mirvis SE, Shanmuganathan K, et al. Exclusion of instable cervical spine injury in obtunded patients with blunt trauma: is MR imaging needed when multi-detector row CT findings are normal? Radiology 2005;237(1):106-113
16. Groves CJ, Cassar-Pullicino VN, Tins BJ, et al. Chance-type flexion-distraction injuries in the thoracolumbar spine: MR imaging characteristics. Radiology 2005;236(2):601-608
17. Jewkes F, Lubas P, McCusker K. Pre-Hospital Paediatric Life Support, the Practical Approach,third ed., London: BMJ Books, 2002
18. Turner NM, Vught AJ. Advanced Paediatric Life Support, de Nederlandse editie. Maarssen: Elsevier Gezondheidszorg, 2004
19. Yoganandan N, Kumaresan S, Pintar F. Biomechanics of the cervical spine part 2. Cervical spine soft tissue responses and biomechanical modelling. Clinical biomechanics 2001;16:1-27
20. Totten VY, Sugerman DB. Respiratory effects of spinal immobilization. Prehospital Emergency Care 1999;4:347-352
21. Kwan I,Bunn F. Effects of prehospital spinal immobilization: a systematic review of randomized trials on healthy subjects. Prehosp Disaster Med 2005;20(1),47-53

22. Hauswald M, McNally T. Confusing extrication with immobilization: the inappropiate use of hard spine boards for interhospital transfers. Air Med J. 2000;19(4):126-127
23. Karbi OA, Caspari DA, Tator CH.Extrication, immobilization and radiologic investigation of patients with cervical spine injuries. CMAJ 1989;140(2):114-115
24. Krell JM, McCoy MS, Sparto PJ, et al. Comparison of the Ferno Scoop Stretcher with the long backboard for spinal immobilization. Prehosp Emerg Care 2006;10(1),46-51
25. Hastings RH, Wood PR. Head extension and laryngeal view during laryngoscopy with cervical spine stabilization maneuvers. Anesthesiology 1994;81(4):1081-1082
26. Hauswald M, Gracie O, Tandberg D,et al. Out-of-hospital spinal immobilization: Its effect on neurologic injury. AcadEmerg Med 1998;5:214-216
27. Markenson D, Foltin G, Tunik M, et al. The Kendrick extrication device used for pediatric spinal immobilization. Prehosp Emerg Care 19999;3(1):66-69
28. Howell JM, Burrow R, Dumontier C, et al. A practical radiographic comparison of short board technique and Kendrick Extrication Device. Ann Emerg Med 1989;18(9):943-946
29. Huerta C, Griffith R, Joyce SM. Cervical spine stabilization in pediatric patients: evaluation of current techniques. Ann Emerg Med 1987;16(10):1121-1126
30. Nypaver M, Treloar D. Neutral cervical spine positioning in children. Ann Emerg Med 1994;23(2):208-211
31. Herzenberg JE, Hensinger RN, Dedrick DK, et al. Emergency transport and positioning of young children who have an injury of the cervical spine. Journal of Bone Joint Surgery of America. 1989;71:15-22
32. Curran CBS, Dietrich AM, Bowman MJ, et al. Pediatric cervical-spine immobilization: achieving neutral postion? Journal of Trauma 1995; 39:729-732
33. Schafermeyer RW, Ribbeck RM, Gaskins J, et al. Respiratory effects of spinal immobilisation in children, Annals of Emergency Medicine 1991; 20:1017-1019
34. Chan D, Goldberg RM, Mason J, et al. Backboard versus mattress splint immobilization: a comparison of symptoms generated. J Emerg Med 1996 14(3): 293-298
35. Chan D, Goldberg R, Tascone A, et al. The effect of spinal immobilization on healthy volunteers. Ann Emerg Med 1994;23(1):48-51
36. Cordell WH, Hollingsworth JC, Olinger ML, et al. Pain and tissue-interface pressures during spine-board immobilization. Ann Emerg Med 1995;26(1):31-36
37. Lee SL, Sena, Greenholz, Fledderman M. A multidisciplinary approach to the development of a cervical spine clearance protocol: process, rationale, and initial results. Journal of Pediatric Surgery. 2003;38:358-362
38. McCarthy C, Oakley E. Management of suspected cervical spine injuries – the paediatric perspective. Accident and Emergency Nursing 2002;10:163-169
39. Browne GJ, Lam LT, Barker RA. The usefulness of a modified adult protocol for the clearance of paediatric cervical spine injury in the emergency department. Emerg Med 2003;15:133-142
40. Khanna G, El-Khoury GY. Imaging of cervical spine injuries of childhood. Skeletal Radiol 2007;36:477-494
41. Hernandez JA, Chupik C, Swischuk LE. Cervical spine trauma in children under 5 years: productivity of CT. Emerg Radiol 2004;10(4):176-178
42. Frank JB, Lim CK, Flynn JM, Dormans JP. The efficacy of magnetic resonance imaging in pediatric cervical spine clearance. Spine 2002;27(11):11760-1179

Chapter 9

Prehospital intraosseous access with the bone injection gun by a Helicopter Emergency Medical Service

Bastiaan M Gerritse MD[1], Jos MT Draaisma MD, PhD[2]

1. Department of Anaesthesiology, Amphia Hospital, Breda
2. Department of Paediatrics, Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands

Journal of Trauma 2009;66(6):1739-41

ABSTRACT

Background: To evaluate the use of the bone injection gun to obtain vascular access in the prehospital setting by a Helicopter Emergency Medical Service (HEMS).

Methods: Prospective descriptive study to assess the frequency and success rate of the use of the bone injection gun in prehospital care by a HEMS.

Results: In 40 of 780 (5.1%) patients an attempt was made to obtain intraosseous access with the bone injection gun. Intraosseous access was attempted more often in children than in adults. ($p< 0.01$) The success rate was 71% (10 out of 14) in children< 16 years and 73% (19 out of 26) in adults ($p=1.0$) There were no complications to the health care providers involved, and no unwanted sequels to the patients involved.

Conclusions: The bone injection gun is an effective and safe device for the resuscitation of patients in a prehospital setting. It seems to be equivalent in success rate as intra-osseous needles in children, but it appears to be more successful in adults.

INTRODUCTION

The use of the intraosseous infusion technique to obtain vascular access has been widely advocated in recent years. This procedure is endorsed by the American Heart Association and the European Resuscitation Council if intravenous access is difficult or impossible.[1,2]

Although normally considered as an alternative route for vascular access in children, it can also be effective in adults. Intraosseous injection of drugs achieves adequate plasma concentrations in a time comparable with injection through a central venous catheter.[1-3]

Many countries have started to use intraosseous infusion techniques in prehospital care as well as emergency department care. Although the technique of intraosseous infusion is well established in children, the use of the intraosseous infusion in adults is less well documented.

There are different intraosseous devices on the market. Manual needles in use are: Jamishidi (Cardinal Health, McGaw Park, IL), the standard hand-driven Sur-Fast needle, and the Dieckman modified needle (both by Cook Critical Care, Bloomington, IN).[4] Three mechanical intraosseous devices approved by the Food and Drug Administration: the FAST1 (Pyng Medical, Vancouver, British Colombia, Canada), the EZ-IO (Vidacare Corporation, San Antonio, TX) and the Bone Injection Gun (BIG; Waismed, Yokneam, Israel). The bone injection gun is a small automatic spring-loaded device with a trigger. After the removal of a safety catch, the needle is inserted through the cortex.[5,6]

There are, to our best knowledge, no published studies of a comparable patient group describing the prehospital use of the bone injection gun. The purpose of this study was to evaluate the success rate of the use of the Bone Injection Gun in prehospital care by a Helicopter Emergency Medical Service (HEMS).

MATERIALS AND METHODS

Settings

To facilitate prehospital medical interventions, a HEMS was introduced in 2001 in the eastern part of the Netherlands to provide optimal prehospital care. The HEMS covers an area of about 10088 square kilometres in the eastern part of the Netherlands and in the western part of Germany. Approximately 19.5% of this population is younger than 16 years of age. The HEMS consists of a doctor (anaesthesiologist or trauma-surgeon), nurse and a pilot. The HEMS-crew has received special education and training in prehospital paediatric and adult emergency care and is well experienced in the everyday clinical routines of the care of vitally compromised children and adults. The HEMS is activated either by the Emergency Medical Services (EMS)-dispatch centre or by the EMS-paramedics at the scene of the incident.

Training

The HEMS-crew was taught the intraosseous infusion technique by one trainer who was formally instructed by representatives from Waismed, Israel. A standardized technique was taught for the application of the device on the proximal tibia. The instruction included a 60 minutes didactic lecture, supported by educative material supplied by the manufacturer. Subsequently, a 30 minutes skill station with an individual examination was given, using a manikin supplied by the manufacturer.

Proper placement in a patient was assumed if bone marrow could be aspirated easily and fluid could be injected. Special attention was given to the safety aspects for the patients and the providers using a spring-loaded device.

Data collection

A prospective analysis of a standardized HEMS-form was performed of the patients who got an intraosseous infusion in the period from February 2006 till June 2007. These data include age, sex, type of incident, reason for the use of intraosseous infusion, success or failure, reason for failure and ease of use. Time to placement was not measured because of the variety of circumstances while treating the patient: the bone injection gun was applied in entrapped patients, during transport by ground ambulance or in flying helicopters.

As the bone injection gun is approved for use in prehospital care in the Netherlands, approval by a medical ethics committee was not required for this descriptive study. The use of the bone injection gun was supported by the local representative of the manufacturer by a 10% reduction on the retail price of the product. There was no interference of any kind by the representative or manufacturer on the study or the manuscript.

Statistical analysis

The data were analyzed with SPSS (version :12.0.1). For statistical analysis, the Fisher's exact test, with a significance threshold of $p \leq 0.05$ was used.

RESULTS

In this period the HEMS examined and treated 780 patients on scene. Of these patients, in 40 (5.1%) patients an attempt was made to obtain intraosseous access with the bone injection gun. The indication for the intraosseous infusion in these patients was the failure to get a peripheral venous access in 40 patients, 21 of these patients received cardiopulmonary resuscitation. Intraosseous access was attempted in 12% of all children<16 years (14 out of 117 children) and 4% of all adults (26 out of 663 adults) ($p<0.001$). Twelve patients were medical, 28 were trauma cases.

The success rate was 25% in children aged less than 1 year, 100% in children aged 1 to 2 years, 86% in children 3 to 9 years, and 74% in patients above 10 years. However, in three patients more attempts were needed. (Table 1).

Table 1. Patient age and intraosseous infusion line success rates

Patient age	0-11 months	1-2 years	3-9 years	≥10 years	total
No. Patients	4	2	7	27	40
No. Attempts	4	3	8	28	43
Success rate/patient (%)	25	100	86	74	73
Success rate/attempt (%)	25	67	88	96	67

The reasons of failure were entering the bone but not the marrow in eight patients and missing the bone altogether in one patient. In two patients, the failure occurred after successful initial insertion: in these two patients, the operator could not remove the trocar needle although the needle was not bend. Presumably, the cortex was not fully penetrated.

Safety concerns were stated by the health care providers involved at the introduction of a spring loaded device able to penetrate adult bones. However, there were no mishaps in the use of the device. Three complaints were made that the trigger fired too easily, the providers involved stated that the training device required more firing pressure than the bone injection gun used for patients. Overall, the device was described as (very) satisfactory in 80% of the cases.

All intraosseous needles were removed within 24 hours, 21 patients survived until hospital discharge. No unwanted sequelae as fractures, osteomyelitis, or extravasation of fluid were described in all the patients involved.

DISCUSSION

Over the past decades the intraosseous infusion technique has become a widely accepted procedure for the resuscitation of critically ill children and adults. However, until now, it is used infrequently compared to other advanced life support skills as well in hospital as out of hospital. Out of hospital, this is not only true for emergency medical technician or paramedic units, but also for HEMS.[7,8]

As the necessity for intraosseous access seems to be a rare event, the placement of an intraosseous line should be easy, fast, with a high success rate and without complications.

In 1993, Glaeser et al published a five-year experience in the prehospital use of intraosseous infusions (Jamshidi® needle by using the proximal tibia) in children and adults by emergency medical technician-paramedic units.[7] The success rate was 76% per patient and 70% per attempt. However the success rate was 77% in children aged 1 – 2 years, 70% in children aged 3 – 9 years and only 50% in patients above ten years. Overall success rates in our study are similar to Glaeser's. The bone injection gun seems more successful in adults than the Jamshidi needle described in Glaeser's study and may be less successful in infants than the Jamshidi needle. However, the number are too small to make a definite conclusion.

In 1997 Waisman and Waisman published their experience with a new device for intraosseous access: the bone injection gun.[5] The success rate for an adequate insertion was 100% in a group of seven patients requiring emergency resuscitation, three patients were resuscitated in the field.

A prospective cross-over study was conducted to compare the time to line placement and ease of insertion for both traditional (Jamshidi) and the bone injection gun by Spriggs e.a. [9]

EMT-P students and practicing paramedics provided information about their previous experience with intraosseous line placement. They were assigned to establish an intraosseous line in a paediatric leg mannequin using each technique and rated the ease of use of each method. This was confirmed in a study for the potential use of intraosseous devices in special circumstances with physicians wearing full protective gear (antichemical body suit, face mask and butyl gloves).[10] Even in this setting, the use of the bone injection gun was reported as rapid and easy. More recently, a best evidence report stated that the bone injection gun seems to be equivalent in terms of success and possibly faster to use than standard intraosseous needles.[11] A total of 129 papers were found in this report, of which three represented the best evidence to the clinical question which method of intraosseous access is the most successful. However, Curran e.a. stated that the differences in time to placement were unlikely to be clinically significant.

From our study, it may be concluded that the success rate of the bone injection gun is in the same range as that found in medical literature for the use of standard intraosseous needles, but may be more successful in adults than the Jamshidi needle. The use of a spring-loaded device able to penetrate bone causes concern regarding the safety of the providers and patients, but no accidents occurred in this study.

CONCLUSION

The bone injection gun is an effective and safe device for the resuscitation of patients in a prehospital setting. It seems to be equivalent in terms of success rate as standard intraosseous needles in both adults and children, except the children aged 0 month to 11 months. Further evaluation and comparison with other mechanical intraosseous devices is required.

REFERENCES

1. American Heart Association. 2005 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2005;112:IV58–66
2. Nolan JP, Deakin CD, Soar J, Böttiger BW, Smith G. European Resuscitation Guidelines for Resuscitation 2005. resuscitation 2005;67S1:S39-S86
3. Haas NA. Clinical review: vascular access for fluid infusion in children. Critical care 2004;8:478-484
4. Blumberg SM, Gorn M, Crain EF. Intraosseous infusion, a review of methods and novel devices. Ped Emerg Care 2008;24:1:50-59
5. Waisman M, Waisman D. Bone marrow infusion in adults. J Trauma 1997;42:288-293.
6. Calkins MD, Fitzgerald GF, Bentley TB, Burris D. Intraosseous infusion devices: a comparison for potential use in special operations. J Trauma 2000;48:1068-1074
7. Glaeser PW, Helmich TR, Szewczuga D, Losek JD, Smith DS. Five-year experience in prehospital intraosseous infusions in children and adults. Ann Emerg Med 1993;22:1119-1124
8. Helm M, Hauke J, Bippus N, Lampl L. Die intraossäre Punction in der präklinischen Notfallmedicin. Der Anaesthesist 2007;56:18-24
9. Spriggs NM, White LJ, Martin SW, Brawley D, Chambers RM. Comparison of two intraosseous infusion techniques in an EMT training program. Acad Emerg Med 2000;7:1168
10. Ben-Abraham R, Gur I, Vater Y, Weinbroum AA. Intraosseous emergency access by physicians wearing full protective gear. Acad Emrg Med 2003;10 (12):1407-10
11. Curran A, Sen A. Best evidence topic report. Bone injection gun placement of intraosseous needles. Emerg Med J. 2005 May;22(5):366.

Chapter 10

Prehospital sonography in the Netherlands by a Helicopter Emergency Medical Service

BM Gerritse[1], PJ Dirven[2], GJ Scheffer[3], JMT Draaisma[4]

1. Amphia Hospital Breda, Department of Anaesthesiology
2. Erasmus Medical Centre Rotterdam, Department of Anaesthesiology
3. Radboud University Nijmegen Medical Centre, Department of Anaesthesiology
4. Radboud University Nijmegen Medical Centre, Department of Paediatrics

Nederlands Tijdschrift voor Anesthesiologie 2010;22(2):17-21

ABSTRACT

Background: The introduction of a Helicopter Emergency Medical Service (HEMS) in the Netherlands improves the diagnostic possibilities for vitally compromised patients in the field. The article describes the use of prehospital sonography.

Methods: Description of two cases, and a review of relevant medical literature

Discussion: Imaging of heart, lungs and abdomen can support decision making for the provider of trauma care, especially regarding the ABC's in the primary survey. Special consideration should be given to the training of the personnel involved, and to the prevention of unnecessary time delay through the use of sonography.

Conclusion: Prehospital sonography can give important support in diagnosing under difficult circumstances.

INTRODUCTION

The Netherlands has had Helicopter Emergency Medical Team (HEMS) on standby since 1995. Their tasks and the expectations regarding their deployment are described in the government's 'Policy Vision on Emergency Care 2006-2010'.[1] A HEMS consists of a medical specialist (anaesthesiologist or surgeon-emergency physician), a nurse and a pilot. In close collaboration with the Emergency Medical Service (EMS) they provide specialist care before admission to a hospital. HEMSs are used mainly in accidents. Their main task is to quickly and efficiently perform medical interventions to stabilise vital functions that could otherwise not be done until the patient got to the clinic. Similar prehospital treatment systems have been in use for some time in many European countries.[2-6]

As a result of the introduction of HEMS-physicians with comprehensive training in critical care, there has also been an expansion of the diagnostic possibilities. An important diagnostic tool that was introduced into the field by the HEMS-Nijmegen in the Netherlands is prehospital sonography for vitally endangered patient. Walcher e.a. has demonstrated in Germany that prehospital sonography has a clear benefit in the treatment of intra-abdominal haemorrhage after trauma.[7] This is the first description of the application of prehospital sonography in the Netherlands.

CASE A

A young man, aged 15, is hit by a car doing an estimated speed of 65 km/hr when crossing a country road. In view of the nature of the incident report, the EMS dispatcher mobilises both an ambulance and a HEMS. When the HEMS arrives 12 minutes after the accident, the patient is found lying on the ground. To provide optimum treatment in the shortest possible time the Advanced Paediatric Life Support (APLS) guidelines are followed.[8] Primary survey: Airway: partially obstructed, halting breaths. Breathing: reduced breath sounds on the left, trachea in central position. Circulation: pulse 48/minute, systolic blood pressure 110 mm Hg, no major external blood loss, gray skin colour. Disability: unresponsive, both pupils slow to respond, middle position. Exposure: small cuts, abrasions head, subcutaneous haematoma / abrasions chest..

The ambulance crew has administered 15 litre/min O_2 via a non-rebreathing mask, there is intravenous access and the patient has been hooked up to a monitor. After preoxygenation the HEMS-physician administers a sedative and a muscle relaxant, when using a laryngoscope the vocal cords are easily seen. The endotracheal tube is positioned with the cuff closely below the vocal chords, the depth is 16 cm. Endotracheal intubation is confirmed by positive mainstream capnography, at auscultation less ventilation sounds are heard over the left lung. The patient is placed in the ambulance to be transported to the nearest trauma centre, a 19-minute drive away. When the patient is placed in the ambulance the O_2 saturation is only 81% with a volume control ventilator setting, frequency 14, 6 litres/minute and an inspiratory O_2 fraction of 1,0.

Parameters at this point: Airway: secure: endotracheal tube, depth 16 cm. Breathing: still reduced breath sounds on the left, good breath sounds on the right, trachea in central position. Percussion of the chest is not possible in a moving ambulance with siren. Circulation: pulse 98/minute, blood pressure 127/84 mm Hg. Disability: unresponsive, sedated. Exposure: cyanotic. At this point the most likely causes of the low O_2 are single lung ventilation through accidental intubation of the right bronchus, pneumothorax or a lung contusion. In the first case a direct laryngoscopy will have to be performed to pull back the breathing tube by sight, not an easy task in a moving ambulance. If there is a strong suspicion of a pneumothorax based on the physical examination, a thoracic puncture or thoracic drain has to be provided. This has been described as a high risk procedure outside of a hospital.[9] At this moment an ultrasound examination of the patient is performed in the ambulance with a mobile ultrasound machine (Sonosite®, Micromaxx, 4-8 MHz transducer). A pneumothorax is excluded of the left and the right lung, it is clearly observed that both lungs are ventilated. Ultrasound examination of the abdomen shows no lesions. This examination eliminates both a pneumothorax and an endobronchial intubation of the right lung. A pulmonary contusion of the left lung is the most likely diagnosis. Ten cm H_2O Positive End-Expiratory Pressure is added to the ventilator, the O_2 saturation improves. Upon arrival at the Accident and Emergency Department the diagnosis of pulmonary contusion is confirmed on the chest X-ray. Repeat sonography of the abdomen shows no lesions.

CASE B

A boy of 7 is hit by a car doing 55 km/hr when crossing the road in a residential area. When the EMS arrives they find a child with strongly diminished consciousness, the HEMS is subsequently alerted. Upon arrival of the HEMS 18 minutes after the accident, the child is immobilised on a back board. After the handover from the EMS the child is examined by the HEMS-physician using the guidelines of the APLS. Primary survey: Airway: clear, 15 litres O_2/min per non-rebreathing mask. Breathing: symmetrical breath sound. Circulation: pulse 110/min, blood pressure 90/65 mmHg. Disability: unresponsive, mid-size pupils on both sides, slow to respond. Exposure: various abrasions and skin cuts of the chest and abdomen. After being given an anaesthetic and a muscle relaxant the child is endotracheally intubated by the HEMS with a cuffed tube size 5,0. Upon intubation a hyper-mobile, possibly fractured mandible is noted. In consultation with the EMS will be decided which hospital is most appropriate for this child. The dilemma is either ground transportation in eleven minutes to the nearest community hospital, or helicopter transportation in twenty-two minutes to a trauma centre with paediatric intensive care and neurosurgery. This dilemma is frequently occurring, and error can have dire consequences for the patient. Despite the time that has already elapsed (it is now 34 minutes after the accident), and the chances of internal injuries, it is decided to take the child to the trauma centre. During the flight, in which the patient is fully monitored and ventilated, an ultrasound examination of the thorax and abdomen is performed. It is obvious that the lungs are being ventilated symmetrically and that the endotracheal tube is in a correct position. Ultrasound examination of the abdomen shows an absence of free fluid; an intra-abdominal haemorrhage is unlikely. Upon arrival at the trauma centre (56 minutes after the accident) a skull fracture, mandible fracture and cerebral contusion are diagnosed. If there had been any suspicion of intra-abdominal haemorrhage, the patient would have been transported to the community hospital, however regarding the neurotrauma the trauma centre would be more appropriate. Through the application of prehospital sonography, the transport conditions were fully optimised.

PREHOSPITAL SONOGRAPHY

As a result of the revolutionary developments in the electronic field, small, relatively cheap and portable sonography equipment has become available in recent years. This makes sonography possible in locations and conditions where it would have been unthinkable before. Through sonography can quickly be determined whether air or free fluid is present in the abdomen or pleural cavities. Being able to exclude a pneumothorax is particularly valuable when the physical examination cannot provide a definitive answer, or if the patient is in a location where it is impossible to obtain a chest X-ray.[10,11] Liechtenstein e.a. and Noble e.a. demonstrated that no pneumothorax will be present if two sonographic signs are observed. These signs are the gliding sign and the comet-tail sign. Sonography also makes it possible to determine the performance of the heart out-of-hospital. Sonography for the detection of the intra-abdominal free fluid can be performed out-of-hospital as it has been successfully provided by trained physicians in an Accident and Emergency Department.[12]

The study by Walcher e.a. also concluded that prehospital sonography for diagnosing intra-abdominal free fluid makes a useful contribution to the treatment of multi-traumas .[7] Two-hundred thirty patients treated by a HEMS were included in this study. The prehospital sonography and physical examination was compared to all imaging diagnostics in the hospital (sonography and CAT-scan). A complete follow-up was obtained in 202 patients. The sensitivity, specificity and accuracy were respectively 93%, 99% and 93% versus 93%, 52% and 57% for the prehospital physical examination. The prehospital sonography was performed 35 minutes (SD 13) earlier than the hospital sonography. The prehospital sonography caused a change of treatment in 30% of the patients, and influenced the choice of hospital in 22%.

Structured education is essential for the physicians involved, to enable successful evaluation of sonographic images. The study by Noble e.a. showed that after a brief training module, there was a considerable improvement in the ability to read sonographic images among physicians working in pre-admission care.[11] Quick sonography using a fixed process is not difficult to learn for non-radiologists / non-sonographers. After a 1-day training course, surgeons were able to perform the FAST (Focused Abdominal Sonography in Trauma) on children with blunt abdominal trauma with a high level of specificity; in this study sonography by non-radiologists / non-sonographers also proved to be a valuable aid in cases of blunt trauma.[13]

Internationally, the best-known training courses for sonography in trauma patients for non-radiologists / non-sonographers are the FAST and the PREP (Polytrauma Rapid Echo-evaluation Program). The FAST is a 1-day course that focuses completely on the sonographic examination of the abdomen. Over a period of 2 days the PREP provides, in addition to the abdomen, insight into sonographic imaging of the thorax and major blood vessels. By rigidly tracking 5 ultrasound windows (PREP 1-5, see figure 1), sonographic diagnoses can quickly be made. Both courses emphasise that the entire sonographic examination should not take more than 3 minutes. In this way the physician involved does not lose control of the care and treatment of the patient.

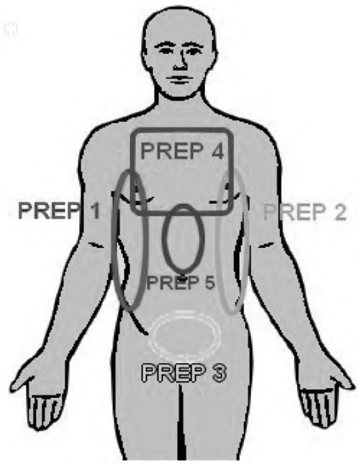

Figure 1 Ultrasound windows according to the 'Polytrauma Rapid Echo-Evaluation Program'
PREP 1: liver and right kidney
PREP 2: spleen and left kidney
PREP 3: uterus, bladder and cavum douglasi
PREP 4: heart and pericardium
PREP 5: abdominal aorta

Sonography is a regular item on the training of 95% of the emergency physicians in the United States.[14] In military conditions experience has also been gained with prehospital sonography by non-radiologists. Trained physicians demonstrated a high sensitivity and specificity when evaluating blunt abdominal trauma in the field.[15] It is also possible to perform a sonography in a flying helicopter if the competent authority has issued an airworthiness certificate for the sonography equipment in question. Auscultation is impossible in a flying helicopter, but in addition to the usual diagnostics the position of an endotracheal tube can be checked in part by visualising the lung movements.[16-18] Finally, the potential negative impact of prehospital sonography should be stated. Sonography can never replace anamnesis and physical examination of the trauma patient. Performing sonography can lead to loss of valuable time in the field, and can cause distraction of the physician from his main task: to get the patient in the best condition to the best suitable hospital. In a systematic review and meta-analysis by Stengel e.a. appeared that sonography had a high specificity but a low sensitivity in diagnosing free abdominal fluid.[19] Sonography of the abdomen in the Accident and Emergency Department will lead to a lower diagnostic rate of free fluid in the abdomen than a CAT-scan.[20] Due to the lack of large trials special care should be taken to introduce this technique in the Netherlands, with preference for a prospective trial by all four HEMS.

CONCLUSION

In conclusion, the introduction of prehospital sonography will not reduce the need to take a patient history and to perform physical examination in the prehospital treatment of vitally compromised patients. In these difficult circumstances, the physician can be supported by imaging technology. This support could be for decision making concerning medical interventions or logistical choices. In order to validate a reduction of morbidity or mortality through this technique in the prehospital care for vitally compromised patients, a full prospective trial by all four HEMS in the Netherlands is required.

REFERENCES

1. Acute zorg; brief minister met de Beleidsvisie traumazorg 2006-2010 Kamerstukken 2005-2006 29.247,37
2. Langhelle A, Lossius HM, Silfvast T, Björnsson HM, Lippert FK, Ersson A, et al. International EMS systems: the Nordic countries. Resuscitation. 2004;61:9-21.
3. Albert J, Phillips H. Trauma care systems in the United Kingdom. Injury. 2003;34:728-34
4. Masmejean EH, Faye A, Alnot JY, Mignon AF. Trauma care systems in France. Injury. 2003;34:669-73
5. Westhoff J, Hildebrand F, Grotz M, Richter M, Pape HC, Krettek C. Trauma care in Germany. Injury. 2003;34:674-83.
6. Nijs SJ, Broos PL. Trauma care systems in Belgium. Injury. 2003;34:652-7.
7. Turner NM, Vught AJ. Advanced Paediatric Life Support, de Nederlandse editie. Elsevier Gezondheidszorg Maarssen 2e druk 2006.
8. Perkins Z, Gunning M. Life-saving or life-threatening? Prehospital thoracostomy for thoracic trauma. Emerg Med J. 2007;24(4):305-306
9. Lichtenstein G, Meziere P, Biderman A, Gepner A. The comet-tail artifact: an ultrasound sign-ruling out pneumothorax Intensive Care Med (1999) 25: 383±388
10. Noble VE, Lamhaut L, Capp R, Bosson R, Liteplo A, Marx J,Carli P. Evaluation of a thoracic ultrasound training module for the detection of pneumothorax and pulmonary edema by pre-hospital physician care providers BMC Med Educ. 2009; 9: 3.
11. Connolly J. Brooks A. Davies B, Smethhurst M. Prospective evaluation of non-radiologist performed emergency abdominal ultrasound for haemoperitoneum. Emerg Med J. 2004 Sep;21(5):e5.
12. Walcher F, Weinlich M, Conrad G2, Schweigkofler U, Breitkreutzs R , Kirschnings T, Marzi1 L. Prehospital ultrasound imaging improves management of abdominal trauma. British Journal of Surgery 2006; 93: 238–242
13. Soundappan SVS, Holland AJA, Cass DT, Lam A. Diagnostic accuracy of surgeon-performed focused abdominal sonography (FAST) in blunt paediatric trauma. Injury. 2005 Aug;36(8):970-5
14. Counselman FL, Sanders A, Slovis CM, Danzl D, Binder LS, Perina DG. The status of bedside ultrasonography training in emergency medicine residency programs. Acad Emerg Med. 2003 Jan;10(1):37-42
15. Brooks A, Davies B, Connolly J. Prospective evaluation of handheld ultrasound in the diagnosis of blunt abdominal trauma. J R Army Med Corps. 2002 Mar;148(1):19-21.
16. Melanson SW, McCarthy J, Stromski CJ, Kostenbader J, Heller M. Aeromedical trauma sonography by flight crews with a miniature ultrasound unit. Prehosp Emerg Care. 2001 Oct-Dec;5(4):399-402
17. Price DD, Wilson SR, Murphy TG. Trauma ultrasound feasibility during helicopter transport. Air Med J. 2000 Oct-Dec;19(4):144-6
18. Ward DI. Prehospital point-of-care ultrasound use by the military. Emergency Medicine Australasia (2007) 19, 282
19. Stengel D, Bauwens K, Sehouli J, Porzolt F, Rademacher G, Mutze S, Ekkernkamp A. Systematic review and meta-analysis of emergency ultrasonography for blunt abdominal trauma. Br J Surg 2001;88:901-12
20. Miller MT, Pasquale MD, Bromberg WJ, Wasser TE, Cox J. Not so Fast. J Trauma 2003;54:52-60

Chapter 11

Evaluation by an expert panel of the prehospital care of critically ill children provided by a Helicopter Emergency Medical Service

Bastiaan M Gerritse MD[1],
Rob Malschaert MSc[2],
Gert Jan Scheffer MD, PhD[3],
Gert Jan van der Wilt PhD[2],
Jos M.Th Draaisma MD, PhD[4]

1. Department of Anaesthesiology, Amphia Hospital, Breda, the Netherlands
2. Department of Biomedical Sciences, Radboud University Nijmegen Medical Centre, the Netherlands
3. Department of Anaesthesiology, Radboud University Nijmegen Medical Centre, the Netherlands
4. Department of Paediatrics, Radboud University Nijmegen Medical Centre, the Netherlands

ABSTRACT

Objective: To evaluate the necessity and performance of prehospital care of critically ill children by a Helicopter Emergency Medical Service.

Methods: The RAND/UCLA Appropriateness Method was used to evaluate a random sample of 20 patients from a consecutive sample of paediatric patients who were treated by a HEMS between January 2001 and September 2005. The evaluation was performed by a panel of nine experts in prehospital emergency care in children.

Results: In almost a quarter of the items the expert-panel did not give a rating concerning the APLS-guidelines, because they believed they were not applicable to the case. No inappropriate procedures or decisions were noted by the expert panel. The HEMS performs very good in triage (85-95%) and diagnosing (100%). The appropriateness of the actual HEMS dispatch is uncertain in seven (35%) patients.

Conclusion: The results from this study suggest that HEMS has a useful role in the prehospital care for vitally compromised children, but raises questions on dispatch criteria for calling the HEMS.

INTRODUCTION

The Helicopter Emergency Medical Service (HEMS) as established in the Netherlands is extensively trained to provide specialized care on scene, to triage and transport the patient to a trauma centre in optimal conditions.[1-4] The rationale of HEMS is that a short delay between the onset of the compromising event and start of the emergency treatment will result in a better prognosis of the patient.[5] HEMS was instituted on the presumption that emergency medical care by a paramedic staffed ambulance may not be sufficient in vitally compromised children, as ambulance paramedics have less experience in advanced paediatric life support skills and triage. The HEMS is activated either by the Emergency Medical System-dispatch centre (primary call) or by the Emergency Medical System-paramedic at the incident location (secondary call). Activation of the HEMS is according to a list of injury mechanisms or suspected morbidity. The HEMS can be cancelled before arrival if the vital signs of the patient are stable or if the patient has deceased, in all cases in this study the EMS-paramedics arrived first at the incident location.

In some countries, prehospital care consists only of basic medical procedures with swift transportation to a trauma centre.[6-9] These basic medical procedures consist of interventions such as oxygen administration , venous access, wound dressing, immobilization, fracture splinting, and cardiopulmonary resuscitation. With the introduction of the HEMS-physician in the Netherlands in 1996, advanced medical procedures were introduced in the field. The HEMS use the international accepted guidelines as educated and trained in the Advanced Paediatric Life Support (APLS) course. In 2000 the European Resuscitation Council adopted the Advanced Paediatric Life Support course (originating in the UK and now available in a number of countries) as its course for providers caring for children. The APLS consists of all basic medical procedures and extensive medical invasive procedures for the child with a serious trauma or serious illness. The rationale behind the APLS is that it reduces the physiological and hemodynamic deterioration, thus stabilizing the patient before transport to the hospital.[10] The APLS course does have an important effect on perceived self-efficacy.[11] It is expected that this results in increased chances of survival and better outcome of the patient. The paradox is, that APLS could increase the time spent on scene and thus delay in-hospital care.[8]

The purpose of this study is to evaluate if a group of experienced HEMS-physicians, all APLS providers, perform medical procedures in the field according to the APLS guidelines. Also studied are the triage of the patients, and the necessity of the HEMS dispatch in hindsight.

METHODS

A modified Delphi technique, the RAND/UCLA Appropriateness Method (RAM), was used in this study. The RAM is only one of several methods that have been developed to identify the collective opinion of experts.[12] Although it is often viewed as a consensus method, the actual objective is to detect when the experts agree. It is based on the Delphi method which was developed in the 1950s as a tool to predict the future, in application to political-military, technological and economic topics.[13,14] According to the RAM guidelines an expert panel was recruited consisting of nine members. The experts were all practicing in large teaching hospitals in the field of (pre)hospital paediatric trauma care. The medical specialties were paediatrics, paediatric intensive care medicine, anaesthesiology and paediatric surgery. All experts involved were experienced APLS instructors, seven out of nine experts were not related to the specific HEMS operation studied.

A random sample of 20 patients was drawn from 550 consecutive patients treated between 1-1-2001 and 1-9-2006. All patients were aged below 16 on the day of the HEMS dispatch. A case-report file was constructed for every case, containing all available prehospital data (including mechanism of injury, Revised Trauma Score, Glasgow Coma Scale, Oxygen Saturation, heart rate, blood pressure, treatment and medication), data from the Emergency Department, HEMS report, intensive care or ward charts, discharge letter, laboratory and radiology reports.

Questionnaire

A questionnaire was developed with eleven questions concerning: the APLS-guidelines (Airway, Breathing, Circulation and Disability), choice of hospital, choice of transportation method (ambulance without HEMS-physician / ambulance with HEMS-physician / Helicopter with HEMS-physician), justification of time-delay caused by arrival and actions executed by the HEMS, diagnose, eventual injury caused by HEMS, and necessity/appropriateness of the HEMS dispatch. The questions were scored on a 9-point Likert scale. There were two options when a question was unanswerable: 'not of application', or 'not to assess'. There was room for remarks on each questionnaire. The questionnaire and case-files were sent to the experts by email, but each individual expert was free to choose between a electronic or paper & pencil completion of the questionnaires.

Analysis

The mean 9-point Likert scale of the expert panel was interpreted as followed: scores ranging from 1-3: *inappropriate*, 4-6: *uncertain*, 7-9: *appropriate*. The level of agreement among the panel was calculated using the RAND Disagreement Index (DI).[14]

The DI is based on the distribution of the scores on the 9-point scale and it is calculated by using the interpercentile range (IPR) and the interpercentile range adjusted for symmetry (IPRAS). The IPR is a well known measure of the dispersion in a distribution. In this study, it is defined as the difference between the 25^{th} en 75^{th} percentile scores for a scale. The IPRAS is calculated with this equation:

$$IPRAS = IPRr + (AI * CFA)$$

IPRr is the interpercentile range required for disagreement when perfect symmetry exists, and this is set at a constant of 2.35, which is determined by original RAND Corporation validation studies. The AI is the 'Asymmetry Index' and it represents the distance between the central point of the IPR and the central point of the 9-point scale: 5. The CFA is the Correction Factor for Asymmetry, which is a constant set at 1.5. When the IPR and IPRAS are known, the RAND Corporation DI is calculated by using this equation:

$$DI = IPR / IPRAS$$

DI > 1.0 indicates a high variation among the ratings. However, a DI ≤ 1.0 indicates no significant variation. The lower the DI, the higher the level of agreement.[14]

Only those questions with a DI ≤ 1.0 were regarded as meaningful opinions.

RESULTS

Study population

The mean age of the twenty patients selected was 9 years at the time of the event, the gender was distributed equally. The mean Glasgow Coma Scale was 9.5 upon arrival of the HEMS, 90% of the patients were endotracheal intubated in the field by the HEMS-physician.

For transportation, the helicopter was used in half of the cases. In five cases because of the condition of the patient, and in four cases because of the distance to the trauma centre. In one case, the helicopter was used to transfer a patient from a level 2 hospital to a level 1 trauma centre. In all the other cases, the ambulance was used as the transportation mode. In seven cases with the HEMS doctor, and in three cases without the HEMS doctor.

Questionnaires

All nine members of the expert panel completed and returned the questionnaires. In less than 1%, the expert-panel was unable to assess the items concerning APLS-guidelines. In 22% of the cases, the expert-panel members did not rate an item because in their opinion the item was not applicable in the corresponding case. The other items on the questionnaire all had less than 1% missing items. (Table 1) There was a high variation among the ratings in only 11 of the 220 (5%) opinions. Four of these were in the same patient; a four your old girl with a severe neurotrauma after being hit by a car initially brought by ambulance to a district hospital. The HEMS was called for transportation to a level 3 hospital for eventual neurosurgical intervention.

Table 1. Missing ratings

	Not applicable	Not to assess
	n (%)	**n (%)**
Airway	54 (30)	1 (0.6)
Breathing	43 (24)	3 (1.7)
Circulation	23 (13)	1 (0.6)
Disability	38 (21)	1 (0.6)
Total APLS	158 (22)	6 (0.8)

Table 2. Appropriateness of application of APLS-guidelines, Triage (choice hospital, choice transportation mode), Time-delay caused, Diagnose, Injury caused by HEMS, and Dispatch of HEMS necessary. A = appropriate, U = uncertain, I = Inappropriate, NA = not applicable/ not to assess (≥ 5 experts), X = high variation among expert panel (DI > 1.0)

	APLS-guidelines				Diagnosing		Triage		Time	Injury	Dispatch
	Airway	Breathing	Circulation	Neurology	Diagnose	According	Hospital	Transportation	Time-delay	Damage	Dispatch
1	NA	NA	A	NA	A	A	A	A	A	A	A
2	A	A	A	A	A	A	A	A	A	A	A
3	NA	A	X	U	A	A	A	A	X	X	X
4	NA	U	A	NA	A	A	A	A	A	A	A
5	A	A	A	A	A	A	A	A	A	A	A
6	A	A	A	A	A	A	A	A	A	X	A
7	U	U	NA	NA	A	A	A	U	U	A	U
8	A	A	A	A	A	A	A	A	A	A	A
9	U	NA	A	A	A	A	A	A	A	A	A
10	NA	NA	NA	NA	A	X	X	A	U	A	U
11	NA	NA	U	NA	A	A	U	A	U	A	U
12	A	A	A	A	A	A	A	A	A	A	A
13	A	A	U	A	A	A	A	A	X	A	A
14	A	A	A	A	A	A	A	A	A	A	A
15	NA	NA	U	NA	A	X	U	A	X	A	X
16	U	U	U	U	A	A	A	A	A	A	U
17	A	A	A	A	A	A	A	A	A	A	A
18	A	A	A	A	A	A	A	A	A	A	A
19	A	A	A	A	A	A	A	A	A	A	A
20	U	U	U	U	A	A	X	A	A	A	U

Opinion of the expert panel

APLS guidelines

None of the APLS guidelines were applicable in one case (5%) according to the expert panel.

The expert panel disagreed highly (DI > 1) on 12 items out of the total of 220 items. In nine cases (45%), the treatment of all four systems (Airway, Breathing, Circulation, Neurology) was rated as *appropriate* by the expert-panel. In two cases (10%), the expert-panel was uncertain on the treatment of the four systems. There were no inappropriate treatment according to the panel.

Diagnosing

The HEMS was successful in diagnosing all relevant diagnoses in all cases, and acted appropriately in 90% of the cases according to the expert-panel. There was no panel agreement in the other 10% of the cases.

Triage

According to the expert-panel, triage of the vitally compromised child was carried out very well by the HEMS. In two patients there was no panel agreement (DI > 1) on the choice of hospital level, and in two patients the panel was uncertain about the choice of hospital level..

In only one case (5%) the panel was uncertain about the transportation-mode. In all other cases, the panel rated the choice of hospital and the transportation-mode as appropriate.

Time-delay

In three cases (15%) there was no panel agreement (DI > 1) and in three cases (15%) the expert-panel was *uncertain* if the time-delay was caused by dispatching the HEMS and/or the procedures carried out by the HEMS was useful. In all other cases, the expert-panel agreed that the time-delay was worth the waiting.

Injury

In 90% of the cases, the HEMS caused no further harm. In two cases, there was no panel agreement. One of these cases was the reason for a prospective study, published as: 'Prehospital tracheal tube cuff pressure: an important risk factor for iatrogenic tracheal stenosis'. This case, number six, underwent an uneventful endotracheal intubation in the field with an appropriate size endotracheal tube. On detubation twelve days after the incident, an inspiratory stridor developed that eventually led to a tracheal stenosis.[15]

Dispatch

In two cases there was no panel agreement (DI > 1). In five cases (25%), the panel was uncertain if the HEMS dispatch was necessary. Case three was a secondary transfer of a four- year old girl with severe brain jury to a hospital with neurosurgical facilities, a case beyond the actual daily task of the HEMS in the Netherlands.

DISCUSSION

In less than 1% of the cases, the expert-panel was unable to judge the items concerning APLS-guidelines on the questionnaire using the case-report-forms, meaning the case-report-forms contained enough information for the experts to judge the cases. In almost half of the cases, the expert-panel rated the treatment of all four systems as appropriate according to the APLS-guidelines. The expert panel rated all of these cases as: *useful HEMS dispatch* with *an appropriate time-delay caused by arrival and procedures undertaken by the HEMS* as well. So in almost half of the cases (45%) according to the expert panel, the HEMS provided appropriate additional care a normal ambulance paramedic could not provide, and the time-delay which was caused by arrival of the HEMS, and undertaking advanced life procedures, was justified.

However, in almost a quarter of the items (23%; table3) the expert-panel did not give a rating concerning the APLS-guidelines because they believed they were not applicable to the case. Bearing in mind that the HEMS is there to provide APLS procedures in addition to basic procedures provided by ambulance paramedics, this could mean that the HEMS is dispatched too often. This is supported by the fact that in five cases (25%), the expert-panel was uncertain, and in two cases disagreed, whether the HEMS dispatch was useful.

The HEMS seems to perform well at triage of the vitally compromised child. In 80% of the study sample the choice for the level of hospital, and in 95% the transportation-mode was appropriate according to the expert panel.

The diagnostic qualities of the HEMS outperform the triage capabilities with 100% appropriate (relevant) diagnosing and 90% appropriate acting according the diagnose made. Remarkably, there were no inappropriate items in this study.

CONCLUSION

The results from this study suggest that HEMS has a useful role in the prehospital care for vitally compromised children, but raises questions on dispatch criteria used and the application of guidelines in the field.

REFERENCES

1. Burton J, Baumann M, Maoz T, Bradshaw J, Lebrun J. Endotracheal intubation in a rural EMS state: procedure utilization and impact of skills maintenance guidelines. Prehosp Emerg Care 2003; 7(3);p 352-356
2. Einav S, Donchin Y, Weissman C, Drenger B. Anesthesiologists on ambulances: where do we stand? Curr Opin Anaesthesiol 2003; 16;p585-591
3. Lossius H, Søreide E, Hotvedt R, Hapnes S, Eielsen O, Førde O, Steen P. Prehospital advanced life support provided by specially trained physicians: is there a benefit in terms of life years gained? Acta Anaesthesiol Scand 2002; 46;p771-778
4. Thomas SH, Biddinger PD. Helicopter trauma transport: an overview of recent outcomes and triage literature. Curr Opin Anaesthesiol 2003; 16:153-158
5. Lerner EB, Moscati RM. The Golden hour. Scientific fact or "Urban legend"? Acad Emerg Med, 2001; 8: 758-760
6. Gold, CR. Prehospital advanced life support vs. Scoop and Run in trauma management. Annals of Emergency Medicine 16.7 (1987): 797-801.
7. Krausz MM, Bar-Ziv M, Rabinovici R, Gross D. Scoop and run or stabilize hemorrhagic shock with normal saline or small-volume hypertonic saline? Journal of Trauma 33.1 (1992): 6-10.
8. Liberman M, Mulder D, Lavoie A, Denis R, Sampalis J. Multicenter Canadian Study of Prehospital Trauma Care. Annals of Surgery 237.2 (2003): 153-160.
9. Potter D, Goldstein G, Fung SC. A controlled trial of prehospital advanced life support in trauma. Annals of Emergency Medicine 17 (1998): 582-588.
10. Phillips BM, Mackway-Jones K, Jewkes F.The European Resuscitation Council's Paediatric Life Support Course 'Advanced Paediatric Life Support' Resuscitation; 2000;3(47),329-334
11. Turner NM, Dierselhuis MP, Draaisma JMTh, Cate ten OTJ, The effect of the Advanced Paediatric Life Support course on perceived self-efficacy and use of resuscitation skills Resuscitation,2007,3, 430-436
12. Fink A. Kosecoff J, Chassin M, Brook RH. Consensus methods: characteristics and guidelines for use. American Journal of Public Health; 1984:74; 979-998
13. Linstone HA, Turoff M. The Delphi method: techniques and applications. Reading Massachusetts: Addison-Wesley 1975
14. Fitch K, Bernstein SJ, Aguillar MS, Burnand B, LaCalle JR, Lazoro P, Loo M van het, McDonnell J, Vader J, Kahan JP. The RAND/UCLA Appropriateness Method User's manual. RAND Corp Santa Monica CA 2001
15. Gerritse BM, Draaisma JMT, Besselink-Lobanova A, Pelzer BJ, Marres HA, Scheffer GJ. Prehospital tracheal tube cuff pressure: an important risk factor for iatrogenic tracheal stenosis. Resuscitation 2009;80(8):962

Chapter 12

Long-term Health-related Quality of Life in children managed by a Helicopter Emergency Medical Service for vitally compromising conditions

Bastiaan M Gerritse MD[1],
Rob Malschaert MSc[2],
Gert Jan Scheffer MD, PhD[3],
Gert Jan van der Wilt PhD[2],
Jos M.Th Draaisma MD, PhD[4]

1. Department of Anaesthesiology, Amphia Hospital, Breda, the Netherlands
2. Department of Epidemiology, Biostatistics and Health Technology Assessment, Radboud University Nijmegen Medical Centre, the Netherlands
3. Department of Anaesthesiology, Radboud University Nijmegen Medical Centre, the Netherlands
4. Department of Paediatrics, Radboud University Nijmegen Medical Centre, the Netherlands

ABSTRACT

Objective: Long-term outcome is rarely an endpoint in evaluating paediatric pre-hospital care. The aim of this study was to assess the long-term outcome of vitally compromised children who were treated by a Helicopter Emergency Medical Service (HEMS). Outcomes were compared with norm data from peers matched for age- and sex.

Methods: All surviving paediatric patients who were treated by the local HEMS and who received care at the Paediatric Intensive Care Unit in the period between January 2001 and September 2006 were included in this study. The Child Health Questionnaire Parental Form – 50 (CHQ-PF50) was sent to the parents of the survivors. Results were compared with published norms for healthy Dutch schoolchildren, published data of children with traumatic brain injury and published data of children with a chronic disease.

Results: The CHQ-PF50 was sent out to the parents of 82 children. Of these, 55 were completed and returned (response-rate: 65%). The study population scored significantly lower on the mean physical summary score (48.2, SD vs. 56.4, SD; $p < 0,005$) and mean psychosocial summary score (48.5 SD, vs. 53.2 SD; $p < 0.005$) compared with their peers from the open population. The mean physical and psychosocial summary scores of children in our study population were comparable with those from children with chronic diseases such as asthma and epilepsy.

Conclusion: At 2-5years follow up, the quality of the lives of children who were treated by a HEMS for vitally compromising conditions does not match the quality of the lives of their peers from the open population. It is comparable to those with chronic conditions such as asthma and epilepsy.

INTRODUCTION

In vitally compromised children, routine emergency medical care by a paramedic staffed ambulance may not be sufficient to optimize survival and long-term outcome. Ambulance paramedics have less experience in triage and advanced paediatric life support than a Helicopter Emergency Medical Service (HEMS). The HEMS is extensively trained to provide specialized care on scene and to transport the patient to a trauma centre in optimal conditions.[1-4] The rationale of HEMS is that a short delay between the onset of the compromising event and start of the emergency treatment will result in a better prognosis of the patient.[5]

The focus of most of the research in this field concerns the performance of various triage systems and modes of pre-hospital care.[6-16] These studies use endpoints as mortality, length of hospitalization, and length of Intensive Care Unit admission. Long-term outcome is rarely used as an endpoint in evaluating paediatric pre-hospital care, except for management of children with traumatic brain injury, where the Glasgow Outcome Score is often used.[17-19]

However, although there is little doubt that HEMS can improve the survival of vitally compromised children, the importance of its impact on the long-term, health-related quality of life of these children is increasingly recognized: are these children being rescued at the price of long-term, sometimes serious disability?

The objectives of our study are to describe the long-term HRQOL of vitally compromised paediatric patients who received pre-hospital care provided by HEMS and who were admitted to a Paediatric Intensive Care Unit. The long-term HRQOL of these patients was compared with norm data of children from the open population and children with traumatic brain injury, isolated orthopaedic injuries, or a chronic disease.

PATIENTS AND METHODS

Study population

The study population consisted of a cohort of children younger than 16 years of age who received pre-hospital care by the HEMS-Netherlands-East and were subsequently admitted to the Paediatric Intensive Care Unit of the Radboud University Nijmegen Medical Centre in the period between January 2001 and September 2006. The HEMS-Netherlands-East covers an area of about 10.088 square kilometres area , with a population of 4.5 million inhabitants. Approximately 19.5% of the Dutch population in this area is younger than 16 years of age. Critically ill or injured paediatric patients are resuscitated in the field and transported by the HEMS. The HEMS consists of a physician, a nurse and a pilot who received special education and training in out-of-hospital paediatric and adult emergency care. The HEMS is activated either by the Emergency Medical Services (EMS)-dispatch centre (primary dispatch) or by the EMS-paramedics at the scene of the incident (secondary dispatch). A criteria list of injury mechanisms or suspected morbidity is used for activation of the HEMS. (Table 1)

Table 1. Specific dispatch criteria for HEMS dispatch, as approved by the Dutch ministry of Health [20]

Criteria based on circumstances surrounding or nature of the incident
High energetic motor-vehicle accident
Frontal collision on hardened roads outside urban area
Train- or airplane accident
Fall from height, >6 meters
Vehicle extrication situation
Overwhelming with debris, including head and/or chest
Electricity or lightening accident
(Near)drowning
Multiple victim incident (>4)
Accident with >1 victim, 1 of which died
Ejected from vehicle/motorbike
Explosion
Exposure to hazardous materials
Fire in confined space (i.e. inhalation trauma)
Severe burns, >15% body surface, or >10% body surface combined with other injuries
Diving accident
Pedestrian collision, >30 km/h or thrown for a distance
Criteria based on vital parameters of patient
Respiratory rate <10 or >30/ minute (adult)
Thoracic injuries with an O2 saturation <96%, despite O2 administration
Shock: systolic blood pressure <95 mm Hg, or pulse >120 beats/minute (adult)
RTS<11
Estimated blood loss of >1 litre
Loss of consciousness, GCS < 9
Signs of paralysis or paresthesia
Penetrating trauma to cranium, thorax or abdomen
Fractured femur, pelvis or spine
All open fractures to extremities

The study population was identified using the HEMS dispatch database. This database contains general information and incident characteristics of the child including the Revised Trauma Score, the Glasgow Coma Scale, endotracheal intubation and time of follow-up (Table 2). The Revised Trauma Score is a physiological scoring system, with high inter-rater reliability and high predictive value for survival. It is based on the first set of data obtained from the patient, and consists of the Glasgow Coma Scale, Systolic Blood Pressure and Respiratory Rate. [21] The Glasgow Coma Scale is a measure of coma and impaired consciousness.[22] To provide an overall severity score for the children with multiple injuries, the Injury Severity Score (ISS) was computed.[23]

The hospital information system was used to check which patients were discharged alive. The General Practitioner of each child meeting our inclusion criteria was asked to return a written statement whether the patient was still alive. General Practitioners who did not respond were contacted by telephone. Parents of the surviving children were sent the Dutch version of the Child Health Questionnaire-Parent Form 50. After three weeks, parents were sent a reminder. Approval for the conduct of the study was obtained from the ethical review board of the Radboud University Nijmegen Medical Centre.

Table 2: The Child Health Questionnaire PF-50, adapted from CHQ users manual[24]
[a] Multi-item scales containing a single item scale as well; [b] single item scales.

Scale	Low score	High Score
Physical Functioning	Child is limited in performing all physical activities, including self-care due to health	Child performs all types of physical activities, without limitations due to health
Role/Social-Emotional	Child is limited a lot in school work or activities with friends as a result of emotional or behavioural problems	Child has no limitations in school work or activities with friends as a result of emotional or behavioural problems
Role/Social-Physical	Child is limited a lot in school work or activities with friends as a result of physical health	Child has no limitations in school work or activities with friends as a result of physical health
Bodily Pain/Discomfort	Child has extremely severe, frequent, and limiting bodily pain	Child has no pain or limitations due to pain
Behaviour [a]	Child very often exhibits aggressive, immature, delinquent behaviour	Child never exhibits aggressive, immature, delinquent behaviour
Mental Health	Child always feels anxious and depressed	Child always feels happy and calm
Self-esteem	Child is very dissatisfied with abilities, looks, relationships, and life overall	Child is very satisfied with abilities, looks, relationships, and life overall
General Health [a]	Parent believes child's health is poor and likely to get worse	Parent believes child's health is excellent and will continue to be so
Parent Impact-Emotional	Parent experiences much emotional worry/ concern as a result of child's physical or psychosocial health	Parent doesn't experience emotional worry/ concern as a result of child's physical or psychosocial health
Parent Impact-Time	Parent experiences many limitations in time available for personal needs due to child's physical or psychosocial health	Parent doesn't experience limitations in time available for personal needs due to child's physical or psychosocial health
Family Activities	Child's health often limits/interrupts family activities or is a source of tension	Child's health never limits/interrupts family activities nor is a source of tension
Family Cohesion [b]	Family often has difficulty getting along	Family never has difficulty getting along
Change in Health [b]	Compared with 1 year ago, child's health is much worse now	Compared with 1 year ago, child's health is much better now

Study design

This study is a retrospective cohort study.

Questionnaire

The Child Health Questionnaire™ (CHQ) is a family of generic quality of life instruments that have been designed and used as a norm for children 5-to-18 years of age. The CHQ measures 14 unique physical and psychosocial concepts. The CHQ has been extensively translated using rigorous international guidelines. The CHQ assesses a child's physical, emotional, and social well-being from the perspective of a parent or guardian (Table 2).[24-26] In this study, the caregiver version (CHQ-PF 50) was used. The CHQ-PF50 has been tested in normative populations as well as children with a wide variety of chronic diseases.[27-30]

It comprises 14 concepts, containing 2 single- and 2 multi-item child health scales. Responses are transformed to scores ranging from 0 to 100, 0 indicating the lowest possible level of functioning and 100 indicating the highest possible level of functioning.

Reference groups

Reference data gathered from a random sample of 353 healthy Dutch schoolchildren are available from the literature to compare with our study population.[30] In addition, the HRQOL data of our study group were compared with that of three cohorts of injured children including 42 children with severe traumatic brain injury and 42 with moderate traumatic brain injury, and 50 children with isolated orthopaedic injuries.[31] Further, the HRQOL data of our study group were compared with the HRQOL of four groups of children with a chronic disease.[24]

Statistical analysis

The CHQ-PF 50 was scored in accordance with the algorithm provided by the instrument developer.[24] If more than 50% of the items in a scale were missing, the scale score was not computed. Data were collected and analyzed using SPSS 14.0. Descriptive statistics were used to summarize the study population's composition and demographics. Responders and non-responders were compared in terms of demographics. Data were analyzed using the Mann-Whitney–U test, the Chi-square test and the Student's t-test, as appropriate. A p-value < 0.05 was considered as statistically significant. The effect size is calculated as the difference of the means divided by the pooled standard deviation (found as the root mean square of the two standard deviations).

RESULTS

Study population

In the period January 2002 to January 2006, HEMS had been dispatched for 128 patients aged < 16 years. From these, 116 were discharged alive from hospital. Of 21 children, the General Practitioner could not be retrieved Of 10 patients, the General Practitioners refused to cooperate to this study. After evaluation of the study population, 3 children turned out to be older than 16 years on the day of the HEMS dispatch, and were excluded from this study.

Eventually, parents of 82 children were sent the Dutch version of the CHQ-PF 50. (Figure 1) From these, 55 (65%) completed and returned the questionnaire. Completion of the questionnaire was excellent with only six missing items, all on different items and therefore all scale scores could be computed.

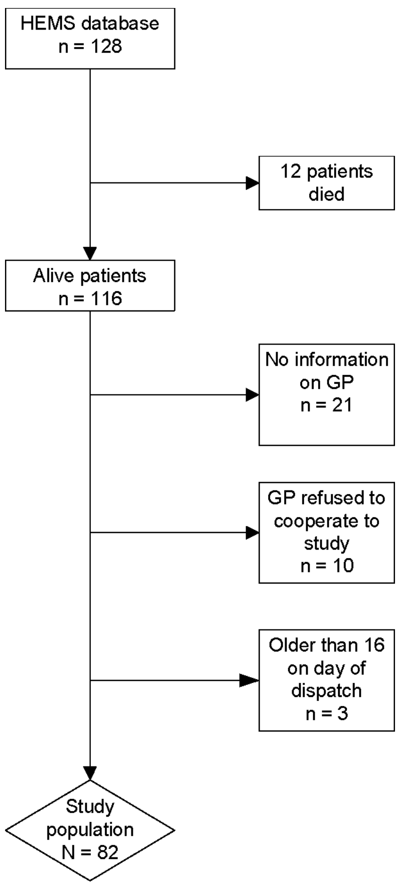

Figure 1. Flowchart study population

Comparison of responders to non-responders did not reveal statistically significant differences in gender, RTS, GCS, ISS and intubation at the site of the incident. However, the mean age of the study population was significantly lower than of the non-responders. Median follow-up (time between incident and filling out the questionnaire) was 25 months, ranging from 7 to 73 months.

Table 3. Study population demographics, comparing responders and non-responders

	Study population (N=55)	Non-responders (N=27)	P
Age	Mean 5.0 ± 4.9 years	Mean 11.0 ± 4.7 years	0.005*
Gender Male	25 (47.2%)	15 (55.6%)	0.481**
ISS	Mean 16.7 ± 11.1	Mean 14.5 ± 8.3	0.541 ***
RTS	Mean 6.11 ± 1.9	Mean 6.9 ± 1.2	0.075 *
GSC	Mean 10.0 ± 4.7	Mean 11.2 ± 4.2	0.284 ***
Intubation	29 (52.7%)	12 (44.4%)	0.481**
Follow-up time	Median 25.0 months (range, 7-73)	-	-

* Mann-Whitney U test; ** Chi-square test; *** t-test

Traffic accidents were the most frequent type of incident, followed by fall from heights and other mechanisms of injury.

Table 4. Mechanism of injury

Type of incident	N	%
Traffic accident	47	57
Fall from height	10	12
Other type of accident	10	12
Epileptic insult	4	5
Aspiration / Suffocation	4	5
Apnoea	4	5
Drowning	3	4

HRQOL of vitally compromised children compared with healthy Dutch children

The mean scores on the CHQ-PF50 scale of children in our study population are presented in Table 5 , together with reference values from their peers from the open population.

Table 5. Study population compared with healthy Dutch schoolchildren, as published by Raat et al.[30], on CHQ-PF50 scales .
* Significant at alpha = 0.0037 based on Bonferroni correction for alpha of 0.05 with multiple Student's t-tests.[14]

	Study population (n=55)		Dutch children (n=353)[26]			
Summary measures	Mean	SD	Mean	SD	P value	Effect size
Physical Summary	48.2	14.0	56.4	5.7	0.000*	0.77
Psychosocial Summary	48.5	10.6	53.2	6.4	0.002*	0.54
Sub domains						
Physical Functioning	86.7	22.5	99.1	4.3	0.000*	0.77
Role/social-emotional	85.5	25.1	95.8	15.6	0.004	0.49
General health perceptions	66.6	22.9	82.9	13.4	0.000*	0.87
Bodily pain	84.3	23.8	85.7	17.2	0.679	0.06
Family activities	78.8	25.1	91.5	11.9	0.001*	0.64
Role/social limitations	86.0	23.4	97.9	7.2	0.000*	0.68
Parental impact-time	79.6	28.1	94.0	13.0	0.000*	0.66
Parental impact-emotion	71.6	26.6	86.3	15.2	0.000*	0.68
Self-esteem	74.8	16.6	79.2	11.0	0.066	0.31
Mental health	78.0	17.7	81.4	12.1	0.163	0.22
Behaviour	72.8	18.2	78.5	13.1	0.027	0.35
Family cohesion	67.2	24.2	72.2	19.4	0.143	0.22

The children of the study population were rated significantly lower on almost all CHQ-PF50 sub domains, including Physical Functioning, General Health, Family Activities, Role/Social-Emotional/Behavioural, Parental time, Parental emotional scales and the Physical and Psychosocial summary scores. Effect sizes greater than 0.8 can be considered as a large non-overlap of the groups. Only the sub domain general health perceptions has an effect size of 0.8, followed closely by physical summary and physical functioning at a medium non-overlap of groups with an effect size of 0.77

DISCUSSION

To the best of our knowledge, this is the first study to assess the effects of prehospital care by a HEMS on the quality of life of vitally compromised children. The low mean RTS and GCS, the fact that many of those children needed endotracheal intubation in the field, the high mean ISS, and the fact that all children were admitted to the Paediatric Intensive Care Unit reflect the severity of the injury or illness of this group of vitally compromised children.

The main finding of this study was that children who had survived a life-threatening condition for which they had been managed by a HEMS-team differed from their peers in terms of health-related quality of life, as measured at a median of 2 years after the

Table 6. Study population compared with children with moderate to severe TBI and orthopaedic injuries only on CHQ-PF50, as published by Stancin et al.[31]
* significant difference between the study population and severe TBI; P < 0.05
† significant difference between the study population and moderate TBI; P < 0.05
‡ significant difference between the study population and orthopaedic injuries only; P < 0.05

	Study population (n=55)		Severe TBI (n=42)		Moderate TBI (n=42)		Orthopaedic injuries only (n=50)	
Summary measures	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Physical summary	48.2	14.0	51.3	7.8	50.8	10.0	52.0	8.1
Psychosocial summary*	48.5	10.6	42.5	12.5	46.3	10.6	47.8	10.2
Sub domains								
Physical functioning ‡	86.7	22.5	93.1	12.4	93.4	16.9	94.3	12.6
Role/social limitations physical †	85.5	25.1	91.7	17.4	95.5	11.2	93.3	15.1
General health	66.6	22.9	64.4	14.7	68.2	17.5	72.1	15.3
Bodily pain †‡	84.3	23.8	75.9	23.2	71.5	26.7	74.2	23.7
Family activities	78.8	25.1	73.8	25.1	78.7	21.3	82.5	19.4
Role/social limitations emotional	86.0	23.4	78.0	29.1	88.1	22.4	87.8	24.8
Parent impact-time‡	79.6	28.1	81.2	23.6	84.0	21.7	90.4	17.5
Parent impact-emotion *†	71.6	26.6	59.7	27.0	56.5	30.4	69.3	25.8
Self-esteem	74.8	16.6	68.7	18.8	71.4	15.8	70.7	21.4
Mental health *	78.0	17.7	69.5	16.3	75.4	12.6	75.8	13.6
Behaviour*	72.8	18.2	60.7	23.0	70.5	19.1	71.0	20.2
Family cohesion	67.2	24.2	64.8	26.3	70.2	21.3	68.9	22.0

incident. There was a statistically significant difference both in the physical and the psychosocial summary. In six out of twelve sub-domains, a significant difference was encountered as well. An effect size higher than 0.7 was measured in physical summary, physical functioning and general health perception. Physical consequences of the type of life event studied seemed to have more lasting effect than the psychological consequences. Another explanation could be that the children already had a physical limitation before the event, and where therefore more prone to get into harm's way.

A comparison was also made between the data in this study and comparable studies in children with traumatic injuries and chronic disease.

HRQOL of vitally compromised children compared to children with traumatic injuries

The results from this study were compared with data from a study by Stancin et al. of HRQOL in children with moderate and severe traumatic brain injury (TBI) and isolated orthopaedic injuries. [31]

Mean scores on the CHQ-PF50 for the study population, severe and moderate TBI and orthopaedic injuries only groups are presented in table 6. The study population scored significantly higher than the severe TBI group on the Psychosocial Summary Score ($F(1.95) = 6.529$; $P = 0.012$) and on the CHQ-PF50 sub domains: Parent-Impact-Emotional ($F(1.95) = 4.705$; $P = 0.033$), Mental Health ($F(1.95) = 5.877$; $P = 0.017$), and Behaviour ($F(1.95) = 8.370$; $P = 0.005$). The study population had a lower mean score on the Role/Social-Physical ($F(1.95) = 5.777$; $P = 0.018$) and higher mean scores on Bodily Pain/Discomfort ($F(1.95) = 6.197$; $P = 0.015$) and Parent Impact-Emotional ($F(1.95) = 6.779$; $P = 0.011$). Compared with the orthopaedic injuries only group, the study population scored significantly lower on the Physical Functioning ($F(1.105) = 4.437$; $P = 0.038$) and Parent Impact-Time ($F(1.105) = 5.458$; $P = 0.021$) but higher on the Bodily Pain/Discomfort ($F(1.105) = 4.736$; $P = 0.032$) sub domains.

HRQOL of vitally compromised children compared to children with a chronic disease

The mean physical and psychological/social summary scores of the CHQ-PH50 for the study group were compared with four groups of chronically ill children as presented in table 7. The mean Physical and Psychosocial summary scores of the study population were compared with mean scores for the diseases: Attention Deficit Hyperactivity Disorder (ADHD), Asthma, Juvenile Rheumatoid Arthritis (JRA), and Epilepsy as published in the CHQ manual.[24]

Children in the study population group were rated as functioning more poorly than children with ADHD on the Physical Summary Score, but significantly better than children with

Table 7. Study population compared with four groups of chronically ill children, as published in the CHQ manual.[24]

Summary measures		Mean (SD)	N	P
Physical summary score	Study population	48.2 (14.0)	55	
	ADHD	57.6 (6.2)	83	0.000*
	Asthma	45.7 (8.4)	178	0.208
	JRA	42.1 (13.9)	74	0.003*
	Epilepsy	47.7 (13.9)	34	0.800
Psychosocial summary score	Study population	48.5 (10.6)	55	
	ADHD	36.9 (10.9)	83	0.000*
	Asthma	51.2 (8.6)	178	0.070
	JRA	53.4 (9.2)	74	0.002*
	Epilepsy	46.5 (11.7)	34	0.192

JRA. Compared with children with Asthma and Epilepsy, there is no significant difference on the Physical summary score.

Children with JRA score significantly better on the Psychosocial Summary Score than the children in the study population, and children with ADHD score significantly worse than the study population. There are no significant differences between the study population, children with Asthma and children with Epilepsy on the Psychosocial Summary Score.

At the level of the individual child, the differences may be large. Adolescents with severe traumatic brain injury in general do not rate their HRQOL differently than adolescents with orthopaedic injuries.[31] This is in contrast with the HRQOL as rated by their parents as shown in table 6. The parents' perception of their children's HRQOL was related to indicators of functional impairment, including the extent to which the child had ongoing medical problems, changes in behaviour, school problems and adaptive behaviour.

The HRQOL of the study population was compared with the HRQOL of a healthy population of schoolchildren from the Netherlands. According to the parents' perception of their child's HRQOL, the study population scored significantly lower on six sub-domains of the questionnaire (physical functioning, general health, family activities, role limitations due to emotional/behaviour problems, impact on parental time, emotional impact on parent) and on both summary measures (physical and psychosocial) than a healthy population of Dutch schoolchildren. Nevertheless, there was no difference between the study population and the children with severe and moderate TBI and isolated orthopaedic injuries on the Physical Function Summary score. The children with severe TBI scored lower on the Psychosocial Summary scores compared with the study population. In comparison with children with a chronic disease, there was no difference between the study population and children with asthma and epilepsy. In conclusion, we need to acknowledge that the acute compromising event could have long-term consequences, the results from this study are far from reassuring. The children treated by a HEMS could benefit from a structured follow-up in a multidisciplinary-staffed outpatient clinic with a screening of the HRQOL. Such follow-up is not uncommon in other groups of children (leukaemia, cleft palate), and could improve the physical and psychosocial outcome.

There a several limitations in this study. For the interpretation of the results the response rate needs to be considered. The response rate in this study was 65%. Several previous studies on outcomes of paediatric injuries encountered difficulties in achieving a high participation rate, but in the response rate of our study was comparable to studies by other researchers in the Netherlands.[32] Because of the nature of this study and the mean age of the children, we thought it to be inappropriate to study the self-reports of the children. All the data in this study, and the studies it was compared to, are parented reported HRQOL scores. In a study by Davis, there was discordance between parents and children in terms of rating scale and in terms of the reasoning for their answer.[33] Children tended to have different response styles to parents, where for example, children tended to provide extreme scores (highest or lowest score) and base their response on one single example, more than parents. Parents and children interpreted the meaning of the items very similarly. In general, children focus more on the concurrent psychosocial situation, where parents focus on future aspects.[34] Agreement is most apparent on the more visible aspects as physical functioning or symptoms. However, less agreement is apparent on the social-emotional domains, bodily pain and mental health.[35] The HRQOL in this study was not prospectively assessed any further, so it is unclear how HRQOL may change over time. Another limitation may be sample attrition. The children of the non-responders were significantly older than the children of responders, so this may have yielded biased estimates of HRQOL. However, as the responders as a group have a, although statistically not significant, lower mean RTS and GCS, a higher mean ISS and more children were intubated initially, sample attrition may have overestimated the impact of the incident on the sample as a whole.

CONCLUSION

The focus of most of the research in emergency medicine concerns the performance of various triage systems and modes and methods of pre-hospital care. These studies use endpoints as mortality, length of hospitalization, and length of Intensive Care Unit admission. Long-term outcome is rarely used as an endpoint in evaluating paediatric pre-hospital care, except for management of children with traumatic brain injury.

At 2-5years follow up, the quality of the lives of children who were treated by a HEMS for vitally compromising conditions does not match the quality of the lives of their peers from the open population. Both the long-term physical and psychosocial health is lower in paediatric patients treated by a HEMS in the field in comparison to healthy Dutch children.

The range of these scores can be compared with children with chronic diseases as epilepsy and asthma. A structured follow-up of these children is required. These results call for more studies on the long term outcome in paediatric pre-hospital trauma care.

REFERENCES

1. Burton J, Baumann M, Maoz T, Bradshaw J, Lebrun J. Endotracheal intubation in a rural EMS state: procedure utilization and impact of skills maintenance guidelines. Prehosp Emerg Care 2003; 7(3);p 352-356
2. Einav S, Donchin Y, Weissman C, Drenger B. Anesthesiologists on ambulances: where do we stand? Curr Opin Anaesthesiol 2003; 16;p585-591
3. Lossius H, Søreide E, Hotvedt R, Hapnes S, Eielsen O, Førde O, Steen P. Prehospital advanced life support provided by specially trained physicians: is there a benefit in terms of life years gained? Acta Anaesthesiol Scand 2002; 46;p771-778
4. Thomas SH, Biddinger PD. Helicopter trauma transport: an overview of recent outcomes and triage literature. Curr Opin Anaesthesiol 2003; 16:153-158
5. Lerner EB, Moscati RM. The Golden hour. Scientific fact or "Urban legend"? Acad Emerg Med, 2001; 8: 758-760
6. Carli PA, Orliaguet GA. Prehospital trauma care. Curr Opin Anaesthesiol 1995; 8:157-162
7. Jacobs LM, Sinclair A, Beiser A, et al. Prehospital advanced life support: Benefits in trauma. J Trauma 1984; 24:8-13
8. Schmidt U, Frame SB, Nerlich ML, et al. On-scene helicopter transport of patients with multiple injuries – comparison of a German and a American system. J Trauma 1992; 33:548-553
9. Hamman BL, Cue JI, Miller FB, et al. Helicopter transport of trauma victims: Does a physician make a difference? J Trauma 1991; 31:490-494
10. Nicholl JP, Brazier JE, Snooks HA: Effects of London helicopter emergency medical service on survival after trauma. BMJ 1995; 311:217-222
11. Sampalis JS, Lavoie A, Williams JI, et al. Impact of on-site care, prehospital time, and level of in-hospital care on survival in severely injured patients. J Trauma 1993; 34:252-261
12. Sampalis JS, Boukas S, Lavoie A, et al. Preventable death evaluation of the appropriateness of the on-site trauma care provided by Urgeness-Sante physicians. J Trauma 1995; 39:1029-1035
13. Applebaum D, Slater PE. Should the mobile intensive care unit respond to pediatric emergencies? Clin Pediatr 1986; 25:620-623
14. Tsai A, Kallsen G. Epidemiology of pediatric prehospital care. Ann Emerg Med 1987; 16:284-292
15. Ramenofsky ML, Luterman A, Curreri PW, et al. EMS for pediatrics: Optimum treatment or unnecessary delay? J Pediatr Surg 1983; 18:498-504
16. Suominen P, Baillie C, Kivioja A, Korpola R, Rintala R, Silfvast T, Olkkola KT. Prehospital care and survival of pediatric patients with blunt trauma. J Pediatr Surg 1998; 33:1388-1392
17. Cheung PS, Lam JM, Yeung JH, Graham CA, Rainer TH. Outcome of traumatic extradural haematoma in Hing Kong. Injury 2007; 38: 76-80
18. Ducrocq SC, Meyer PG, Orliaquet GA, Blanot S, Laurent-Vannier A, Renier D, Carli PA. Epidemiology and early predictive factors of mortality and outcome in children with traumatic severe brain injury: experience of a French pediatric trauma center. Pediatr Crit Care Med 2006; 7: 461-467
19. Hackbarth RM, Rzeszutko KM, Sturm G, Donders J, Kuldanek AS, Sanfilippo DJ. Survival and functional outcome in pediatric traumatic brain injury: a retrospective review and analysis of predictive factors. Crit Care Med 2002; 30: 1630-1635

20. Ringburg AN, Frissen IN, Spanjersberg WR, Jel G de, Frankema SPG, Schipper IB. Physician-staffed HEMS dispatch in the Netherlands: adequate deployment or minimal utilization? Air Med J 2005;24(6):248-251

21. Hunt TK, Champion HR, Sacco WJ. Trauma severity scoring to predict mortality. World Journal of Surgery 1983;1: 4-11

22. Teasdale GM, Jennett B. Assessment of coma and impaire consciousness. Lancet 1974; 2: 81-84

23. Baker SP, O'Neill B, Haddon W. The injury severity score: a method for describing patients with multiple injuries and evaluating trauma care. Journal of Trauma 1974;14: 187-196

24. Landgraf JM, Abetz L,Ware JE. The CHQ User'sManual. Second Printing Boston, MA: HealthAct, 1999

25. Hemmingway H, Stafford M, Stasfeld S, et al. Is the SF-36 a valid measure of change in populational health? Results from the Whitehall II study. BMJ 1997; 315;p1273-9

26. Ruperto N, Ravelli A, Pistorio A, et al. Cross-cultural adaptation and psychometric evaluation of the Childhood Health Assessment Questionnaire (CHAQ) and the Child Health Questionnaire (CHQ) in 32 countries: review of the general methodology. Clin Exp Rheumatol 2001; 19 (4 Suppl 23); S1-S9

27. Sawyer M, Antoniou G, Toogood I, Rice M. A comparison of parent and adolescent eports describing the health-related quality of life of adolescents treated for cancer. Int J Cancer Suppl 1999; 12: 39–45.

28. Powers PM, Gerstle R, Lapey A. Adolescents with cystic fibrosis: Family reports of adolescent health-related quality of life and forced expiratory volume in one second. Pediatrics 2001; 107: E70.

29. Waters EB, Salmon LA, Wake M, Wright M, Hesketh KD. The health and well-being of adolescents: A school-based population study of the self-report Child Health Questionnaire. J Adolesc Health 2001; 29: 140–149.

30. Raat H, Bonsel GJ, Essink-Bot ML, Landgraf JM, Gemke RJBJ. Reliability and validity of comprehensive health status measures in children: The Child Health Questionnaire in relation to the Health Utilities Index. J Clin Epidemiol 2002; 55: 67-76

31. Stancin T, Drotar D, Taylor HG, Owen Yeates K, Wade SL, Mercuru Minich N.: HRQOL of children and adolescents after traumatic brain injury. Pediatrics 2002;109(2):E34.

32. Sturms LM, van der Sluis CK, Groothoff JW, ten Duis HJ, Eisma WH. Young traffic victims' long-term health-related quality of life: child self-reports and parental reports. Arch Phys Med Rehabil 2003;84:431-6.

33. Davis E, Nicolas C, Waters E, Cook K, Gibbs L, Gosch A, Ravens Sieberer U. Parent-proxy and child self-reported health-related quality of life: using qualitative methods to explain the discordance. Qual Life Res 2007;16(5):863-71

34. Loonen HJ, Derkx BH, Koopman HM, Heymans HS. Are parents able to rate the symptoms and quality of life of their offspring with IBD? Inflamm Bowel Dis 2002;8(4):270-6

35. Theunissen NC, Vogels TG, Koopman HM, Verrips GH, Zwinderman KA, Verloove-Vanhorick SP, Wit JM. The proxy problem: child report versus parent report in health-related quality of life research. Qual Life Res 1998;7(5):387-97

Summary of the thesis and recommendations

Helicopter Emergency Medical Services were established in the Netherlands to improve pre-hospital care for trauma patients. In the past 15 years HEMS has become a well-established part of the medical care provided to patients in the field. At an international level extensive research has been conducted into the potential benefits and drawbacks of HEMS to supplement the standard EMS. Due to the differences in organisation and training, research from other countries cannot easily be extrapolated to the Netherlands. Various studies have substantiated the fact that Helicopter Emergency Medical Services provided in the Netherlands reduce morbidity and possibly mortality, and that HEMS is cost-effective in terms of life years gained.

The data used for this thesis was compiled from all HEMS calls involving children (under the age of eighteen) in the period from March 1st 2001 to January 1st 2008, for which the HEMS Nijmegen (Lifeliner 3) was activated. The HEMS Nijmegen had 6,749 callouts in this period, 891 of which involved children. These 891 HEMS callouts are the basis of the studies described in this thesis. The author of this thesis was involved as an HEMS physician in a significant number of cases. A research database was constructed by using the data from the HEMS database and adding relevant information from hospital files.

As explained in the introduction to this thesis, this data was analysed to answer the following questions:

1. **Dispatching.** What were the HEMS calls made by the dispatcher, classified by indication and dispatch region?
2. **Epidemiology.** What is the epidemiology of the vitally compromised children for whom the HEMS is called out?
3. **Intervention.** Which medical interventions were provided by the HEMS? Was there a benefit or a disadvantage to the HEMS intervention? Were the medical interventions properly applied?
4. **Outcome.** What was the outcome in respect of the children who were treated by the HEMS in comparison to peer groups?

Chapter 2 gives an overview of the history and epidemiology of the vitally compromised child. It wasn't until the 19th century that the life of a child came to be considered extremely valuable, and that children became the building blocks of society. Millions of children still die every year from preventable causes. In the Netherlands the first year of life has the highest mortality rate for all persons in the ages 0 - 24; infant mortality in the Netherlands is higher than in most European countries. Mortality due to traffic accidents has decreased in the Netherlands over the years; death due to other traumatic causes is rare. When extrapolating data from other countries, it appears that an important percentage of the deaths are preventable.

Chapter 3 describes the differences between the deployment frequencies in different dispatch regions. There is a strong correlation between the number of inhabitants in a dispatch region and the number of deaths resulting from trauma, the number of traffic accidents involving injuries and the number of emergency calls for the EMS. There is no correlation between the number of inhabitants and the number of HEMS calls. Only the HEMS coordinating dispatch regions have more HEMS calls with a lower cancellation rate; the deployment of HEMS varies significantly between emergency dispatch centres. Helicopter Emergency Medical Services in the Netherlands are still not fully integrated in the emergency care system and a strict application of the rules for dispatching would significantly augment the number of calls. Unfortunately there is no national policy for the cancellation of HEMS callouts.

Chapter 4 provides a description of HEMS dispatching for children from one HEMS operation. Thirteen percent of all calls were paediatric emergencies, with a cancellation percentage significantly lower than the calls for adults. The HEMS coordinating dispatch region had a higher percentage of less compromised children. The non-trauma incidents had the lowest 24-hour survival rate; the highest 24-hour survival rate was in the incident group of HEMS calls based on the mechanism of injury. Dispatch criteria based on mechanism of injury are a poor triage tool, and several types of severe illnesses prevalent in childhood should be included. Cancellation criteria for HEMS callouts involving children are not applied in a consistent manner.

Chapter 5 describes the 891 HEMS callouts involving children of the HEMS Nijmegen for the period 2001 - 2008. The objective was to determine the number of advanced life support procedures provided by the EMS and the HEMS, and to establish whether the arrival of the HEMS added any useful interventions. Of the 646 children examined and treated by the HEMS, 77.5% had a NACA score of IV-VII (severely wounded to pre-terminal). Sixty-five percent of the children received one or more advanced life support procedures that are limited to the HEMS, and 80% of the children received one or more procedures in which the HEMS tends to be more experienced than the EMS. HEMS provided vitally important interventions in respect of airways, circulation and pain management.

Chapter 6 focuses on the airway interventions. Of the children examined in the field, an important percentage required endotracheal intubation. Endotracheal intubation by EMS paramedics required emergency correction by the HEMS in 37% of the intubations, more often in the smaller children. Out-of-hospital endotracheal intubation by HEMS is safe and effective for securing the airway and facilitating artificial ventilation.

Chapter 7 is a study that monitors three patients diagnosed with iatrogenic tracheal stenosis following endotracheal intubation in the field. A prospective cohort study was conducted into the known risk factors: cuff pressure, use of alpha-agonists, occurrence of shock or a combination of these factors. One or more risk factors for iatrogenic tracheal stenosis could be identified in 89% of all patients. The predominant risk was elevated cuff pressure, which occurred even though national guidelines had been complied with.

Chapter 8 is a review of Cervical Spine Injury (CSI) in children. A structured search of the Pub med database, comparable to similar reviews on CSI in adults, was performed. No randomised controlled trials of spinal immobilisation strategies in children were found. Although adult trauma protocols are applied to children, validated studies are lacking. The type and location of a CSI depend on the age and development of the child; the detrimental effects of spinal immobilisation on children are well documented. CSI immobilisation should only be applied in children with special care on the part of the providers, and the need for immobilisation should be evaluated continuously.

Chapter 9 is an evaluation of the use of the bone injection gun, used in order to obtain circulatory access in a pre-hospital setting. The bone injection gun is an effective and safe device for the resuscitation of patients in a pre-hospital setting. Its use appears to be more successful in adults than in children. Although the patient numbers are small, there seem to be disadvantages to using the bone injection gun in children under the age of one.

Chapter 10 describes pre-hospital sonography by the HEMS, using two patient cases and a review of relevant medical literature. Ultrasound imaging of heart, lungs and abdomen can support the decision-making process for the provider of pre-hospital care, especially with respect to the ABCs in the primary survey. Special consideration should be given to the training of the personnel involved, and to the prevention of unnecessary time delays caused by the use of sonography.

Chapter 11 is an evaluation by an expert panel of the diagnostics, interventions and triage by the HEMS physicians. A random sample of 20 patients was taken and evaluated extensively by a panel of nine experts in pre-hospital emergency care in children. For almost a quarter of the items the expert panel did not give a rating concerning the application of advanced life procedures as none was necessary. No inappropriate procedures or decisions were noted by the expert panel. The HEMS performed very well in triage and diagnostics; the appropriateness of the HEMS dispatch was uncertain in seven out of twenty patients.

Chapter 12 describes the long-term impact on children treated by the HEMS. The results of these children were compared to norm data from healthy peers, children with a traumatic brain injury and children with a chronic disease. The study population scored significantly lower on the mean physical summary score and the mean psychosocial summary score than their peers from the open population. The mean physical and psychosocial summary scores of children in our study population were comparable to those of children with chronic diseases. At a 2-5 year follow-up the quality of life of children who were treated by an HEMS does not match the quality of life of their peers.

RECOMMENDATIONS:

Dispatching:

- *Structured teaching of protocols to dispatchers.* There is too much variation in the way dispatchers interpret HEMS call criteria.
- *Strict adherence to nationwide dispatching protocols.* The distribution of HEMS calls across the Netherlands is uneven, and not related to the number of inhabitants, flying distance, number of traffic accidents or number of ambulance emergency calls.
- *Adjustment of dispatch criteria to include paediatric non-trauma and trauma causes.* Any emergency call to the dispatcher involving a vitally compromised child should automatically activate the HEMS.
- *Inclusion of a GCS or AVPU related score.* Dispatching according to trauma mechanism does not result in the optimal determination of the children who would benefit from an HEMS.

EMS:

- *Cooperation between EMS and HEMS.* The EMS and the HEMS should be natural partners in the care for the vitally compromised child. As paediatric experience is scarce in the EMS, the cooperation with respect to training, development of protocols and medical care must be improved.
- *Structured teaching of care for vitally compromised children.* Medical experts should be committed to train the EMS in medical interventions and triage. (PHPLS/EPLS)
- *Training in the paediatric airway.* Recognition and treatment of a compromised airway is paramount. Endotracheal intubation should only be performed as a last resort by competent and trained professionals
- *Training in pain management for children.* Out-of-hospital pain management could be improved significantly.
- *Nationwide protocol for cancellation of HEMS.* The primary activation of the HEMS by the dispatcher can be cancelled by the EMS paramedic at the scene. The cancellation of HEMS seems to be related to local interpretation, and not to standardised national criteria.

HEMS:

- *Selection of HEMS physicians.* Only physicians with in-hospital experience in paediatric resuscitation should be active in HEMS care.
- *Extensive training.* The HEMS physicians and nurses should all have completed the appropriate life support courses (APLS, PHPLS), and should preferably be active as instructors. Medical crew resource management training would be beneficial.

- *Medical 'flight check'* As customary in aviation, all medical personnel should be evaluated regularly for proficiency in medical interventions. Training and examination in a simulated setting would be useful.
- *HEMS equipment.* All medical aids, disposables and medications should be suitable and prepared for all required paediatric interventions.
- *National study in pre-hospital ultrasound.* A study into the benefits and drawbacks of pre-hospital ultrasound in vitally compromised patients is feasible through the cooperation of the four HEMS bases in the Netherlands.
- *Nationwide HEMS database.* This would enable further medical research, quality control and benchmarking.
- *Structured debriefing by the receiving hospital.* Due to privacy laws in the Netherlands, the HEMS cannot access patient data and results once the patient has been admitted to a hospital. The structured discharge letter the hospital sends to the general physician should also be sent to the HEMS organisation involved.
- *Follow-up of children.* The current protocols could be improved if a standardised follow-up was performed.

RÉSUMÉ ET RECOMMANDATIONS

L'Équipe Médicale Mobile en Hélicoptère ou EMM-H (en néerlandais : helikopter Mobiel Medisch Team ou H-MMT) a été à l'origine créée aux Pays-Bas en vue d'améliorer les soins médicaux dispensés en dehors de l'hôpital aux patients victimes d'accidents. De vastes études scientifiques internationales ont été réalisées pour analyser les avantages et les inconvénients potentiels de l'adjonction d'une EMM-H aux soins ambulanciers réguliers. En raison des importantes différences au niveau de l'organisation et de la formation, le résultat des études à l'étranger dans ce domaine n'a qu'une pertinence limitée pour la pratique néerlandaise. Diverses études scientifiques aux Pays-Bas ont toutefois permis d'établir que l'EMM-H engendre un gain en matière de santé et diminue éventuellement le risque de décès des patients. Une EMM-H présente un bon rapport coût-efficacité si la relation entre les coûts de l'EMM-H et les gains financiers est considérée en termes d'années de vie.

On a obtenu les données pour l'étude dans cette thèse en rassemblant tous les appels d'EMM-H reçus par l'Équipe Médicale Mobile de Nimègue entre le 1er mars 2001 et le 1er janvier 2008. Durant cette période, 6749 appels d'EMM-H ont été enregistrés, dont 891 concernaient des enfants (<18 ans). Ces 891 appels d'EMM-H pour des enfants constituent la base des divers chapitres de cette thèse. L'auteur a été lui-même directement impliqué auprès d'un certain nombre de ces enfants en tant que médecin traitant sur le terrain. À partir de diverses sources d'informations, une banque de données complète a été constituée, dans laquelle ont été introduites les données médicales avant, durant et après l'hospitalisation.

On a analysé ces données EMM-H pour pouvoir répondre aux questions suivantes :

1. **Appels.** Quels ont été les appels d'EMM-H de la centrale d'appels pour le Service d'Ambulance (centrale d'appels SA) et quels sont ceux de ces appels qui concernaient des enfants ? Quelle a été la répartition sur les diverses centrales d'appels, en relation avec le signalement et l'éventuelle annulation de l'EMM-H ?
2. **Nature de l'incident.** Quelles ont été les causes qui ont mis l'enfant en péril ?
3. **Actes médicaux.** Quels actes médicaux ont été accomplis par l'EMM-H ? Quels actes ont été utiles et quels actes ont été préjudiciables ? Les actes ont-ils été effectués correctement et au bon moment ?
4. **Aboutissement à long terme.** Quel a été l'état ultérieur des enfants ? Comment s'est déroulé le rétablissement après l'incident par rapport à des groupes d'enfants comparables ?

Le chapitre deux dresse un tableau de l'histoire et de la prévention de l'enfant en péril. Ce n'est qu'à partir du dix-neuvième siècle que s'est généralement répandue l'idée qu'une vie d'enfant est précieuse et que les enfants doivent être protégés. Un changement qui a été stimulé par l'idée alors nouvelle selon laquelle les enfants peuvent être considérés comme

les pierres qui construisent la société. Malgré les nombreux efforts, des millions d'enfants meurent encore chaque année à la suite de causes facilement traitables. À la première année de vie correspond le taux de mortalité relative le plus élevé par rapport à tous les âges de zéro à vingt-quatre ans, le décès autour de la naissance étant plus élevé aux Pays-Bas que dans la plupart des pays environnants. Ces dernières années, les décès d'enfants dus aux accidents de la circulation ont diminué aux Pays-Bas, les décès dus à d'autres mécanismes d'accident sont rares. Dans les autres pays, on constate aussi que dans un pourcentage important de tous les enfants qui décèdent à la suite d'un accident, le décès aurait pu être évité. La responsabilité indirecte en incombe généralement aux adultes.

Le chapitre trois décrit les différences entre les fréquences d'appel des EMM-H aux Pays-Bas par rapport aux différentes centrales d'appels pour le Service d'Ambulance (centrales d'appels SA). Le nombre d'habitants d'une centrale d'appels SA est directement proportionnel au nombre de personnes décédées suite à des accidents, au nombre d'accidents de la circulation avec lésions et au nombre d'appels urgents reçus par la centrale d'appels SA. Il n'y a pas de relation entre le nombre d'habitants d'une centrale d'appels SA et le nombre d'appels d'une EMM-H. Seules les centrales d'appels SA qui coordonnent l'EMM-H, qui sont au nombre de quatre aux Pays-Bas, ont une fréquence d'appels supérieure à la moyenne nationale. Il existe une différence notable entre les centrales d'appels SA en ce qui concerne l'engagement d'une EMM-H. Le chapitre quatre porte sur les appels d'EMM-H concernant des enfants d'une seule centrale d'appels SA. Treize pour cent de tous les appels d'EMM-H concernent des enfants en péril ; le pourcentage d'annulation d'un appel d'EMM-H est moins élevé que chez les adultes. La région d'EMM-H concernée se compose de sept centrales d'appels SA, mais la centrale d'appels qui coordonne l'EMM-H a le plus haut pourcentage d'enfants de légèrement à moyennement blessés. Les six autres centrales SA de la région appellent de préférence l'EMM-H seulement si l'enfant se trouve dans une situation critique. Les enfants pour lesquels on a appelé une EMM-H et chez lesquels le problème médical n'était pas dû à un accident avaient les plus grands risques de décès les premières 24 heures. Le pourcentage de survie le plus élevé a été enregistré chez les enfants pour lesquels l'appel avait eu lieu sur la base des circonstances d'un accident. L'engagement d'une EMM-H en raison d'une certaine sorte d'accident est une façon moyennement efficace de sélectionner les enfants. Il serait préférable d'adjoindre aussi aux motifs d'intervention d'une EMM-H divers syndromes graves. Les motifs d'annulation d'une intervention d'une EMM-H déjà appelée sont appliqués de façon très différente par les diverses centrales d'appels SA.

Le chapitre cinq décrit les 891 appels d'EMM-H pour des enfants durant les années 2001 à 2008, pour lesquels l'EMM-H de Nimègue a fourni une assistance. Le but de cette étude était de mieux connaître la quantité d'actes accomplis par l'EMM-H et de comparer ce nombre avec les actes d'un service d'ambulance. On obtient ainsi un tableau des actes réservés à un médecin de l'EMM-H et des actes pour lesquels ce médecin a davantage d'expérience. Chez 77,5 % des 646 enfants traités par l'EMM-H, il était question d'un accident ou d'un syndrome de grave à très grave. 65 % de ces enfants ont subi un traitement médical réservé à l'EMM-H. Quatre-vingts pour cent de tous les enfants ont reçu un traitement médical pour lequel l'EMM-H était plus expérimentée que l'assistance en ambulance. L'EMM-H a accompli des actes concernant le dégagement des voies respiratoires, la stabilisation de la circulation sanguine et le traitement de la douleur. Le chapitre six indique les traitements concernant la protection des voies respiratoires chez les enfants. Dans un pourcentage considérable de tous les enfants qui ont été traités par l'EMM-H, on a dû pratiquer une intubation trachéale. Chez les enfants qui avaient déjà été intubés par l'assistance en ambulance et étaient ventilés, cette opération s'est avérée dans 37 % des cas incorrectement effectuée. Chez ces enfants, dont la grande majorité étaient des petits enfants, le médecin de l'EMM-H a dû de façon urgente recommencer l'intubation pour permettre à nouveau l'administration d'oxygène et la ventilation. L'introduction d'un tube endotrachéal chez des enfants ne peut être effectuée que par des assistants très expérimentés.

Au chapitre sept figure une étude qui a été réalisée à la suite de complications survenues chez trois enfants qui avaient été intubés en dehors de l'hôpital. Chez ces trois enfants, il s'est avéré après le retrait du tube que la trachée avait été endommagée, ce qui avait provoqué un grave rétrécissement de la trachée. On a dû pratiquer une opération chez ces trois enfants pour enlever la partie rétrécie de la trachée. C'est pourquoi on a ensuite rassemblé toutes les données concernant les patients chez lesquels un tube endotrachéal avait été introduit par une EMM-H. On a ainsi étudié quels étaient les facteurs de risque d'endommagement de la trachée dans cette situation. Les trois facteurs de risque qui sont connus dans la littérature médicale sont : l'utilisation de médicaments qui provoquent une contraction des vaisseaux sanguins, une baisse sérieuse de la pression artérielle et un gonflement excessif du ballonnet du tube endotrachéal entraînant une obturation de la trachée. Un ou plusieurs de ces facteurs ont été constatés chez 89 % de tous les patients. Le facteur de risque le plus fréquent était un ballonnet trop gonflé du tube endotrachéal, bien que les assistants aient dans ces cas appliqué la directive en vigueur du protocole national des soins ambulanciers. Le chapitre huit énonce la littérature médicale relative aux traumatismes du rachis cervical (TRC) chez les enfants. On a cherché dans la base de données Pubmed des articles pertinents, avec les mêmes données de recherche que celles utilisées plus tôt pour un article de synthèse comparable sur les TRC chez les adultes. Il n'existe pas d'études randomisées sur l'immobilisation du rachis cervical chez les enfants. Bien que beaucoup de protocoles qui ont été conçus pour les adultes soient aussi appliqués aux enfants, toute base scientifique pour cela fait défaut. La nature et le niveau des TRC chez les enfants sont fortement liés à l'âge et peuvent considérablement différer de ceux chez les adultes. Chez les enfants, on a toutefois consigné les effets négatifs de l'immobilisation du rachis cervical. Lorsqu'on pose un collier cervical à un enfant et que celui-ci est immobilisé, ceci demande beaucoup de soins et d'attention de la part des assistants concernés. La nécessité de cette mesure doit être en permanence réévaluée de façon critique et supprimée dès que possible.

Le chapitre neuf est une évaluation du Bone Injection Gun (BIG). Ce dispositif permet un accès intravasculaire instantané lorsqu'une aiguille de perfusion est difficile à introduire. Le BIG propulse par un système de détente une aiguille creuse dans un os, permettant l'administration d'un liquide de perfusion et de médicaments. Par la cavité de l'os, on atteint alors rapidement la circulation sanguine. Un BIG est un dispositif efficace et sûr pour traiter les patients en dehors de l'hôpital. Bien qu'il s'agisse ici d'une étude portant sur des petits nombres, le BIG semble néanmoins moins efficace chez les enfants de moins d'un an.

Le chapitre dix décrit la pratique d'une échographie rapide par l'EMM-H. À partir de deux patients et d'une liste de la littérature médicale pertinente, on dresse le tableau des possibilités. L'examen échographique du cœur, des poumons et de l'abdomen permet d'obtenir des informations importantes qui peuvent influencer la prise des décisions. C'est un moyen d'évaluer et de stabiliser les voies respiratoires, la respiration et la circulation sanguine. On peut en outre mieux déterminer vers quel hôpital il est préférable de transporter le patient. Il faut toutefois consacrer une attention spéciale à la formation du médecin qui pratique cet examen échographique. On doit en tout temps éviter que cet examen ne cause un retard indésirable de l'arrivée du patient à l'hôpital.

Le chapitre onze consiste en une évaluation par un panel d'experts de l'étude, du traitement et du choix de l'EMM-H. Au moyen d'un échantillon aléatoire de vingt patients de l'effectif total, ce panel évalue les soins médicaux dispensés aux enfants. Pour près d'un quart des sujets, les experts n'ont pas pu se prononcer sur l'EMM-H, parce que des actes médicaux spécialisés n'avaient pas été nécessaires. Le panel n'a pas constaté d'actes ou de décisions injustifiés. L'EMM-H prenait de bonnes décisions en ce qui concerne le choix de l'hôpital et le diagnostic. Dans sept des vingt cas, il n'apparaissait pas clairement que l'intervention de l'EMM-H ait ou non été nécessaire.

Le chapitre douze décrit l'aboutissement à long terme chez les enfants qui ont été traités par l'EMM-H. Les résultats de ces enfants ont été systématiquement comparés avec des enfants sains du même âge, avec des enfants ayant subi une lésion cérébrale et avec des enfants souffrant d'une maladie chronique. Les enfants traités par l'EMM-H enregistraient un score moyen inférieur au niveau du fonctionnement physique et intellectuel par rapport aux enfants du groupe sain. Le fonctionnement physique et intellectuel moyen des enfants qui avaient été traités par l'EMM-H était plutôt comparable à celui des enfants souffrant d'une maladie chronique. Même après deux à cinq ans, les enfants qui avaient été traités par l'EMM-H n'avaient pas la même qualité de vie que les autres enfants du même âge.

RECOMMANDATIONS

Centrale d'appels pour le Service d'Ambulance :

- Formation structurée portant sur les critères d'appel d'une EMM-H. Il existe trop de différences d'évaluation entre les différentes centrales d'appels SA.
- Stricte observation du protocole EMM-H. La répartition des appels d'EMM-H sur les Pays-Bas est variable et ne dépend pas de critères évidents tels que : nombre d'habitants, distance de vol, nombre d'accidents de la circulation, ou nombre de trajets urgents d'une ambulance.
- Adaptation des critères d'appel de façon à faire intervenir l'EMM-H aussi bien pour les enfants gravement malades que pour les enfants gravement blessés.
- Appels sur la base d'un critère rattaché à l'état de conscience du patient. L'appel d'une EMM-H sur la base du mécanisme d'accident ne s'avère pas très efficace dans le cas des enfants.

Soins ambulanciers :

- Meilleure collaboration entre les soins ambulanciers et l'EMM-H. Les assistants ambulanciers et l'EMM-H sont des partenaires qui fournissent des secours à l'enfant dont la vie est menacée. Étant donné que ce type d'expérience n'est pas fréquente chez les assistants ambulanciers, la collaboration en ce qui concerne l'élaboration des protocoles, l'exercice et les soins médicaux devra être améliorée.
- Enseignement structuré portant sur l'enfant dont la vie est menacée. Les experts dans ce domaine doivent dispenser un enseignement auprès des assistants ambulanciers sur les actes médicaux et le bon choix d'hôpital.
- Formation portant sur les voies respiratoires. La reconnaissance et le traitement des voies respiratoires menacées sont d'une importance capitale. L'introduction d'un tube endotrachéal chez un enfant est un acte spécialisé qui ne peut être accompli que par un personnel très expérimenté.
- Formation en matière de traitement de la douleur. Les traitements anti-douleur chez les enfants en dehors de l'hôpital peuvent être améliorés.
- Critères d'annulation nationaux pour l'EMM-H. Après l'engagement initial de l'EMM-H par la centrale d'appels SA, les assistants ambulanciers peuvent annuler l'EMM-H sur place. Cette annulation semble sujette à une interprétation locale, il n'y a pas de critères nationaux.

EMM-H :

- Choix des médecins de l'EMM-H. Seuls des médecins ayant acquis une large expérience en matière d'accueil des enfants en péril à l'hôpital peuvent accomplir cette tâche au sein d'une EMM-H.

- Formation. Le médecin de l'EMM-H et l'infirmier/infirmière doivent tous avoir suivi les formations APLS (Advanced paediatric life support) ou EPLS (European paediatric life support), et continuer de maîtriser le sujet au niveau des instructeurs. Ces formations avec examen pourraient parfaitement avoir lieu lors d'une session de simulation.
- 'Flight check' médical. Comme il est usuel dans la navigation aérienne, le personnel médical de l'EMM-H devra subir régulièrement un examen pratique en ce qui concerne l'aptitude médicale. La formation Crew Resource Management training (Formation en gestion des ressources du poste de pilotage) telle qu'elle est usuelle pour l'équipage du poste de pilotage peut aussi fournir des acquis utiles pour l'assistance médicale.
- Équipement de l'EMM-H. Tous les moyens, matériels et médicaments doivent être appropriés pour des enfants, quelle que soit la cause du problème médical.
- Étude nationale sur l'échographie préhospitalière. La collaboration entre les quatre EMM-H devrait permettre de réaliser une étude minutieuse des avantages et des inconvénients de l'échographie pour ce type d'assistance.
- Banque de données EMM-H nationale. Elle permettrait une poursuite de l'étude médicale et un contrôle de qualité. En Allemagne, une banque de données de ce type est opérationnelle.
- Informations depuis l'hôpital d'accueil. Actuellement, il est pratiquement impossible, pour des raisons relatives à la protection de la vie privée, d'obtenir de l'hôpital où le patient a été transporté des informations médicales complémentaires. L'obtention des informations standard, ne serait-ce que l'avis au médecin généraliste, permettrait à l'EMM-H de mieux connaître l'aboutissement de ses interventions.
- Aboutissement à long terme. On dispose de peu de données sur la façon dont l'état des enfants évolue par la suite. Une meilleure connaissance pourrait influencer le traitement primaire.

SAMENVATTING EN AANBEVELINGEN

Het helikopter Mobiel Medisch Team (H-MMT) is oorspronkelijk opgericht in Nederland om de medische zorg voor ongevalpatiënten buiten het ziekenhuis te verbeteren. Er is internationaal uitgebreid wetenschappelijk onderzoek verricht naar de potentiële voor- en nadelen van de toevoeging van een H-MMT aan de reguliere ambulancezorg. Vanwege grote verschillen in organisatie en training, is het resultaat van buitenlands onderzoek op dit gebied maar beperkt relevant voor de Nederlandse praktijk. Divers wetenschappelijk onderzoek in Nederland heeft echter bewezen dat het H-MMT gezondheidswinst oplevert, en mogelijk de kans op overlijden van patiënten vermindert. Een H-MMT is kosteneffectief als de relatie tussen kosten van het H-MMT en de financiële winst in levensjaren worden vergeleken.

De gegevens voor het onderzoek in dit proefschrift zijn verkregen door het verzamelen van alle H-MMT oproepen van het Nijmeegse MMT tussen 1 maart 2001 en 1 januari 2008. Er waren in deze periode 6749 H-MMT oproepen, waarbij in 891 gevallen kinderen (<18 jaar) betrokken waren. Deze 891 H-MMT oproepen voor kinderen vormen de basis voor de diverse hoofdstukken van het proefschrift. De auteur was zelf bij een deel van deze kinderen direct betrokken als behandelend arts in het veld. Vanuit diverse gegevens bronnen is een volledige database samengesteld, waarin zowel medische gegevens van voor, tijdens en na de ziekenhuis opname zijn ingevoerd.

De analyse van deze H-MMT gegevens is verricht om de volgende vragen te kunnen beantwoorden:

1. **Oproepen.** Wat waren de H-MMT oproepen van de Meldkamer Ambulancedienst (MKA), en welke daarvan hadden betrekken op kinderen. Wat was de verdeling over de MKA's, gerelateerd aan de melding en eventuele annulering van het H-MMT.
2. **Aard van het incident.** Wat waren de oorzaken waardoor het kind in nood was gekomen?
3. **Medische handelingen.** Welke medische handelingen werden verricht door het H-MMT? Welke handeling waren nuttig, en welke handeling waren schadelijk? Werden de handelingen correct en op het juiste moment toegepast?
4. **Lange termijn uitkomst.** Hoe was de latere conditie van de kinderen? Hoe was het herstel na het incident in relatie met vergelijkbare groepen kinderen?

In hoofdstuk twee word een overzicht gegeven van de geschiedenis en het vóórkomen van het kind in nood. Pas vanaf de negentiende eeuw is het een algemeen aanvaard idee dat een kinderleven kostbaar is, en dat kinderen beschermd moeten worden. Deze verandering wordt gestimuleerd door de toen nieuwe gedachte dat kinderen beschouwd kunnen worden als bouwstenen van de samenleving. Ondanks vele inspanningen overlijden ook nu nog miljoenen kinderen per jaar door goed behandelbare oorzaken. Het eerste levensjaar heeft het hoogste relatieve sterftecijfer van alle leeftijden van nul tot vierentwintig jaar, daarbij is de sterfte rond de geboorte hoger in Nederland dan in de meeste omringende landen. Sterfte bij kinderen door verkeersongevallen is in Nederland de laatste jaren gedaald, sterfte door andere ongevalmechanismen is zeldzaam. In andere landen blijkt ook dat bij een belangrijk percentage van alle kinderen die overlijden door een ongeval, sterfte vermijdbaar had kunnen zijn. De indirecte verantwoordelijkheid hiervoor ligt meestal bij volwassenen.

Hoofdstuk drie beschrijft de verschillen tussen de oproep frequenties van de H-MMT's van Nederland in relatie tot de verschillende Meldkamers Ambulancedienst (MKA). Het aantal bewoners van een MKA is recht evenredig met het aantal overledenen door ongevallen, het aantal verkeersongevallen met letsel en het aantal spoedeisende oproepen aan de MKA. Er is geen relatie tussen de hoeveelheid inwoners van een MKA en het aantal oproepen van een H-MMT. Alleen de H-MMT coördinerende MKA, waarvan er vier zijn in Nederland, hebben een hogere oproepfrequentie dan het landelijk gemiddelde. Er is een aanmerkelijk verschil tussen de MKA's met betrekking tot het oproepen van een H-MMT. In hoofdstuk vier worden de H-MMT oproepen met betrekking tot kinderen van één MKA weergegeven. Dertien procent van alle H-MMT oproepen betreffen kinderen in nood, het cancel percentage van een H-MMT oproep is lager dan bij volwassenen. De betrokken H-MMT regio bestaat uit zeven MKA's, maar de H-MMT coördinerende MKA heeft het hoogste percentage van licht tot matig gewonde kinderen. De andere zes MKA's in de regio roepen bij voorkeur alleen het H-MMT op als het kind in kritieke toestand is. De kinderen waarvoor een H-MMT werd opgeroepen, en waarbij het medische probleem niet door een ongeval werd veroorzaakt, hadden de grootste kans om de eerste 24 uur te overlijden. Het hoogste overlevingspercentage was bij de kinderen waarbij de oproep had plaatsgevonden op basis van de toedracht van een ongeval. Het inzetten van een H-MMT vanwege een bepaald soort ongeval, is een matig effectieve manier om de kinderen te selecteren. Het zou beter zijn als bij de redenen om een H-MMT op te roepen ook diverse ernstige ziektebeelden worden toegevoegd. De redenen om een reeds opgeroepen H-MMT te annuleren worden heel verschillend door de diverse MKA's toegepast.

Hoofdstuk vijf beschrijft de 891 H-MMT oproepen voor kinderen van het jaar 2001 tot en met 2008 waarbij het Nijmeegse H-MMT hulp heeft verleend. Het doel van dit onderzoek was om inzicht te krijgen in de hoeveelheid verrichtingen van het H-MMT en dit te vergelijken met de verrichtingen van de ambulancedienst. Er wordt hierdoor een overzicht verkregen van de handelingen voorbehouden aan een H-MMT arts, en de handelingen waar deze arts meer ervaring mee heeft. Van de 646 kinderen behandeld door het H-MMT, had 77,5% een ernstig tot zeer ernstig ongeval of ziektebeeld. 65% van deze kinderen onderging een medische behandeling voorbehouden aan het H-MMT. Tachtig procent van alle kinderen kreeg een medische behandeling waarin het H-MMT meer ervaren is dan de ambulance hulpverlening. Het H-MMT verzorgde handelingen met betrekking tot het zekeren van de luchtweg, het stabiliseren van de bloedsomloop en het behandelen van pijn.

Hoofdstuk zes geeft de handelingen met betrekking tot het veilig stellen van de luchtweg bij de kinderen weer. Een aanzienlijk percentage van alle kinderen die door het H-MMT behandeld werden, moest een beademingsbuis in de luchtweg krijgen. Bij de kinderen die reeds door de ambulance hulpverlener van een beademingsbuis waren voorzien en beademd werden, bleek in 37% van de gevallen dit niet correct te zijn verricht. Bij deze kinderen, waarbij de kleinere kinderen oververtegenwoordigd waren, moest de arts van het H-MMT met spoed het inbrengen van de beademingsbuis herhalen om zuurstof toediening en beademing weer mogelijk te maken. Het inbrengen van een beademingsbuis bij kinderen mag alleen door hierin zeer ervaren hulpverleners plaatsvinden.

In hoofdstuk zeven staat een onderzoek dat verricht werd naar aanleiding van complicaties die ontstaan waren bij drie kinderen die buiten het ziekenhuis een beademingsbuis ingebracht hadden gekregen. Bij deze drie kinderen bleek na het uithalen van de beademingsbuis een beschadiging van de luchtpijp te zijn ontstaan, waardoor de luchtpijp ernstig vernauwd was. Door middel van een operatie moest bij deze drie kinderen het vernauwde deel van de luchtpijp verwijderd worden. Hierom werden vervolgens alle gegevens verzameld van de patiënten waarbij door een H-MMT een beademingsbuis werd ingebracht. Zo werd bestudeerd welke risico factoren voor beschadiging van de luchtpijp aanwezig waren in deze situatie. De drie risico factoren, bekend uit de medische literatuur zijn: het gebruik van medicijnen die de bloedvaten laten samentrekken, een ernstige bloeddruk daling, en het te hard opblazen van het ballonnetje van de beademingsbuis de luchtpijp afsluit. Eén of meerdere van deze factoren werd gevonden in 89% van alle patiënten. De meest voorkomende risico factor was een te hard opgeblazen ballonnetje van de beademingsbuis, hoewel door de hulpverleners ook in deze gevallen wel de hiervoor geldende richtlijn van het landelijk protocol ambulancezorg gevolgd was. Hoofdstuk acht is een overzicht van de medische literatuur over halswervelletsel (CSI) bij kinderen. Er werd in de Pubmed database gezocht naar relevante artikelen, met dezelfde zoekgegevens die eerder bij een vergelijkbaar overzichtsartikel naar CSI bij volwassenen was gebruikt. Er zijn geen gerandomiseerde onderzoeken naar het immobiliseren van de halswervelkolom bij kinderen. Hoewel veel protocollen die ontwikkeld zijn voor volwassenen ook bij kinderen worden toegepast, ontbreekt daarvoor iedere wetenschappelijke basis. De aard en het niveau van CSI bij kinderen is sterk gerelateerd aan de leeftijd, en kan aanmerkelijk anders zijn dan bij volwassenen. Bij kinderen zijn wel de nadelige gevolgen van het immobiliseren van de wervelkolom vastgelegd. Als een kind een halskraag krijgt, en verder wordt geïmmobiliseerd, vraagt dat veel zorg en aandacht van de betrokken hulpverleners. De noodzaak van deze maatregel moet voortdurend kritisch worden herbeoordeeld, en zo spoedig mogelijk worden opgeheven.

Hoofdstuk negen is een beoordeling van de bone injection gun (BIG). Dit hulpmiddel wordt gebruikt om snel een toegang tot de bloedsomloop te krijgen als een infuusnaald moeilijk in te brengen is. De BIG schiet door middel van een sterke veer een holle naald in een bot, daardoor kan dan infuusvloeistof en medicijnen gegeven worden. Via de holte van het bot, wordt dan snel de bloedsomloop bereikt. Een BIG is een effectief en veilig hulpmiddel om patiënten buiten het ziekenhuis mee te behandelen. Hoewel het hier om een onderzoek met kleine aantallen gaat, lijkt de BIG toch minder efficiënt te zijn bij kinderen jonger dan een jaar.

Hoofdstuk tien beschrijft het toepassen van snelle echografie door het H-MMT. Aan de hand van twee patiënten en een overzicht van de relevante medische literatuur, wordt een beeld gegeven van de mogelijkheden. Door echografisch onderzoek van het hart, de longen en de buik kan belangrijke informatie gekregen worden die besluitvorming kan beïnvloeden. Het is een hulpmiddel voor het beoordelen en stabiliseren van de luchtweg, ademhaling en bloedsomloop. Tevens kan een betere inschatting gemaakt worden naar welk ziekenhuis de patiënt het beste vervoerd kan worden. Er moet wel speciale aandacht gegeven worden aan de training van de arts die dergelijk echografisch onderzoek verricht. Ten alle tijde moet voorkomen worden dat dit onderzoek ongewenste vertraging van de aankomst van de patiënt in het ziekenhuis veroorzaakt.

Hoofdstuk elf bestaat uit de beoordeling door een panel van deskundigen van het onderzoek, de behandeling en de keuze van het H-MMT. Door een willekeurige steekproef van twintig patiënten uit het totale bestand, wordt door dit panel de medische zorg voor de kinderen beoordeeld. In bijna een kwart van de items konden de deskundigen geen oordeel geven over het H-MMT, omdat er geen specialistische medische handelingen nodig waren. Er werden geen onterechte handelingen of beslissingen door het panel vastgesteld. Het H-MMT maakte goede keuzes met betrekking tot de keuze van het ziekenhuis en de diagnostiek. In zeven van de twintig gevallen was het onduidelijk of de inzet van het H-MMT wel nodig was.

Hoofdstuk twaalf beschrijft de lange termijn uitkomst van kinderen die door het H-MMT zijn behandeld. De uitkomst van deze kinderen werd op systematische wijze vergeleken met gezonde kinderen van dezelfde leeftijd, met kinderen met hersenletsel en met kinderen met een chronische ziekte. De kinderen behandeld door het H-MMT hadden een lagere gemiddelde score op lichamelijk en geestelijk functioneren dan kinderen uit de gezonde groep. Het gemiddelde lichamelijk en geestelijk functioneren van de kinderen die door het H-MMT behandeld waren, was eerder vergelijkbaar met kinderen met een chronische ziekte. Zelfs na twee tot vijf jaar hadden de kinderen die door het H-MMT behandeld waren niet dezelfde kwaliteit van leven als hun leeftijdsgenoten.

AANBEVELINGEN

Meldkamer Ambulancedienst:

- Gestructureerde scholing over de oproep criteria van een H-MMT. Er zijn teveel beoordelingsverschillen tussen de verschillende MKA's.
- Strikte naleving van het H-MMT protocol. De verspreiding van H-MMT oproepen over Nederland is wisselvallig, en niet afhankelijk van voor de hand liggende factoren als: inwonersaantal, vliegafstand, aantal verkeersongevallen, of aantal spoedritten van een ambulance.
- Aanpassing van de oproep criteria zodat een zowel bij ernstig zieke als ernstig gewonde kinderen het H-MMT opgeroepen wordt.
- Oproepen op basis van een criterium gerelateerd aan het bewustzijn van de patiënt. Het oproepen van een H-MMT op basis van het ongevalmechanisme blijkt niet erg efficiënt te zijn bij kinderen.

Ambulancehulpverlening (AHV):

- Betere samenwerking tussen de AHV en het H-MMT. De AHV en het H-MMT zijn de partners in de hulpverlening van het vitaal bedreigde kind. Omdat dit type ervaring schaars is bij het AHV, zal samenwerking met betrekking tot het ontwikkelen van protocollen, oefening en medische zorg verbeterd moeten worden.
- Gestructureerd onderwijs over het vitaal bedreigde kind. De deskundigen op dit gebied moeten onderwijs verzorgen aan de AHV over medische handelingen en juiste keuze van ziekenhuis.
- Scholing met betrekking tot de luchtweg. Herkenning en behandeling van de bedreigde luchtweg is van vitaal belang. Het inbrengen van een beademingsbuis bij een kind is een specialistische handeling die alleen door zeer ervaren personeel mag worden gedaan.
- Scholing in het behandelen van pijn. Pijnbestrijding bij kinderen buiten het ziekenhuis kan verbeterd worden.
- Landelijke cancel criteria voor het H-MMT. Na de primaire inzet van het H-MMT door de MKA kan de AHV ter plaatse het H-MMT annuleren. Deze annulering lijkt onderhevig te zijn aan plaatselijke interpretatie, er zijn geen landelijke criteria.

H-MMT:

- Keuze van H-MMT artsen. Alleen artsen met uitgebreide ervaring in het opvangen van kinderen in nood in het ziekenhuis, kunnen deze taak verrichten bij een H-MMT.
- Training. De H-MMT arts en verpleegkundige moeten allen de APLS of EPLS cursus hebben gevolgd, en de stof blijven beheersen op instructeurs niveau. Deze training met bijbehorend examen zouden uitstekend in een simulator sessie kunnen plaatsvinden.

- Medische 'flight check'. Net zoals gebruikelijk is in de luchtvaart, zal het medische personeel van het H-MMT regelmatig praktijk examen moeten afleggen met betrekking tot de medische vaardigheid. Ook uit de Crew Resource Management training zoals gebruikelijk voor een cockpit bemanning, kunnen nuttige zaken voor de medische hulpverlening geleerd worden.
- Uitrusting van het H-MMT. Alle hulpmiddelen, materialen en medicijnen moeten geschikt zijn voor kinderen, ongeacht de oorzaak van het medische probleem.
- Landelijk onderzoek over prehospitale echografie. Door samenwerking van de vier H-MMT's zou het mogelijk zijn zorgvuldig onderzoek te doen naar de voordelen en nadelen van echografie bij dit type hulpverlening.
- Landelijke H-MMT database. Hierdoor zou verder medisch onderzoek en kwaliteitscontrole mogelijk zijn, in Duitsland is een dergelijke database operationeel.
- Informatie vanuit het ontvangende ziekenhuis. Op dit moment is het om privacy redenen bijna onmogelijk om vanuit het ziekenhuis waar de patiënt naar toe is toegebracht, aanvullende medische gegevens te krijgen. Het krijgen van de standaard informatie, al was het maar het bericht aan de huisarts, zou het inzicht van de H-MMT in de uitkomst van zijn handelingen vergroten.
- Lange termijn uitkomst. Er zijn weinig gegevens over de verdere ontwikkeling van de kinderen, een beter inzicht zou de primaire behandeling kunnen beïnvloeden.

LIST OF PUBLICATIONS

1. Gerritse BM, Gielen MJM. Subdurale blokkade tijdens spinale anesthesie. Nederlands Tijdschrift voor Anesthesiologie 1995(8), 79-81
2. Gerritse BM, Dongen RTM van, Crul BJP. Epidural fibrin glue stops persistent cerebral spinal fluid leak during long-term intrathecal catheterization. Anesthesia and Analgesia 1997;84(5):1140-1
3. Gerritse BM, Dongen RTM van, Crul BJP. Epidural fibrin glue injection. Dolor 1997 (12), 27
4. Gerritse BM, Voss A, Schneeberger P, Gielen MJM. Meningitis na spinale anesthesie, incidentie en preventie van infectie. Nederlands Tijdschrift voor Anesthesiologie 1997(10),49-51
5. Gerritse BM, Liem TH. Thoracic epidural analgesia is not associated with an increase of serum creatinine. Regional Anaesthesia 1997(9),172
6. Crul BJP, Gerritse BM, Dongen RTM van, Schoonderwaldt HC. Epidural fibrin glue injection stops persistant postdural puncture headache. Anesthesiology 1999;91(2):576-7
7. Gerritse BM, Gielen MJM. Seven months delay for epidural blood patch in post-dural puncture headache. European Journal of Anaesthesiology 1999;16(9):650-1
8. Dongen RT van, Gerritse BM. Epidural blood patch in varicella infection. Anesthesia Analgesia 2005;101(4):1248
9. Gerritse BM. Letsel van de cervicale wervelkolom bij kinderen. Intensive Care Capita Selecta 2005, redaktie J Bakker ea. Uitgeverij Venticare, Utrecht.
10. Gerritse BM, Hek LFGM van 't, Kramer WLM, Eijk RJR. Triage en transport van vitaal bedreigde kinderen. In: Handboek Kindertraumatologie 2006, redactie WLM Kramer ea. Uitgeverij de Tijdstroom, Utrecht
11. Gerritse BM, Biert J, Vugt AB van, Scheffer GJ. A single nighttime trauma helicopter does not represent a significant improvement in emergency assistance. Nederlands Tijdschrift voor Geneeskunde 2006;150(30):1701-2
12. Lemson J, Grunsven PM, Schipper IB, Valk JP, Christiaans HM, Gerritse BM, Scheffer GJ. Helikopter Mobiel Medische Teams in Nederland. Belangrijke verschillen in inzetfrequentie tussen meldkamer regio's. Nederlands Tijdschrift voor Geneeskunde 2008;152(19), 1106-1112
13. Gerritse BM, Draaisma JMT, Schalkwijk A, Grunsven PM van, Scheffer GJ. Should EMS-paramedics perform paediatric tracheal intubation in the field? Resuscitation 2008;79(2):225-9
14. Eijk RJR, Gerritse BM. De inzet van het MMT bij een ernstige beknellings situatie. Critical Care 2008;5(6):6-9

15. Gerritse BM, Draaisma JMT, Besselink-Lobanova A, Pelzer BJ, Marres HA, Scheffer GJ. Prehospital tracheal tube cuff pressure: an important risk factor for iatrogenic tracheal stenosis. Resuscitation 2009;80(8):962
16. Gerritse BM, Scheffer GJ, Draaisma JMT. Prehospital intraosseous access with the bone injection gun by a helicopter-transported emergency medical team. Journal of Trauma 2009;66(6):1739-1741
17. Gerritse BM, Schalkwijk A, Draaisma JMT, Scheffer GJ. Advanced medical life support procedures in vitally compromised children by a Helicopter Emergency Medical Service. BMC Emergency Medicine 2010,10:6
18. Gerritse BM, Dirven PJ, Draaisma JMT, Scheffer GJ. Prehospitale echografie in Nederland door het Mobiel Medisch Team. Nederlands Tijdschrift voor Anesthesiologie 2010,22(2):17-21
19. Gerritse BM, Pelzer B, Draaisma JMT, Scheffer GJ. The deployment of a Helicopter Emergency Medical Service for vitally compromised children in the Netherlands. Internet Journal of Aeromedical Transportation 2010;2:1

MATERIAL FROM THIS THESIS HAS BEEN PRESENTED AT THE FOLLOWING MEETINGS:

Waarom speciale aandacht voor het vitaal bedreigde kind?
BM Gerritse
PAOG Urgentiegeneeskunde, 2005, Vrij Universiteit Amsterdam

Cervicale wervelkolom letsels bij kinderen.
BM Gerritse
Venticare 2005, Utrecht

Prehospital endotracheal intubations in vitally comprised children in The Netherlands
A Schalkwijk, BM Gerritse, JMT Draaisma
27th International Symposium on Intensive Care and Emergency Medicine, 2006 Brussel Belgium

Added medical value of a helicopter-transported medical team on emergency prehospital pediatric care in The Netherlands
Gerritse BM, Schalkwijk A, Draaisma JMT
27th International Symposium on Intensive Care and Emergency Medicine, 2006 Brussel Belgium

Prehospital tracheal intubation in vitally compromised children in the Netherlands.
JMT Draaisma, BM Gerritse
ERC Resuscitation, 2006 Stavanger

Prehospital Risk Factors for Iatrogenic Tracheal Stenosis
BM Gerritse, A Besselink-Lobanova, JMT Draaisma,
World Congress of Disaster and Emergency Medicine, 2007 Amsterdam

Prehospital tracheal intubation in vitally compromised children in the netherlands
JMT Draaisma, BM Gerritse, A Schalwijk
9th Scientific Congress European Resusciation Council, 2008 Ghent Belgium

The bone injection gun as a rapid method to get circulatory access
JMT Draaisma , GJ Scheffer , BM Gerritse
9th Scientific Congress European Resusciation Council, 2008 Ghent Belgium

Pediatric endotracheal intubations in the field by a helicopter transported medical team

BM Gerritse, JMT Draaisma
Airmed 2008, Prague, Czech Republic

Long-term health related quality of life of children treated by a Helicopter Emergency Medical Service
R Malschaert, BM Gerritse
Airmed 2008, Prague, Czech Republic

Risicofactoren voor iatrogene tracheastenose bij prehospitale endotracheale intubatie
A Besselink-Lobanova, BM Gerritse, JMT Draaisma
Anesthesiologendagen, Nederlandse Vereniging voor Anesthesiologie, Maastricht 22 mei 2008

Prehospitale opvang van vitaal bedreigde kinderen: hoe noodzakelijk is het Mobiel Medisch Team?
H Custers, BM Gerritse, JMT Draaisma
Anesthesiologendagen, Nederlandse Vereniging voor Anesthesiologie, Maastricht 23 mei 2008

ABBREVIATIONS

AHV	Ambulance hulpverlening
ALS	Advanced life support
APLS	Advanced Paediatric Life Support
ATLS	Advanced Trauma Life Support
BIG	Bone Injection Gun
BVMV	Bag-valve-mask-ventilation
CFA	Confounding Factor Asymmetry
CHQ	Child Health Questionnaire
CHQ-PF	Child Health Questionnaire-Parental Form
CPR	Cardiopulmonary resuscitation
CSI	Cervical Spine Injury
DI	Disagrement Index
EMS	Emergency Medical Service
EPLS	European Pediatric Life Support
EZ-IO	Easy Intraosseous
FAST	Focused Abdominal Sonography in Trauma
GCS	Glasgow Coma Scale
HEMS	Helicopter Emergency Medical Service
HRQOL	Health Related Quality Of Life
IPR	Interpercentile Range
IPRAS	Interpencentile Range Adjusted for Symmetry
ISS	Injury Severity Score
JRA	Juvenile Rheumatio Arthritis
KED	Kendrick Extrication Device
MESH	Medical Subject Heading
MRI	Magnetic Resonance Imaging
MKA	Meldkamer Ambulancedienst
MMT	Mobiel Medisch Team
NACA	National Advisory Committee for Aeronautics
PREP	Programme Rapide d'Echo-évaluation du Polytraumatisé
RAM	RAND/UCLA Appropriateness Method
RAND	Research and Development Corporation
RTS	Revised Trauma Score
SAD	Supraglottic Airway
SCIWORA	Spinal Cord Injury Without Radiologic Abnormalities
SD	Standard deviation
SPSS	Statistical Package for the Social Sciences

RTS	Revised Trauma Score
TBI	Traumatic Brain Injury
TI	Tracheal intubation
TRNE	Trauma Region Netherlands East
WHO	World Health Organisation

DANKWOORD

De huidige Dalai Lama heeft ooit gezegd: 'Judge your success by what you had to give up in order to get it'. Als ik terug kijk naar de afgelopen jaren, heb ik niet veel hoeven opgeven om het proefschrift succesvol af te ronden. Het schrijfwerk heeft voornamelijk plaatsgevonden in de avonduren thuis en tijdens rustige diensten op de helikopter-basis of in het ziekenhuis. Ik heb wel veel gewonnen; door alle steun die ik gekregen heb van de mensen om mij heen, voel ik me een rijk en gelukkig mens.

Mijn bijzondere dank gaat uit naar:

Mijn Co-promotor: dr. Jos Draaisma. Zonder jouw ontembare enthousiasme was ik niet aan het proefschrift begonnen, en alleen door je positieve energie en vasthoudendheid ben ik tot het einde gekomen. De relatie van co-promotor en promovendus liep door onze andere relaties heen: buren, vrienden en hardloopmaatjes. Je bent altijd optimistisch gebleven over dit project, er is in de afgelopen vijf jaar ook geen onvertogen woord gevallen. Ik sta hierom voor altijd bij je in het krijt, en weet niet hoe ik je moet bedanken. Ik hoop dat ik door dit proefschrift te maken heb bijgedragen aan je professionele levensdoel: het verbeteren van de medische zorg voor kinderen in nood. Het mooiste zou natuurlijk zijn als dit proefschrift iets zou veranderen aan de prehospitale zorg in Nederland. En natuurlijk, als dit proefschrift ook maar iets uitmaakt voor één kind dat in nood is, is het al de moeite waard geweest.

Zaterdag weer hardlopen?

Mijn promotor: prof. dr. Gert Jan Scheffer. Ik ben je erg dankbaar voor al je steun bij het uitvoeren van dit project. Onze samenwerking heeft altijd meer ingehouden dan alleen dit proefschrift, en ik denk met veel plezier terug aan de jaren dat ik als staflid bij jou op de afdeling heb gewerkt. Tijdens je oratie had je het spotlicht al op het Mobiel Medisch Team gezet, en ik merkte vanaf het begin dat je een oprechte interesse voor de prehospitale hulpverlening had. Jij zag bovendien direct in dat de kennis en vaardigheden van de anesthesioloog een onmisbaar deel van dit werk zijn, hierdoor werd de participatie van onze discipline versterkt. Ik had beloofd dat ik dit project af zou maken toen ik vertrok uit het UMC St Radboud. Ik ben er trots op dat ik hierbij het eerste proefschrift over het Nijmeegse helikopter-MMT bij je af kan leveren.

Leden van de manuscriptcommissie:
Prof.dr. Kees van Laarhoven, Prof.dr. Ronald de Groot, Prof.dr. Hans van Vugt, dank voor jullie bereidheid om mijn manuscript te willen beoordelen. Het raakvlak tussen mijn proefschrift en jullie vakgebieden: heelkunde, kindergeneeskunde en kinder-intensive care demonstreert maar weer dat acute geneeskunde altijd een multidisciplinair proces is.

Mijn medeauteurs:
Joris Lemson: We hebben elkaar op de 1e dag van de opleiding tot anesthesioloog ontmoet, en zijn daarna jarenlang als gezworen kameraden door het St. Radboud gegaan. We hebben stages, examens en congresbezoeken gedeeld, en vaak als duo complexe patiënten opgevangen. Ik was eerder actief bij het MMT dan jij, maar jij had bij je komst meer visie hoe dit type hulpverlening tot wetenschappelijke productie zou kunnen leiden. Dankzij jouw investering van heel veel tijd en energie heb je de vier Lifeliners tot wetenschappelijke samenwerking kunnen krijgen, wat resulteerde in de gegevens in hoofdstuk drie. Ook al werken we nu in verschillende ziekenhuizen, de band blijft.

Prof. dr. Gert Jan van der Wilt: Voor het schrijven van dit proefschrift heb ik veel meer van je kennis geprofiteerd dan bij een eerste lezing zou blijken. Door de steun van de door jou geleide afdeling Epidemiologie, Biostatistiek en Health Technology Assessment heb ik kunnen profiteren van je enthousiaste en begaafde studenten en medewerkers. Tijdens onze gesprekken, met koffie en lekkere koekjes, brachten je scherpe analyses en vragen me steeds weer op het juiste pad.

Dr. Pierre van Grunsven: Er kan geen MMT functioneren zonder goede samenwerking met de ambulancehulpverlening, en zonder jou waren er geen bruggen geslagen. Niet alleen het wetenschappelijk onderzoek, maar ook bij 'brandjes blussen' bij de reguliere hulpverlening hadden wij een prima samenwerking.

Prof. dr. Inger Schipper, Herman Christiaans, Jens Valk: Achteraf moeilijk voor te stellen, maar de samenwerking tussen de Lifeliners voor het verkrijgen van de gegevens van hoofdstuk drie was een primeur. Ik wil jullie bedanken voor het leveren van de data, en het kritisch lezen van de tekst.

Dr. Ben Pelzer; We waren al bevriend geraakt via onze zonen, en stonden ze regelmatig samen aan te moedigen bij het hockeyveld. Toen ik door mijn verandering van werkplek verdere support in statistische bewerking moest missen, was je meteen bereid om de berekeningen op je te nemen. Je was, als wiskundige verbonden aan de faculteit der sociale wetenschappen, niet bekend met medische helikopter hulpverlening. Hierdoor werd ik gedwongen mijn vragen helder te formuleren, en kwam je met frisse en verrassende oplossingen.

Annelies Schalkwijk; In principe was jij de stagiaire, en ik de stagebegeleider, maar we wisselden regelmatig van rol. Ik heb veel van je geleerd, en heb veel respect voor je tomeloze inzet, bijzondere intelligentie, en je vermogen om hindernissen te overwinnen.

Anna Besselink-Lobanova; Je hebt, zoals altijd kordaat en gemotiveerd, de gegevens geordend die de basis vormen voor het onderzoek in hoofdstuk zeven. Большое спасибо! Ik ben er trots op dat je nu ook bij ons in de maatschap in Breda gekomen bent.

Prof. Dr. Henri Marres; het onderzoek in hoofdstuk zeven is verricht naar aanleiding van een vraag die je me via de mail stelde. Ik heb het antwoord op je vraag gevonden. Ik ben ervan overtuigd dat dit onderzoek en de daaruit voortvloeiende maatregelen letsel bij patiënten heeft voorkomen. Bedankt voor de samenwerking.

Perjan Dirven; Toen je een Franstalige echocursus voor de snelle opvang van multitrauma patiënten in Nederland wilde introduceren, heb je mij gevraagd als mede-instructeur en tolk/vertaler. Na een vijftiental cursussen kunnen we wel spreken van een doorslaand succes. In hoofdstuk tien is een weergave van de toepasbaarheid van deze nieuwe techniek in het prehospitale veld. Het is mij een genoegen met je bevriend te zijn, al ben ik wel altijd wat jaloers omdat je in nog vreemdere landen dan ik anesthesie heb gegeven.

Rob Malschaert; Je hebt je moedig door een enorme brij van gegevens in databases, patientendossiers en enquête formulieren heen moeten worstelen om de gegevens in hoofdstuk elf en twaalf te kunnen verzamelen. Je hebt gekozen voor een carrière in het bedrijfsleven, maar ik weet zeker dat je met jouw talent je doelen zult bereiken.

Amon Heijne; Database koning! Dank voor je supersnelle hulp bij de getallen voor hoofdstuk vijf.

Bianca Sonneveldt-van Winssen, Laura van der Have, Karen van Driel, Karen van Zuidgeest, Miranda van Tits en Aniek van Heeswijck; jullie zijn de office managers en secretaresses die mij op beslissende momenten steeds weer te hulp schoten. Heel erg bedankt!

Medewerkers en instructeurs van de Stichting Spoedeisende Hulp bij Kinderen; De SSHK loopt als een rode draad door mijn proefschrift. Mijn co-promotor is een van de oprichters, en diverse instructeurs zijn mede-auteur van hoofdstukken of lid geweest van het expert panel in hoofdstuk 11. De expertise binnen de SSHK heeft mijn blik op de acute geneeskunde gevormd, dank voor alle steun bij het verspreiden van mijn proefschrift.

Annelies Willems en Monique Haag van Abbott, Hoofddorp: bedankt voor jullie steun bij het verspreiden van het proefschrift.

Leden van het MMT Nijmegen

Dit proefschrift gaat over de 891 kinderen waarvoor het MMT Nijmegen in de periode van 2001 tot en met 2008 opgeroepen is. Daarnaast zijn we in die periode ook nog opgeroepen voor 5858 volwassenen, maar daar moet iemand anders maar op promoveren.

Jullie weten welke dramatische gebeurtenissen, met beeld en geluid, aan de kille getallen en tabellen verbonden zijn. Als ik blader door het boekje komen ze aan mijn ogen voorbij: hulpverlenen aan de waterkant, op het zebrapad voor een schoolplein, op de grond in een kinderkamer… Een reddingspoging, soms tegen beter weten in, wanhopige ouders kijken toe. De hulpverleners moeten in een enkel moment, en op basis van beperkte gegevens, moeilijke keuzes maken en lastige handelingen verrichten. Er wordt na een dramatische inzet met een kind nog dagen nagepraat in het team. En met alle inzichten achteraf, die slechts in een ziekenhuis verkregen kunnen worden, moeten die keuzes op straat nog steeds de beste zijn geweest. De kinderen waar mijn proefschrift over gaat, zijn ook van jullie. Ik weet dat we allemaal onze uiterste best hebben gedaan.

Ruud Eijk en dr. Jan Biert: Ere wie ere toekomt, jullie zijn de dokters die het MMT Nijmegen van de grond hebben gekregen. Eerst met een bus, later met diverse soorten helikopters, veranderde het MMT in een professionele organisatie. Het begon allemaal met een groepje bevriende collega's die vonden dat de zorg voor mensen in nood beter kon in onze regio. Bedankt dat ik een lid van het team mocht zijn. En Ruud, nog bedankt dat je me toen in het ziekenhuis in Pakistan kwam aflossen, ik wilde inderdaad wel graag naar huis.

René Ligtenberg en Hans van der Meer, chief nurses MMT. En natuurlijk, de eer van voor het oprichten van het Nijmeegse MMT komt minstens, minstens evenveel aan jullie toe. De eerste jaren werden de oproepen van het MMT informeel geregeld, jullie wisten wanneer welke dokter thuis was. Na het telefoontje met 'kan je mee?' haastte ik me dan naar de bushalte bij mijn huis, soms met de overall over mijn pyjama heen. Na een sprong in een bus met nog draaiende banden, volgde altijd een spannende rit. Op de incident locatie werden we met de aller ernstigste zaken geconfronteerd. Het is juist deze periode van 1996 tot 2001 die mij overtuigd hebben van het nut en noodzaak van een MMT.

MMT verpleegkundigen: dank voor jullie steun en kameraadschap. Tijdens de honderden inzetten die ik met jullie gedaan heb, hebben we dingen gezien die anderen in de gezondheidszorg gelukkig zelden zullen meemaken. Jullie hebben ook altijd goed op mij gepast als ik weer eens in of onder een wrak kroop, in een liftschacht hing, of in de cabine zat van een tankwagen met aceton. Bedankt, ik ben nog heel.

Piloten van Schreiner Airways en ANWB-Medical Air Assistance: Het is door jullie professionalisme en ervaring dat al die over-gemotiveerde artsen en verpleegkundigen weer veilig thuis zijn gekomen. Zonder jullie was het allemaal niet mogelijk geweest.

Harry Smit: Als coördinator MMT was je jarenlang de baas, en heb je de organisatie goed op poten gezet. Als een echte pionier trek je dan weer door, maar we komen elkaar vast weer tegen. En dan die ongelooflijk gezellige congresbezoeken in Barcelona, Interlaken en Londen.....!

Lucien Engelen: Hoewel we eigenlijk maar kort in hetzelfde ziekenhuis gewerkt hebben, kunnen we het goed met elkaar vinden. Je kennis en contacten in de ambulance hulpverlening zijn uiterst belangrijk voor de verdere verankering van het MMT in het prehospitale veld. Ik ben je ontzettend erkentelijk dat je het voortouw hebt genomen om aansluitend aan de promotie ook een symposium te organiseren. Hierdoor onstaat weer een kans om de zorg voor vitaal bedreigde kinderen in Nederland te verbeteren.

Beste Ambulance verpleegkundigen, Ambulance chauffeurs, OVD's en MKA-centralisten:
Sinds mijn allereerste kennismaking met de ambulance hulpverlening als geneeskunde student, heb ik respect voor jullie en het moeilijke werk dat jullie verrichten. Jullie staan aan de frontlinie van de gezondheidszorg, en moeten het in de gekste omstandigheden maar weer zien op te lossen. In die honderden MMT-inzetten heb ik veel van jullie geleerd, dank voor de samenwerking.

Uit het ziekenhuis

Stafleden Anesthesiologen UMC St Radboud: Ik wil jullie bedanken voor de goede opleiding die ik genoten heb, en voor de prettige samenwerking in de latere jaren. Ik heb op veel locaties en in diverse landen anesthesie gegeven, en ik was altijd blij met de goede fundering die tijdens mijn opleiding in het UMC St Radboud is gelegd.

Anesthesie-assistenten, chirurgie-assistenten, dokter-assistenten en alle verpleegkundigen van het UMC St Radboud en het Amphia Ziekenhuis: bedankt voor de gezellige samenwerking en jullie geduld bij het aanhoren van mijn sterke verhalen. Net als al die andere dokters ben ik best wel eigenwijs, maar ik heb ook altijd goed naar jullie geluisterd.

Mijn maten van de maatschap Bredase en Oosterhoutse Anesthesiologen (BOA): Ik ben er trots op dat ik door jullie ben aangenomen, en heb het in Breda reuze naar mijn zin. Dank voor het warme onthaal en alle vrolijkheid.

Paranimfen: jullie zijn beiden vriend en voorbeeld. Dr. Marcel Hasenbos, een echte clinicus, kunstliefhebber, maar stiekem ook een succesvolle wetenschapper (meer dan 600 keer geciteerd volgens Google Scholar). Dr. Anton Visser, dank zij jou heb ik een succesvolle overstap naar de periferie gemaakt, en liet je me zien dat promoveren in een drukke perifere praktijk heel goed mogelijk is.

Lieve familie

Papa: Je bent sinds altijd mijn lieve vader, maar ook steeds een vriend en mijn held. Hoewel Mama er al lange tijd niet meer is, leeft ze in onze harten voort, en koesteren wij samen alle mooie herinneringen aan haar. Ik had me geen lievere en leukere ouders kunnen wensen.

Matthijs en Emma: Vader worden was mijn grootste wens, en ik heb het wonder mogen meemaken om jullie te zien opgroeien. Ik geniet enorm van jullie, en ik ben er trots op hoe jullie geworden zijn.

Jessica: Ik ken je nog maar sinds mijn 18e, maar de liefde is van altijd. We delen zoveel met elkaar, en vormen steeds weer samen een sterk team. Naast al onze bezigheden en avonturen, had je zelfs geen bezwaar tegen mijn wens om te promoveren; zonder jou was ik niet hier gekomen. Thanks for all the love.

CURRICULUM VITAE

Bas Gerritse was born in Voorburg, the Netherlands, on 5 May 1963. After living in the United States and Canada for a time in early childhood, he attended secondary school in France. In 1981 he graduated with a Baccalauréat Mathématiques et Sciences de la Nature from the Lycée International in Saint Germain-en-Laye, France. Subsequently he enrolled in the Faculty of Medicine of the University of Amsterdam. Bas was also enrolled in the Faculty of Languages of the University of Amsterdam as a student of Slavic Linguistics and Literature. Bas received his medical degree in 1991 and, after an 8-month general surgery residency at the De Heel Hospital in Zaandam, started his anaesthesiology residency at the Radboud University in Nijmegen from 1992 until 1997. He accepted a position as staff anaesthesiologist and worked in various subspecialties at the Radboud University until 2008. Starting with a special interest in paediatric anaesthesia and paediatric cardiac anaesthesia, he was also drawn into the emerging field of pre-hospital medical care as a member of the Nijmegen Mobile Medical Team. Starting in 1996 with a customised van, and using a helicopter after 2001, Bas provided medical care in the field in hundreds of incidents.

Bas is an instructor for the Advanced Paediatric Life Support course, and was one of the founders of the Dutch version of the French ultrasound course, PREP.

In his spare time he has also worked as a physician at motorcycle and car races, and as an anaesthesiologist in the Diakonessen Hospital, Paramaribo, Surinam, and the Oduber Hospital in Aruba. After the 2005 earthquake in Pakistan Bas was employed by the Cordaid relief agency to provide paediatric anaesthesia in the (highly improvised) District Hospital Menshera, Pakistan. He has also worked for the Eardrop Foundation in the President Moi Hospital, Eldoret, Kenya, in a project dedicated to the prevention and treatment of deafness in children. He has been working in a group practice of 27 anaesthesiologists in the Amphia Ziekenhuis in Breda since 2008.

Bas is married to Jessica de Boer and is the proud father of Matthijs and Emma.