HELICOPTER EMERGENCY MEDICAL SERVICES

Effects, Costs and Benefits

A.N. Ringburg

Colofon

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EFFECTS, COSTS AND BENEFITS

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Introduction and Outline of Thesis

INTRODUCTION

Advanced prehospital medical care with air transport was introduced in the Netherlands in May 1995. The first helicopter Mobile Medical Team, also called Helicopter Emergency Medical Service (HEMS) was a joint venture initiative of the VU Medical Center in Amsterdam and the Algemene Nederlandse WielrijdersBond (ANWB). The medical team consisted of a trauma surgeon or anaesthesiologist and a specialised trauma nurse, whereas, the ANWB Medical Air Assistance (MAA) helicopter company supported the prehospital medical care by providing a helicopter and a helicopter pilot. The HEMS team was on stand-by during daylight hours, from 7.00 – 19.00 hours, and able to take off within 2 minutes after an emergency call. This provisional Helicopter Emergency Service was connected to a study on cost-effectiveness from 1995 till 1998. In this study the cost-effectiveness of HEMS was established for trauma[1].

The main purpose of the Dutch HEMS system was to rapidly transport expert medical care to the trauma patient outside the hospital, in addition to the regular ambulance services (EMS). This way Advanced Trauma Life Support (ATLS) [2] and extensive (invasive) therapeutical options were brought to the accident scene [1, 3]. The supplemental therapeutic options included the administration of specific medication anaesthesia and analgesia, Advanced Airway Management, chest tube drainage or thoracocentesis, and the performance of several surgical interventions. The HEMS medical expert also coordinated overall prehospital management of the trauma patient as in treatment sequence and priorities, and the logistics and decision making concerning transport destinations.

Frequent dispatch of a limited number of (para)medics to seriously injured patients in difficult prehospital situations provided a considerable expertise to a specific group within a short period of time. Management of seriously injured trauma patients on the accident scene was a key issue. Due to topographical and logistical reasons only 5-20% of the HEMS-assisted patients were transported by helicopter in the Netherlands. If indicated, the HEMS physician accompanied the patient in the ambulance in order to monitor the patient and to provide additional medical assistance during transport to the hospital.

Analyses of the first years of prehospital experiences suggested a survival benefit for patients treated by HEMS compared with regular ambulance care, which was found to be most pronounced for moderately injured traffic casualties [1, 4]. Based upon these results, trauma teams transported via helicopter were introduced nationwide in the Netherlands, with HEMS-stations in Amsterdam, Rotterdam, Nijmegen, and Groningen. This added significantly to the improvement of the Dutch trauma system[5].

Since then, the national organization of the trauma system, as well as the level of training of HEMS physicians and the trauma-physicians in the trauma centers, and the availability of expert assistance in trauma care have improved considerably.

Nowadays, HEMS in Amsterdam, Rotterdam, and Groningen are on active stand-by during daylight hours, from 7.00 – 19.00 hours. From 19.00 – 0.00 hours the Mobile Medical Teams are transported by Ambulance bus. The HEMS station in Nijmegen has a 24 hours HEMS-availability.

Limited research has been performed to determine the effects of HEMS on the outcome of severely injured patients. Since the nationwide introduction of HEMS in the Netherlands no well-designed study has been performed to measure such effects of HEMS. This in combination with the lack of randomised-controlled trails, HEMS dispatch in the Netherlands, and not only in the Netherlands, is currently still a subject for discussions. The lack of the evidence based knowledge on the cost, effects and benefits of HEMS have led to initiation of the work described in this thesis.

OUTLINE OF THIS THESIS

After 10 years of Helicopter Emergency Medical Services (HEMS) in the Netherlands, their positive influences on patient survival and reduction of morbidity are still subject of debate. In Chapter 2 we reviewed the literature on

- *Evidence-based support for beneficial effects of Helicopter Emergency Medical Services on survival.*

For optimal estimation of the effects of HEMS on patient outcome it is essential to know how efficiently HEMS is used. HEMS dispatch criteria are a critical tool in the utilization of HEMS. Based upon these criteria HEMS are being dispatched. Inaccurate HEMS dispatch criteria will lead to inefficient use of HEMS. **Chapter 3** provides an overview of the Helicopter Emergency Medical Services dispatch criteria for severely injured patients. A systematic literature search was performed in an attempt to answer the following questions:

- *Which currently available HEMS dispatch criteria are described in the literature?*
- *What is the validity of these criteria defining appropriate HEMS dispatch?*
- *What is the level of evidence for the validity of these criteria?*

In addition to the effectiveness and the accuracy of HEMS dispatch criteria in identifying patients that are in need of HEMS assistance, the protocol adherence of people working with the HEMS dispatch criteria also adds to the effectiveness of HEMS. In **Chapter 4** an analyses was performed of the actual dispatch rates and the protocol adherence of the emergency dispatchers in Rotterdam, concerning HEMS dispatch criteria. The main question of this study was:

- *What is the protocol adherence regarding HEMS dispatch criteria, when used by both emergency dispatchers and ambulance personnel?*

The 'golden hour' is the timeframe after a trauma in which swift and adequate treatment is of vital importance for improving patient outcomes. Current pre-hospital trauma systems focus on delivering patients to hospitals without needless delay, and within the golden hour, On-site advanced trauma life support provided by a physician is often associated with invasive, time-consuming interventions that could lead to increased on-scene-times (OST). In **Chapter 5** the on-scene-times were analysed for patients treated by nurse-staffed emergency medical services (EMS) and compared to those treated by a physician-staffed HEMS. This aimed to answer the questions:

- *Is HEMS assistance at the scene of the accident associated with an increase in OST?*
- *Do on-scene-times relate to mortality?*

To gain more insight into the effects of prehospital actions on in-hospital care an additional analysis was necessary. In **Chapter 6** the prehospital interventions in the primary assessment of blunt trauma patients were assessed, aiming to answer the following research questions:

- *Do higher numbers of interventions result in longer on-scene times when HEMS is involved?*
- *Do prehospitally performed interventions result in an in-hospital time gain?*

The additional value of therapeutic options brought to the scene of an accident by HEMS has been subject of discussion for several years. Therefore procedure and complications of one of the treatment interventions, the chest tube thoracostomy, was further analyzed. Next to advanced airway management is prehospital chest tube thoracostomy one of the most important potential live saving interventions. It remains under debate because of the presumed increased complication risks in on-scene situations. In Chapter 7 we studied in prehospital situations- and in emergency department provided chest tube thoracostomy, in an attempt to answer the following question:

- Does prehospital placement of chest tube thoracostomies result in higher *infectious complication rates?*

Budgetary restrictions and Dutch legislation restricted the HEMS dispatch to the Uniform Daylight Period (UDP), maximized to the time between 7.00h and 19.00h. Outside these hours no professionally trained physicians were available for highly-demanding prehospital trauma situations. These undesirable circumstances combined with a nationwide increasing request for continuous sufficient quality prehospital care resulted in a pilot study that started January 15, 2005 in the Southwestern area of the Netherlands. In this pilot study Mobile Medical Teams (MMT) were dispatched by ambulance bus between 19.00 and 7.00 hours. In **Chapter 8** insights were gained into the quantitative and qualitative aspects of HEMS or MMT dispatch during night hours, aiming to answer the following questions:

- *What are the national quantitative needs for HEMS availability in the evening and night?*

Worldwide, HEMS provide prehospital care for severely injured patients in order to improve outcome and increase chances of survival. The effectiveness of HEMS in general is often questioned, and results from existing studies are contradicting [4, 6-15]. Therefore, in **Chapter 9** the influence of the Rotterdam HEMS on the survival chances of severely injured trauma patients was evaluated. These were the first results after the initial 1995 study that led to the introduction of HEMS in the Netherlands, and they intended to answer the questions:

- *Is HEMS assistance for severely injured patients associated with increased chances of survival?*
- *Do all patients equally benefit from HEMS assistance, or can a subgroups be identified that will benefit more?*

The effectiveness of HEMS comprises more than only survival (chances) as single outcome measure. Only limited research has been performed to determine whether improved chances of survival for severely injured patients also result in an increased burden of the chronic consequences of trauma (shift from acute mortality to morbidity).

In **Chapter 10** we prospectively assessed the effect of HEMS on functional outcome, in an attempt to answer the following question:

- *Does HEMS assistance lead to an increased number of survivors with functional limitations or to equal or improved health-related quality of life?*

Because HEMS is a limited and expensive resource with safety risks involved, it is important to quantify any HEMS-associated value. An integral evaluation of the effects of HEMS is a combination of the effect on quality of life, survival rates, and costs involved. The Dutch trauma system has evolved since 1995 [5]. The organization of the trauma system as well as the level of training of HEMS physicians and the physicians in the trauma centers has improved. In **Chapter 11** the costs per quality adjusted life years (QALY) was calculated, in order to answer to the question:

- *Are the costs per QALY for Helicopter Emergency Medical Services in the Netherlands below the acceptance threshold?*

In the past few years, policy makers have been discussing about the need for an expansion of HEMS to a 24-hour a day availability. In this perspective, the preferences of the general public, on both the positive effects (in terms of lives saved) and negative consequences of HEMS (in terms of noise disturbances and costs) and their willingness to pay for the HEMS facility, should be taken into account. In **Chapter 12** a discrete choice experiment (DCE) was performed in order to answer the following question:

- *What are the preferences of respondents towards (expansion of) HEMS availability?*

Chapter 13 presents a general discussion, and the subsequent reflections on the effects of HEMS assistance on patient outcome for severely injured.

Chapter 14 summarises the findings and the answers presented in this thesis, and **Chapter 15** presents a Dutch summary of the contents.

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Lives saved by Helicopter Emergency Medical Services
An Overview of Literature

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ABSTRACT

Objective The objective of this review is to give an overview of literature on the survival benefits of Helicopter Emergency Medical Services (HEMS). The included studies were assessed by study design and statistical methodology.

Methods A literature search was performed in the National Library of Medicine's Medline database, extending from 1985 until April 2007. Manuscripts had to be written in English and describe effects of HEMS on survival expressed in number of lives saved. Moreover, analysis had to be performed using adequate adjustment for differences in case-mix.

Results Sixteen publications met the inclusion criteria. All indicated that HEMS assistance contributed to increased survival: Between 1.1 and 12.1 additional survivors were recorded for every 100 HEMS uses. A combination of the four reliable studies shows overall mortality reduction of 2.7 additional lives saved per 100 HEMS deployments.

Conclusion Literature shows a clear positive effect on survival associated with HEMS assistance. Efforts should be made to promote consistent methodology, including uniform outcome parameters, in order to provide sufficient scientific evidence to conclude the ongoing debate about the beneficial effects of HEMS.

INTRODUCTION

Worldwide, Helicopter Emergency Medical Services (HEMS) provide prehospital care for severely injured patients in order to improve outcome and increase chances of survival. The effectiveness of HEMS in general is often debated, and results from existing studies are mixed[1-3]. Since HEMS is a limited and expensive resource with safety risks involved, it is important to quantify any HEMS-associated value, in order to facilitate cost-benefit analysis.

Therefore, an objectifiable outcome parameter should be defined. Descriptions of HEMS' impact on "chance of survival" (*e.g.* "20% mortality reduction") have some utility but are somewhat abstract and difficult to apply elsewhere. Survival is the most substantial, the most transferable and least ambiguous variable used to express outcome in HEMS studies. Because of case mix and acuity differences between air and ground-transported trauma patients, multivariate techniques (usually logistic regression models) should be used to evaluate the impact of HEMS on survival.

The objective of this review was to summarize literature on the survival effects of Helicopter Emergency Medical Services. Furthermore, the included studies were assessed by study design and methodology.

METHODS

A computerized literature search was performed in the National Library of Medicine's Medline database, extending from 1985 until April 2007.

The following search terms were used in all possible combinations: Helicopter Emergency Medical Services (HEMS), Emergency Medical Services (EMS), Trauma Injury Severity Score (TRISS), Survival, Trauma Helicopter, Air Ambulances and Outcome.

To be included in our review, studies must have evaluated the effect on survival by HEMS, calculated with a model (*e.g.* TRISS) that included calculation of a "predicted mortality."[4] Only manuscripts written in English and published in peer-reviewed, indexed journals were considered eligible. While this approach may have excluded some worthy studies, the use of indexed journals constituted a well-defined, objective threshold for study inclusion that was tied to scientific quality. In addition, all references in the eligible papers and background papers were checked to ensure no papers had been missed with the search terms chosen.

The quality of the studies we analyzed was rated by two observers (AR and EvL) for their level of evidence as described by Mahid and Sackett [5, 6]. A systematic review of randomized controlled trials (RCTs) with or without meta-analysis was considered level I, single RCTs were level II, cohort studies level III, case-control studies level IV, case series level V, case reports level VI and opinion papers as level VII.

The included manuscripts were then judged by study design and statistical methodology. Multivariate analysis should be used to calculate expected survival, in order to correct for possible confounding variables. The TRISS (logistic regression-based) method is usually the multivariate approach of choice [7]. The coefficients used in the TRISS model are derived from the Major Trauma Outcome Study (MTOS). Many studies did not have a patient population similar to the MTOS population, so to ensure an equivalent case mix between the MTOS and a study population a M-statistic should be calculated. Although M does not follow a specific distribution, it is generally considered acceptable to apply uncorrected TRISS when M is 0.88 or higher. In such case, a W-statistic should be calculated to estimate the number of lives saved for every 100 HEMS cases (Table 1). If M is smaller than 0.88 a standardized (adjusted) W, denoted "Ws", should be calculated in order to correct for case-mix.[8, 9] Ultimately, a Z statistic can be calculated to evaluate whether the difference between the observed and predicted mortality is statistically significant (Table 1). For an optimal measurement of HEMS' mortality effects, ground EMS-assisted patient outcome should be used as the control group. A meta-analysis was not performed since the primary data of all studies included could not be obtained.

Table 1. Formula of W- and Z-statistic

W - statistic	(Number of observed deaths – Number of predicted deaths/ N) x 100
Z - statistic	$\dfrac{\text{Number of observed deaths} - \text{Number of predicted deaths}}{\sqrt{\sum (Ps\,(1 - Ps))}}$

N, total number of dispatches; Ps, probability of survival of an Individual.
When Z-statistic > 1.96, then the survival rate in the HEMS assisted group is superior to the reference database. A Z-statistic < -1.96 implies a worse overall performance.

RESULTS

Sixteen publications met the criteria for inclusion in this review (Table 2). In these manuscripts survival by HEMS was described and calculated using logistic regression analysis. One of these studies was a level II (randomized trial) study [10], the other fifteen were level III (cohort study) studies [9, 11-24].

The level II study of Baxt et al [10] randomized between a 'physician/ flight nurse'-staffed HEMS and a 'paramedic/ flight nurse'-staffed HEMS. They did not randomize between

Table 2. Overview of manuscripts describing mortality reduction by HEMS, sorted by year

Author (year)	Country	Type of Care	Sample size	Control group	Described Statistics	Observed mortality	Expected mortality	Mortality reduction per 100 assistances (calculated W-statistic)	Level of evidence
Baxt (1985) [11§]	USA	Ph / N	1273	MTOS	Z	191	240.7	3.9	III
Rhodes (1986) [17]	USA	Ph	130	MTOS	Z	22	28.6	5.1	III
Baxt (1987)[10§]	USA	Ph / N	574	MTOS	Z	30	36.4	1.1	II
Campbell (1989) [24†]	USA		168	MTOS	Z	31	50.0	11.3	III
Boyd (1989)[12†]	USA	P/N	103	110	Z	33	45.5	12.1	III
Schwartz (1989)[20]	USA		168	709	Z	25	36.7	7.0	III
Hamman (1991)[15]	USA	Ph	259	MTOS	M/W/Z	20	32.0	4.6	III
Schmidt (1992)[18§]	Germany / USA	Ph	407	MTOS	M/W/Z	42	57.0	3.7	III
Cameron (1993)[13]	Australia	P	242	MTOS	Zns	34	41.8	3.2	III
Moront (1996)[22#]	USA	P/N	1460	2896	W/Z	77	93	1.1	III
Gearhart (1997)[14]	USA	P/N	604	MTOS	W/Z	50	90.3	6.7	III
Younge (1997)[9]	UK	Ph	632	MTOS UK	M/W/Ws/Z	161	168.6	1.2	III
Bartolacci (1998)[19*]	Australia	Ph	77	MTOS	M/W/Ws/Z	9	18.0	11.7	III
Oppe (2001)[16*]	Netherlands	Ph	210	307	CANALS	132	143.7	5.1	III
Larson (2004)[23]	USA		1087	MTOS	M/W/Z	59	111.4	4.8	III
Mitchell (2007)[21]	Canada	P/N	225	545	W/Z	40	53.6	6.4	III
Total			7619			956	1247.3	3.8	

N, nurse; P, paramedic; Ph, Physician; † , interfacility transport; §, report two separate cohort, combined in this table *, most methodologically rigorous analysis; CANALS, CANALS-analysis with appropriate statistics; #, pediatric patients; M, M-statistics described; W, W-statistics described; Ws, Ws-statistics described; Z, Z-statistics described; Zns, Z-statistics not significant. Ws-statistics were calculated if M statistics was below 0.88.

HEMS or no HEMS (*i.e.* ground EMS control group). The study results showed that the 'physician/flight nurse'-staffed HEMS group (n=316) achieved outcomes better than predicted by the TRISS methodology (1.9 additional lives saved per 100 dispatches, Z 2.28, $p<0.05$). The 'paramedic/ flight nurse'-staffed group performed slightly better than predicted by TRISS, although the difference did not reach significance. Fifteen of manuscripts retrieved consisted of level III (cohort) studies (Table 2). The majority of these manuscripts were performed in the USA, with a sample size ranging from 77 up to 1460. Only 5 studies used a ground EMS control group ranging from 110 up to 2896 patients. Four of these 5 studies used the TRISS methodology but did not describe M-statistics[12, 20-22]. The fifth study by Oppe et al. used another logistic regression method (CANALS analysis) and showed the appropriateness of the regression model[16].

All 16 papers found that HEMS assistance resulted in mortality reduction. The extent of mortality reduction by HEMS ranged from 1.1 to 12.1 additional lives saved per 100 dispatches. The mean of the 16 papers' W estimates was 4.0 lives saved for every 100 uses.

Of all 16 publications only six studies included all of the components we defined *a priori* as constituting "adequate" statistical methodology. Five studies used the TRISS method with appropriate calculation of M, W (or Ws), and Z-statistics [9, 15, 18, 19, 23]. The other study used a custom fitted regression method [16].

Only one study, by Oppe in 2001[16], incorporated all elements of statistical methodology defined as adequate, and also utilized a ground EMS control group.

DISCUSSION

This study provides an overview of literature on the mortality reduction by Helicopter Emergency Medical Services. All papers that met the inclusion criteria showed mortality reduction by HEMS, varying between 1.1 and 12.1 additional lives saved per 100 uses.

Differences in study design (e.g. inclusion criteria, manner of obtaining data) and statistical analysis may have contributed to the considerable variance in results. Besides geographical distinctions (e.g. urban versus rural) and the organization of trauma systems (e.g. autolaunch versus secondary dispatches), the differences in composition of the population (e.g. ratio of blunt versus penetrating trauma) also influence survival. Also, the differences in the composition of the HEMS crew may be of significant influence on outcome. If a physician is a part of a HEMS team, the scope of diagnostic and therapeutic options and experience at the scene of an accident will usually be more extensive. In a randomized study Baxt et al. [10] demonstrated the beneficial effect of a physician-staffed, as compared to non physician-staffed, HEMS.

Appropriate adjustment for case-mix is important in HEMS outcome studies, in order to make groups comparable. Use of statistical methods such as logistic regression models may enable valid conclusions for clinical strategies. If an existing regression model is used, TRISS is still the method of choice [7]. The TRISS coefficients are based on the MTOS population.

This review found that only a few studies described M-statistics. M-statistics is useful to describe (injury severity) case-mix variety. It is difficult finding studies that are comparable with the MTOS population. Without using the M-statistic comparisons with MTOS would be inaccurate and of questionable usefulness. Especially in non-USA countries M-statistics should be described. Literature demonstrates that M-statistics are significantly lower (e.g. different distribution of injury severity) in non-USA countries than the accepted threshold for the uncorrected use of TRISS [25]. If the study groups are not comparable with the MTOS population from which the TRISS coefficients are derived, Ws-statistics should be calculated [8, 9].

Another alternative to using the TRISS method would be a custom fitted regression model with own coefficients or modification of TRISS coefficients based on a local dataset. This alternative would probably give the most reliable information [25].

In most of the reviewed studies the MTOS population has been used as the control group. By not using a ground EMS control group, these studies only demonstrate that their HEMS population survived better than the MTOS population, as predicted by TRISS. Using the MTOS population as control group risks confounding (*e.g.* by level of trauma center care) and does not reflect upon the specific effects of HEMS. If a proper ground EMS control group is used, and all patients are treated at the same trauma centre, the confounding effects based on selection bias and the quality of the in-hospital care are removed.

The study of Oppe et al.[16] was performed according to the most rigorous methodological practice, and may therefore give the most reliable view on the effect of HEMS on survival. Though the three studies from the USA that incorporated a ground EMS control group did not describe M-statistics, they may also give an adequate reflection of reality [12, 20, 22]. Since the MTOS data are drawn from a U.S. population, the injury severity distributions of these three studies are likely to be comparable with the MTOS population[25]. If the data of these 4 most methodologically rigorous HEMS outcomes manuscripts are considered, there is an average mortality reduction of 2.7 additional lives saved per 100 HEMS interventions.

In the Netherlands, HEMS provide prehospital care in addition to ambulance services. The HEMS crew, consisting of a physician, a nurse and a pilot, provides Basic Life Support, Advanced Trauma Life Support (ATLS) [26], and an expansion of diagnostic, (invasive) therapeutic, and logistics options at the accident scene [27].

Due to topographical and logistical reasons only 5-20% of the HEMS-assisted patients are transported by helicopter in the Netherlands. During transport to the hospital by ambulance the HEMS physician still assists the patient. Frankema et al [28] showed that the Dutch HEMS improves chances of survival, especially for severely injured blunt force trauma patients.

For example the effects of HEMS in the South West Netherlands were calculated as a supplementary analysis, performed on a previously documented patient cohort [28]. We analyzed a total of 346 poly-trauma patients (ISS >15), presented to a Level 1 trauma center's emergency department. Ground EMS personnel treated 239 of these patients; the remaining 107 patients received additional HEMS assistance. A custom fitted regression model, as described previously [28], was used to compensate for possible confounding variables. A predicted mortality was calculated and compared to the observed mortality for both groups. The custom fitted regression model was found to be sufficiently calibrated (Hosmer Lemeshow =11.8: p=0.16) and of good discriminative value (area under the ROC curve: 0.911). Analysis ofthe HEMS-assisted trauma population in South West Netherlands showed that 8.4 lives were saved for each 100 instances of HEMS assistance. The main weakness of this study is the potential for overestimation of HEMS effect due to the fact that patients with ISS <16 were not included in the dataset used for our calculations. [28] In fact, over the study period in South West Netherlands, the total proportion of HEMS dispatches for patients who are later calculated to have ISS >16 is only 12%. If a similar rate of low-ISS patients would be added to the dataset used for the current study, the impact on survival estimates decreases to 1.0 life saved for every 100 dispatches.

Only studies that included "predicted mortality", calculated with a logistic regression model, were included in this review. This causes that valuable studies using Odds Ratios as outcome measure were excluded from this review [29-37]. The results of these studies were ambiguous. Two cohort studies of which one had a study population of 16.999 patients [31, 37] and three expert panel studies [32, 33, 36] described positive effects of HEMS on outcome. Furthermore there was an American study that could not demonstrate any positive effects of HEMS though the included population had a very low average Injury Severity Score [38] suggesting overtriage [29]. Three English studies also failed to demonstrate an added value of HEMS assistance [30, 34, 35]. Major comment on these studies was that patients were transported to 20 different hospitals and not to a single level one trauma centre. Younge et al [9] demonstrated that if these patients were transported to a level one trauma centre, HEMS assistance would save 4.2 additional lives per 100 uses.

Furthermore it should be noted that some of the studies described in this review might not be ideally applicable today, since these studies were performed more then 15 years ago. More studies are needed to assess the present state of prehospital Helicopter Emergency Medical Services.

To render HEMS studies internationally comparable in the future, there should be uniformity in statistics. Uniformity can be achieved by correcting for differences in injury severity (case-mix). Correcting for these differences can be performed by using Ws-statistics [8, 9]. Since the Ws approach corrects for differences in distributions of probability of survival, Ws-results would be very useful as an additional standard outcome parameter for HEMS studies.

CONCLUSION

Sixteen studies, with varying methodological rigour, have assessed the effects of HEMS on trauma survival and reported estimates of lives saved per 100 missions. Evaluation of the four most statistically rigorous studies reveals an average estimated mortality reduction of 2.7 additional (*i.e.* over ground EMS) lives saved per 100 HEMS patient interactions. Overall the literature provides mixed conclusions on the effect of HEMS. However as this paper shows, when rigorous statistical methodology is applied to the literature, those studies that remain show a clear positive effect. Efforts should be made to use uniform statistics and comparable outcome parameters in order to provide sufficient scientific evidence to conclude the ongoing debate about the beneficial effects of HEMS, and acknowledge HEMS as a valuable addition to the EMS systems in the treatment of the severely injured trauma patients. HEMS have a considerable impact on the survival of the more severely injured patient, but does not demonstrate significant effects on the less injured. These findings stress the importance of dispatch triage criteria for prehospital providers that accurately differentiate the more severely injured from the less injured.

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Utilization of Mobile Medical Teams

3

Validity of Helicopter Emergency Medical Services Dispatch Criteria for Traumatic Injuries: A Systematic Review

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ABSTRACT

Objective This review provides an overview of the validity of Helicopter Emergency Medical Services (HEMS) dispatch criteria for severely injured patients.

Methods A systematic literature search was performed. English written and peer-reviewed publications on HEMS dispatch criteria were included.

Results Thirty-four publications were included. Five manuscripts discussed accuracy of HEMS dispatch criteria. Criteria based upon Mechanism of Injury (MOI) have a positive predictive value (PPV) of 27%. Criteria based upon the anatomy of injury combined with MOI as a group, result in an undertriage of 13% and a considerable overtriage. The criterion 'loss of consciousness' has a sensitivity of 93-98% and a specificity of 85-96%. Criteria based on age and/or comorbidity have a poor sensitivity and specificity.

Conclusion Only 5 studies described HEMS dispatch criteria validity. HEMS dispatch based on consciousness criteria seems promising. MOI criteria lack accuracy and will lead to significant overtriage. The first categories needing revision are MOI and age/comorbidity.

INTRODUCTION

In most western countries Helicopter Emergency Medical Services (HEMS) complement ground ambulances in providing prehospital care for severely injured patients. Although debate persists, this combination is believed to improve patient outcome [1]. HEMS dispatch should be efficient, as air transport represents a concentrated allocation of scarce health-care resources. Inappropriate use of HEMS (overtriage, or dispatches for patients with insufficient injury severity to benefit from HEMS), leads to increased costs and unjustifiable safety risks[2]. On the other hand, when HEMS is *not* dispatched to patients that would benefit from specialized medical care (*i.e.* undertriage), patients are deprived from potentially lifesaving assistance. This undertriage results in missed chances to reduce morbidity and mortality in the prehospital setting. Developers of regional HEMS triage protocols must strike a delicate balance between dispatching HEMS too often (overtriage), which incurs unacceptable costs, or risking preventable mortality through insufficient use of HEMS (undertriage).

A 2005 Dutch study demonstrated that national use of HEMS was far from optimal, with air transport dispatch correlating poorly with patients' actual need of prehospital HEMS assistance[3]. The answer to the triage problem is not simply strict adherence to existing protocols; the study finds that consistent dispatch protocol adherence would lead to a sevenfold increase of HEMS dispatches, with subsequent risk of considerable overtriage.

The reasons for suboptimal use and compliance/adherence of dispatch criteria remain unclear. Perhaps the criteria are insufficiently communicated, or perhaps prehospital providers consider them as unreliable and choose not to use them. In either case, the first step in optimizing HEMS dispatch is to gain much more insight into the criteria driving the dispatch process. It is therefore mandatory to gain knowledge of the validity of individual criteria. Unfortunately, such knowledge is not easily gained, since few data are available to inform decision-making about validity of HEMS dispatch parameters.

In general, the HEMS dispatch criteria are derived from the American College of Surgeons (ACS) trip destination guidelines [4] . There are also recommendations to supplement the ACS criteria with parameters based upon local circumstances. Importantly, although the two subjects are related, HEMS dispatch and trip destination constitute two separate issues. ACS guidelines were developed to identify severely injured trauma patients (*i.e.,* patients with a probability of survival [5]{Ps} <0.90), who need to be transported to a level I trauma centre. It is manifestly not the case that every patient who should go to a trauma centre, should go by HEMS. Rather, in many cases ground transport – even basic life support transport along the lines of "scoop and run" – is the best option.

The purpose of this review was to provide an overview of HEMS dispatch criteria for patients with traumatic injuries described in the literature. All criteria described, the level of evidence, and the criterion validity were listed. Based upon this, the validity of HEMS dispatch criteria used was discussed.

METHODS

A computerised literature search was performed. The electronic databases searched were: National Library of Medicine's MEDLINE, Cochrane Library, Scopus, UpToDate, Web of Science, PiCarta and Cumulative Index to Nursing and Allied Health Literature (CINAHL). Databases were examined, from the earliest data available through April 2007, for publications on HEMS dispatch criteria to scene flights for trauma patients. The search terms used were: (Air ambulances *OR* Aeromedical *OR* Air Medical *OR* Emergency Medical Service* *OR* Helicopter) and (Criteri* *OR* Guideline* *OR* Protocol *OR* Standard*) and (Dispatch *OR* Deployment *OR* Triage *OR* Utilization). Herein, the asterisk indicates a wildcard.

Only manuscripts written in English and published in peer-reviewed, indexed journals were considered eligible. While this approach may have excluded some worthy studies, the use of indexed journals constituted a well-defined, objective threshold for study inclusion that was tied to scientific quality. The title and abstracts were first reviewed by two reviewers (AR and GdR). Eligible for inclusion in this review were all publications addressing criteria for HEMS dispatch to a trauma scene. There were no restrictions with respect to study design or the method of analysis. All references in the eligible papers, as well as references in background literature, were also reviewed to ensure no papers were missed with the chosen search strategy.

The included criteria were divided into the following internationally accepted major subgroups: (1) Mechanism of injury (MOI), (2) Patient characteristics – Anatomic, (3) Patient characteristics – Physiologic, and (4) Other.

Since the ACS trauma centre triage guidelines [4] and the criteria for HEMS dispatch constitute separate issues, a distinction between these two is drawn in this review. Only when the ACS guidelines were explicitly named and used as HEMS dispatch criteria, they were accounted as such.

A dispatch criterion is said to be valid, if it identifies what it is meant to identify (*i.e.* if it accurately identifies patients most likely to benefit from HEMS). Data on the validity of HEMS dispatch criteria were either extracted from the studies found, or calculated from the data presented. Validity is determined by a dispatch criterion's sensitivity, specificity, and positive and negative predictive values (PPV and NPV), as outlined in Table 1. The discriminatory values of individual dispatch criteria are usefully expressed by PPV and NPV. The degree of overtriage and undertriage are helpful in determining the relevance of triage criteria within the trauma system.

Table 1. Definitions of validity measures with regard to HEMS dispatch criteria

Validity measure	Definition
Sensitivity = TP / (TP + FN) * 100 % (parameter of the test)	The proportion of patients eligible for receiving HEMS assistance that is correctly identified by the dispatch criterion
Specificity = TN / (TN + FP) * 100 % (parameter of the test)	The proportion of patients not eligible for receiving HEMS assistance that is correctly identified by the criterion
PPV = TP / (TP + FP) * 100 % (utility of the test)	The proportion of patients identified by the criterion that is eligible for receiving HEMS assistance
NPV = TN / (TN + FN) * 100 % (utility of the test)	The proportion of patients not identified by the criterion that is not eligible for receiving HEMS assistance
Overtriage = 1 – Specificity	False-positive rate
Undertriage = 1 – Sensitivity	False-negative rate

TP, True Positive; FN, False Negative; TN, True Negative; FP, False Positive; PPV, Positive Predictive Value; NPV, Negative Predictive Value.

To assess the quality of evidence underlying these validity measures, relevant studies were rated for their level of evidence as described previously [6-8]. A systematic review of randomized controlled trials (RCTs) with or without meta-analysis was considered level I, a single RCT was level II, cohort studies level III, case-control studies level IV, case series level V, case reports level VI and opinion papers as level VII.

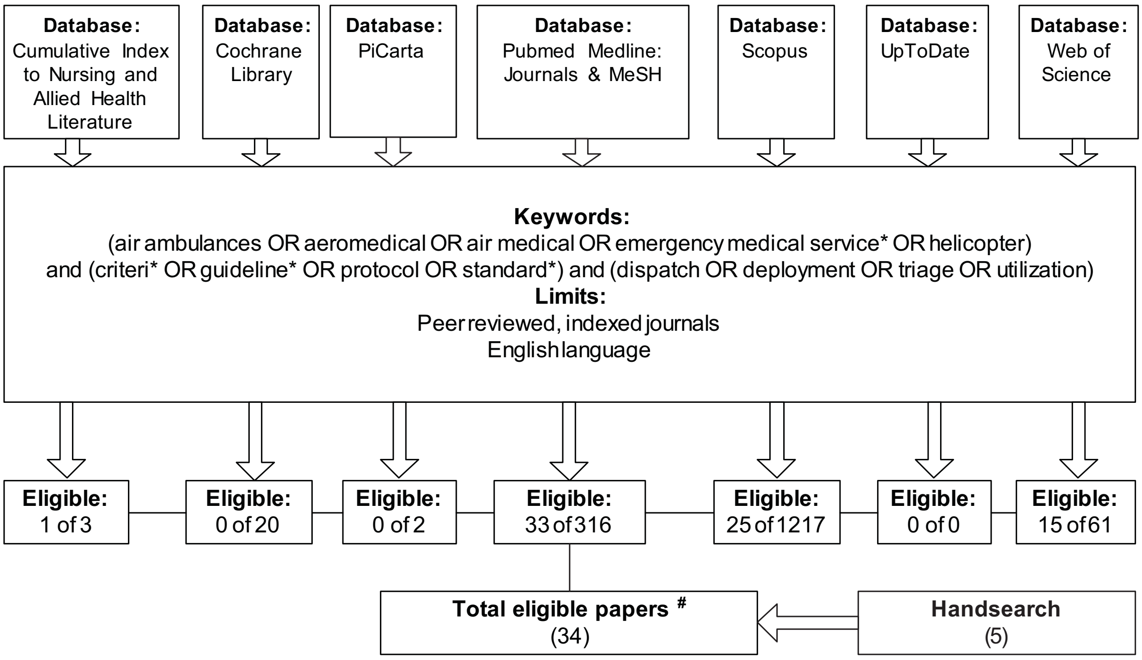
RESULTS

Thirty-four publications met the inclusion criteria (Figure 1). No non-English articles in indexed journals were identified. From these 34 papers a total of 49 HEMS dispatch criteria were identified and categorized into one of the main criterion subdivisions (Table 2). Twenty-two dispatch criteria primarily concerned the MOI. Eleven anatomic and 9 physiologic criteria were identified. The remaining 7 criteria, which dealt with logistics, co-morbidity, or age, fell into the "Other" category.

Five of the 34 manuscripts retrieved addressed accuracy of HEMS dispatch criteria (Table 3). Three of these studies were level III (cohort) evidence [9-11], one was level IV (case control) [12] and one was level V (case series) [13].

Rhodes et al [10] evaluated 143 trauma patients transported by HEMS. In their study, HEMS dispatch was considered correct and justified (*i.e.* true positive, TP) if a patient was severely

Figure 1. Results of the systematic database search



*, Wildcard; #, Duplicates were omitted.

injured as defined by Ps<0.90. The vital sign with the best discriminatory performance was loss of consciousness (LOC), with a sensitivity of 93% and a specificity of 85%. Other physiologic parameters were considered as a group. A sensitivity of 98% and a specificity of 43% were achieved when HEMS dispatch was triggered by abnormalities in one or more of the following: LOC, respiratory rate (RR), pulse (HR) and blood pressure (BP). A conclusion of this study was that the criterion 'entrapment' might not be an effective dispatch indicator, given its poor sensitivity and specificity of 43% and 45%, respectively. The authors also suggested that, although their numbers were insufficient for definitive analysis, the presence of an associated fatality appeared to serve as a valid triage tool.

Table 2. HEMS Dispatch criteria identified by a systematic review of literature

Mechanism of Injury	Reference
High-speed (>40 mph; >65 km/h) moving vehicle accident	3, 9, 13
Multiple casualty incidents	3, 11, 28-32
Motor vehicle collision with significant vehicle deformity	13, 30, 32, 33
Frontal collision on hardened roads outside urban area	3
Significant compartment intrusion on patient side, or on opposite side	13, 34, 35
Significant displacement of front or rear axle	13, 34, 35
Lengthy extrication and significant injury / entrapment	3, 10, 11, 13, 28-30, 33-36
Overwhelming with debris, including head and/or chest	3
Vehicle turnover	13, 30, 34, 35

Mechanism of Injury	Reference
Fatality on high speed roads	30
Death same compartment	3, 10, 13, 31, 34, 35, 37
Patient ejected from vehicle	3, 9, 11, 13, 31, 32, 34-37
Thrown from motorcycle > 20 mph	3, 30, 32, 34, 35
Pedestrian struck ≥ 20mph	3, 9, 13, 30-32, 34-37
Explosion	3
Electricity or lightning accident	3, 31, 38
Fire in confined space, or inhalational injury	3, 31, 38, 39
Logging/farm/industrial accidents	30, 38
Exposure to hazardous materials	3
Fall from height	3, 9, 11, 13, 31, 32, 34, 35
Diving accident	3, 11
(Near) Drowning	3, 30, 31
Patient characteristics – Anatomy	
Penetrating injury to head, neck, chest, abdomen, or groin	3, 9, 13, 30-32, 34, 37 35
Blunt injury with significant involvement of head, neck, chest, abdomen, or pelvis	3, 9, 31, 32, 37, 40
Skull fracture / severe facial and eye injuries	31, 32, 40
Flail chest or pneumothorax	13, 31
Two or more proximal long bone fractures, or open long bone fractures	3, 9, 13, 31, 32
Potential injury to spinal cord, or column	3, 11, 31, 32, 34, 35, 37, 40, 41
Major proximal amputation or deglovement injury	11, 31, 32, 34, 35
Amputation or near amputation when emergent evaluation for reimplantation	31, 32, 34, 35, 37
Fracture or dislocation with vascular compromise	31, 32
Burns of significant BSA or relevant body regions	3, 13, 30-32, 34, 35, 37-39, 41, 42
Multiple system injury	31, 40, 41
Patient characteristics – Physiologic parameters	
Low or high respiratory rate, risk of airway obstruction or other signs of respiratory distress	3, 9, 10, 13, 32, 34, 35, 37, 38, 40
Low systolic blood pressure, tachycardia, or pulse character	3, 9, 10, 12, 13, 31, 32, 34, 35, 37, 40, 43, 44
(Post-traumatic) cardiac arrest	40
Low (CRAMS) score	34, 35
Low Glasgow coma scale	3, 9, 10, 12, 13, 31, 32, 34, 35, 37, 43, 44
Low (Revised) Trauma score	3, 31, 33-35
Age < 5yr or > 55yr	11, 13, 31, 34, 35, 37
Known cardiac or respiratory disease/ cardiovascular instability	13, 33, 37, 38, 41
Known pregnancy	31, 32, 37

Others	Reference
Medical control approval	2, 41, 45-47
Paramedic judgment/intuition	31-33, 48-51
Anticipated need for ATLS procedures	31, 50, 52
(Expectation of) prolonged transport time/prehospital time	2, 10, 11, 13, 31, 33, 37, 41, 48-50, 52-54
Inaccessible road/area	2, 10, 13, 28-31, 33, 37, 51, 52
Heavy traffic conditions	28, 29, 37, 48, 49, 52
Under staffing of ground units in a region/ local resources overwhelmed	13, 31, 32, 37, 42, 48, 49, 52

Table 3. Accuracy of criteria for appropriate HEMS dispatch, sorted by level of evidence

Author	Criterion	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Level of Evidence
Rhodes et al.,1986 [10]	Entrapment	43	45			III
	Physiologic	98	43			
	LOC	93	85			
	RR	52	77			
	P	43	75			
	BP	33	77			
Coats et al., 1993 [9]	MOI group			27		III
Schoetker et al.,2001 [11]	Ejection			59		III
Moront et al., 1996 [12]	GCS	98	96			IV
	P + GCS	99	90			
Wuerz et al.,1996 [13]	MOI + Anatomy	87	20	32	23	V
	Physiologic	56	86	76	30	
	Age + Comorbidity	56	45	23	10	
	Triage Scheme	97	8	47	22	

BP, blood pressure; GCS, Glasgow Coma Scale; LOC, loss of consciousness; MOI, mechanism of injury; ns, not specified; NPV, negative predictive value; P, pulse; PPV, positive predictive value; RR, respiratory rate; III, cohort study; IV, case control study; V, case series.

In a cohort study, Coats et al [9] studied 574 accident-site HEMS dispatch decisions. In their study, HEMS dispatch was retrospectively adjudicated to be indicated when the air medical unit was appropriately used to bypass the closest facility in order to transport patients to a hospital further away. The authors demonstrated that triage by criteria based on MOI alone had a PPV of 27%. An extremely low overall overtriage of 1.2% was reported, but the figure was calculated in terms of adherence to their triage protocols (rather than any *a posteriori* judgment about appropriateness). In other words, the authors used their protocol, consisting of 6 categories, as the benchmark to define appropriateness of dispatch. Such an analysis is a necessary, but not sufficient, approach to addressing overtriage. While HEMS triage should obviously be in line with the extant protocols, meaningful evaluation for overtriage must include an assessment of true "need" as judged externally to triage guidelines. In their protocol, for instance, an ISS of 9 or higher could be adjudicated a "justified dispatch." Critical examination of their data revealed that overtriage actually approached 50%, since at least 269 cases had insufficient injury severity to warrant HEMS assistance. If an ISS of >15 (a common benchmark for "high-acuity" trauma) is used as the demarcation line for HEMS justification, the overtriage rate from the UK group would be substantially greater.

Schoettker et al [11] studied 71 consecutive patients ejected from a four-wheel vehicle. They concluded that ejection was a valid dispatch criterion. When an ISS of at least 16 was used to retrospectively define a justified HEMS dispatch, the ejection criterion had a PPV of 59%.

In a case-control study Moront et al [12] evaluated 3861 pediatric patients who were transported by either ground EMS or HEMS to a level I trauma centre. In their study, HEMS dispatch based upon the Glasgow Coma Scale (GCS) was retrospectively adjudicated as appropriate only if patients had probability of survival (Ps) of less than 0.95. They concluded that the GCS has a high sensitivity and specificity (98% and 96%, respectively) for appropriate HEMS dispatch, and considered it a good HEMS triage tool. Combining HR with GCS increased sensitivity to 99%, but incurred a cost in specificity (which dropped to 90%) that could translate into overtriage.

Wuerz et al [13] evaluated 333 cases of patients transported by HEMS. In their study, HEMS dispatch (based on the ACS Trauma Triage Scheme) was considered indicated if one or more of the following criteria were met: Injury Severity Score (ISS) > 15, transport time > 20 minutes, prolonged entrapment, remote incident site, or need for advanced life support (ALS) personnel at the scene. In this case series it was concluded that the scheme was highly sensitive (97%), but had a very low specificity of 8%. When criteria based upon MOI and anatomic markers were evaluated as a group, there was high sensitivity (87%) and low specificity (20%); predictive values were also poor (PPV of 32%, NPV 23%). In this study the physiologic criteria as a group showed a moderate sensitivity (56%) and a high specificity (86%). Use of abnormal vital signs alone had a high PPV (76%), but resulted in significant undertriage (44%).

DISCUSSION

International HEMS dispatch criteria are largely based on the ACS trip destination guidelines[4]. These ACS-based HEMS dispatch criteria are nearly always supplemented with local criteria. The ACS criteria are meant to identify patients warranting trauma center care, rather than those cases in which HEMS should be deployed. Despite the fact that ACS parameters should not be assumed to apply to HEMS dispatch, the trauma triage literature fails to separately address accuracy of HEMS dispatch criteria.

The failure of the literature to address HEMS dispatch in a methodogically sound fashion is multifactorial. In part, the void in the published data reflects the complexity of research into the validity of HEMS dispatch criteria. A concise population-based trauma registry would be needed to achieve sound results[14]. However, establishment of such a registry is very labour-intensive and requires resources unavailable in most countries at present.

In addition to the low number of studies evaluating HEMS dispatch criteria, the quality of the available evidence is an additional problem. The level of evidence of the few studies investigating HEMS dispatch criteria performance is no better than level III (cohort study). As randomisation is widely viewed as unethical for HEMS scene response studies, investigators and clinicians may have to accept the fact that research addressing HEMS dispatch will never include RCTs.

The limitation in quantity and quality of available evidence should not preclude some overview of conclusions suggested by extant studies. In the few studies that actually describe it, the validity of the HEMS dispatch criteria varies widely (Table 3). In order to draw more meaningful conclusions regarding the validity of HEMS dispatch criteria or per criterion category, a comparison was made with the available data on ACS trip destination guidelines (Table 4).

Criteria based on Mechanism of Injury

The results of this review reveal that the group of HEMS dispatch criteria based upon MOI have a very low PPV (27%). Furthermore, the sole use of the entrapment criterion would indisputably result in significant overtriage and undertriage. The criterion "ejection" (PPV 59%) might be considered a (more) valuable triage tool.

The available literature concerning the ACS MOI guidelines, as considered either individually or as a category, finds a sensitivity between 0-73% and a specificity that ranges 72-97% [15-18] (Table 4). These numbers translate into very little overtriage, but high undertriage. As opposed to the results found regarding appropriate HEMS dispatch, ACS literature regarding the ejection criterion [19, 20] describes low PPV (22-25%), with moderate sensitivity (59%) and high specificity (95%). The low PPV reduces the utility of a positive ejection criterion.

Table 4. Accuracy of ACS guidelines for appropriate trip destination for trauma patients

Author	Criterion	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Level of Evidence
Knopp et al., 1988 [20]	Penetrating injury			60		III
	Extrication			40		
	Ejection			22		
	Fatality			21		
	Space intrusion			19		
	Auto vs Pedestrian			18		
	Age <1 or> 65 years			12		
	Trauma Score < 13			76		
Knudson et al., 1988 [17]	MOI	0-24	72-97			
Norcross et al., 1995 [18]	MOI	54		16		III
	Anatomy	45		22		
	Physiologic	65		42		
	Physiologic/Anatomy	83		27		
	Overall	95		8		
Meredith et al., 1995 [23]	GCSM < 6	59	98			III
	Trauma Score	46	99			
Cooper et al., 1995 [16]	MOI			7		III
Henry et al., 1996 [19]	Flail chest	52	98	38	99	III
	2 Long bone FX	50	98	38	99	
	Ejection	59	95	25	99	
	Penetrating injury	64	91	18	99	
	Intrusion opp. side	71	86	13	99	
	Rollover	73	82	11	99	
	GCS	39	98	39	98	
	RR	57	96	30	99	
	Age	85	70	8	99	
Bond et al., 1997 [15]	MOI	73	91	18	99	III
	PHI	41	98	40	98	
	MOI / PHI	78	89	17	99	

Author	Criterion	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Level of Evidence
Ross et al., 1998 [24]	GCS	62	89			III
	GCSM < 6	61	89			
Engum et al., 2000 [25]	Simplified ACS*	100	29			III
Garner et al., 2001 [22]	GCSM < 6	73	96			III
	RR > 29 (br/min)	15	95			
	10 > RR > 29 (br/min)	25	95			
	P > 160 (b/min)	33	92			
	BP < 80 (mmHg)	30	99			
	Capillary Refill > 2s	36	93			
Báez et al., 2003 [55]	Physiologic/Anatomy	poor	poor			III
Scheetz et al., 2003 [26]	Overall	82-92	31-55			V

BP, blood pressure; b/min, beats per minute; br/min, breaths per minute; FX, fracture; GCS, Glasgow Coma Scale; GCSM, Glasgow Coma Scale Motor Response; Intrusion opp. side, intrusion on the opposite site of the vehicle; MOI, mechanism of injury; NPV, negative predictive value; ns, not specified P, pulse; PHI, Prehospital Index; PPV, positive predictive value; RR, respiratory rate; s, seconds.

Criteria based on Anatomy of Injury

Only Wuerz et al [13] described HEMS dispatch criteria based upon anatomic variables (though combined with MOI). These criteria would result in a nearly acceptable undertriage level (13%), but are associated with unacceptable overtriage.

Literature on ACS trip destination guidelines based on the anatomic parameters suggests a low sensitivity (45%) with a PPV between 22% and 38%[18, 19] (Table 4). The ACS trip destination guidelines based upon anatomic variables such as 'flail chest' and 'two long bone fractures' [19] would lead to an unacceptable rate of undertriage (55%).

Criteria based on Physiologic parameters

Rhodes et al [10] found that, as a group, the HEMS dispatch criteria based on physiologic parameters exhibit high sensitivity but poor specificity (98% and 43%, respectively). This is in contrast to the findings of Wuerz et al [13], who reported these criteria to have moderate sensitivity (56%) and a high specificity (86%). The only plausible explanations for the divergent findings seem to be possible selection bias or the difference in era during which the studies took place (1986 vs. 1996). The criterion LOC seems excellent as a discriminator for appropriate HEMS dispatch, as it will result in minimal overtriage and undertriage [10, 12].

It should be noted that the results of the study by Moront et al [12] have to be interpreted separately, since their study involved pediatric patients. The dispatch criteria for pediatric patients are suspected to differ from the adult population. The pediatric trauma system is still evolving and it has not really been decided which patients really have to go to pediatric centers[21].

Literature addressing the physiologic parameters in the ACS guidelines [15, 18] reports results comparable to the HEMS dispatch criteria results described by Wuerz et al [13]. Overall, application of these criteria would appear to result in little overtriage and moderate undertriage. ACS trip destination guidelines literature based on LOC also indicate this parameter to be a good criterion for trip destination [19, 22-24] (Table 4).

Other criteria

Wuerz et al [13] also concluded that HEMS dispatch criteria based on the ACS triage scheme would result in an acceptable aircraft undertriage (3%), but at a cost of enormous overtriage (92%).

Evaluations of the ACS scheme as a whole (*i.e.* including all categories) show comparable results the results found by Wuerz et al for HEMS dispatch [18, 25, 26] (Table 4). In a point of critical relevance to determining acceptability of HEMS dispatch criteria, the ACS trip destination guidelines conclude that an overtriage rate of 50% must be expected to keep undertriage rates acceptable (no more than 10%) [4].

Differences found between the accuracy of ACS trip destination guidelines and criteria for appropriate HEMS dispatch can be explained by differences in definition and usage. ACS guidelines are intended for use as part of an overall triage plan, rather than as singly applied criteria. Furthermore, it is worth emphasis that meeting an ACS guideline criterion does not necessarily mean that HEMS dispatch is indicated.

Future Research

As noted by others [1, 27], comparing different studies is complicated due to (large) differences in study characteristics and outcomes measures used. In order to facilitate cross-comparison of studies, we recommend developing a consensus definition of which patients actually benefit from HEMS.

The following outcome measures should be included in delineating patients most likely to benefit from HEMS: $Ps < 0.9$ as calculated with Trauma Injury Severity Score (TRISS) or TRISS-like model, direct admission to a critical care unit, immediate non-orthopedic emergency surgery, and death within 24 hours. Additionally, a consensus methodology to allow for retroactive adjudication of HEMS appropriateness should include logistics considerations (*e.g.* time and distance factors).

Further work in the arena of HEMS triage and appropriateness determinations should include assessment of system-specific characteristics such as the HEMS crew's level of medical training (*e.g.* physician, paramedic) and scope of practice. Equally important is the need to draw a distinction between primary and secondary dispatches. Secondary dispatches are more often based on judgment of healthcare professionals, thus improving the quality of information available at the time of dispatch decision-making. Additional attention should focus on the concept of "autolaunch" (*i.e.* HEMS dispatch at the time of rescue/EMS call rather than after evaluation by a healthcare provider), the use of which obviously complicates the process of triage.

The greatest challenge in HEMS dispatch criteria research is to achieve complete population-based (trauma) registration. Only then can the state of the evidence progress past the point of studies describing only the outcome measure of overtriage – an outcome measure that is useful but, given limitations of the current literature, tends to be useful only within a given region. A reliable (trauma) registration system seems likely to significantly reduce overtriage, since the "true negative" patients (the ones most easily missed by current study methods) would be included in such an approach.

In an era of healthcare costs savings correct triage plays an important role, since triage and cost-benefit are inexorably linked. Overtriage results in an increase of costs and reduces the cost-benefit ratio. Overtriage is also associated with unjustifiable safety risk for crew and patients. On the other hand, undertriage can result in adverse outcome for patients, since it can influence survival and functional outcome. To measure the effects of triage on cost-effectiveness is a daunting task, because determining what costs are fair to accredit to HEMS is complicated. The "costs" of HEMS should ideally be considered the difference in costs between air transport and the alternative modalities. Furthermore, cost-benefit calculations should incorporate the occasional instances in which air transport is the only way to get patients to timely care that substantially improves outcome (e.g. Level I trauma centres, percutaneous coronary intervention, hospitals with stroke neurointerventional capabilities).

CONCLUSION

This systematic review of literature shows that there are few studies describing the validity of criteria defining appropriate HEMS dispatch, and that, the results from these studies lack general applicability. At least one HEMS dispatch criterion, loss of consciousness, seems promising, but further assessment of its use is required using more rigorous methodology. Mechanism of injury criteria lack accuracy, and will inevitably lead to significant overtriage. The first HEMS dispatch categories needing revision are mechanism of injury and age/comorbidity. Efforts should be made to achieve results that are comparable and universally applicable. This study shows that it is important that local and regional authorities prospectively evaluate their triage criteria, thereby striving to modify their guidelines based upon a continuous assessment.

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4

Physician-staffed HEMS Dispatch in the Netherlands: Adequate Deployment or Minimal Utilization?

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ABSTRACT

Introduction In the Netherlands, a physician-staffed helicopter emergency medical system (HEMS), called the Helicopter Mobile Medical Team (HMMT), provides prehospital care for severely injured patients in addition to ambulance services. This HMMT has proven to increase chances of survival and reduce morbidity. HMMT dispatch is performed following certain dispatch criteria. The goal of this study was to analyze actual dispatch rates and assess the protocol adherence of the emergency dispatchers in Rotterdam regarding HMMT dispatch.

Methods All high priority ambulance runs between April 1 and July 1, 2003, were prospectively documented and cross-referenced to dispatch criteria. It was determined whether the emergency call warranted either immediate dispatch of the HMMT or a secondary dispatch after arrival of the first ambulance. When dispatch actually occurred, this was also documented.

Results In the studied period a total of 5765 A1 ambulance runs during daylight were documented. Of these, 1148 runs met primary dispatch criteria and 38 runs met secondary dispatch criteria. Actual HMMT dispatch occurred in 162/1186 (14%) cases.

Conclusions HEMS dispatch rates and dispatch criteria adherence are low (14%). Better protocol adherence by emergency dispatchers could lead to a sevenfold increase of HMMT dispatches. The reasons for suboptimal protocol adherence remain unclear and persist, despite proven value of the HMMT in reducing patient mortality and morbidity.

INTRODUCTION

In the care for the severely injured, time is an essential factor. To improve survival of trauma patients, high quality care should be implemented as soon as possible following an accident[1]. In the Netherlands, regular prehospital care for the injured is provided by highly trained ambulance nurses following PHTLS protocol[2]. To increase quality of care, a pilot study regarding the implementation of a physician-staffed helicopter emergency medical services (HEMS) was started in 1995 by Amsterdam's Free University Hospital[3]. This service, called Helicopter Mobile Medical Team (HMMT), enables a specially trained team consisting of a physician (trauma surgeon or anesthesiologist), a registered nurse, and a pilot to be transported to the scene of the accident and to provide specialized medical care as a supplement to regular ambulance services.

The main goal of the HMMT is to get a physician to a severely injured patient, not to transport patients by air. Despite the possible time gained by air transport of patients, the disadvantages combined with small transport distances usually outweigh such benefits. Therefore, patients are only rarely flown to hospitals (2%-15%). By adding a physician to the team, the range of prehospital therapeutic options has increased substantially. Examples are the use of anesthesia and certain analgesics, advanced airway management, tube thoracostomy, and other small surgical procedures. Furthermore, a high dispatch frequency, together with a small number of different flight physicians, enables a high level of experience and skill that cannot be achieved or maintained by ambulance personnel because of the relatively low exposure to severe trauma[4].

Because of the positive results of a pilot study, HEMS Netherlands was extended to three other major cities (Rotterdam, Nijmegen, and Groningen), dividing the Dutch territory into four regions, each covered by a separate HMMT (Figure 1). Despite proven additional value in decreasing mortality and enhancing chances of survival in the Netherlands, budgetary restrictions and legislation prohibit a round-the-clock dispatch[5, 6]. This limits the use of the HMMT to the uniform daylight period (UDP) between 7 a.m. and 7 p.m. and satisfactory weather conditions.

Currently the HMMTs have sufficient coverage to reach 75% of the Dutch population within 15 minutes. The Rotterdam HMMT provides care for over 4.5 million people (Figure 1). In the greater Rotterdam area approximately 80.000 ambulance runs occur each year; an estimated 30,000 are high priority, coded A1[7].

The procedure of an HMMT dispatch is initiated by the EMS dispatcher. Following the distress call, questions regarding the situation are asked to assess the need for medical assistance and its urgency. Based on the apparent seriousness of a distress call or trauma mechanism, the HMMT can be called in immediately, which is known as a primary dispatch

(PD). These dispatches are based on suspicion of high energetic trauma, entrapment, and drowning. Vital parameters may be used to add to this PD indication.

Ambulance personnel arriving at the scene can also request a so-called secondary dispatch (SD), when the gravity of the situation proves too serious. These dispatches are mainly based on patients' condition. The PD can, in turn, also be canceled on authority of the ambulance nurse when severity of injuries proves less serious than initially presumed or in case of scoop and run management. Specific dispatch criteria for both PD and SD exist, which are approved by the Ministry of Health (Table 1).

This study's primary objective is to gain insight into the actual dispatch rates and protocol adherence regarding helicopter dispatch criteria, by both emergency dispatchers and ambulance personnel. Analysis of the relation between the number of registered A1 ambulance runs with regard to dispatch of the HMMT was defined a secondary goal.

Figure 1. Division of Dutch territory into four regions, each covered by a helicopter-MMT (Rotterdam, Amsterdam, Nijmegen, Groningen)

Regions outside the lines are provided HEMS-care by German en Belgium colleagues.

Table 1. Specific dispatch criteria for both primary and secondary helicopter MMT dispatch, as approved by the Dutch ministry of health

Criteria based on circumstances surrounding or nature of the accident:	
•	High energetic motor-vehicle accident
	- Motorbike, moped, estimated speed > 30 km/h
	- Car, estimated speed > 50 km/h
•	Frontal collision on hardened roads outside urban area
•	Train- or airplane accident
•	Fall from height, >6 meters i.e. 2nd story
•	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	
•	RR <10 or >30/ minute
•	Thoracic injuries with an O_2 saturation < 96%, despite O_2 administration
•	Shock: Systolic BP <95mm Hg, or pulse > 120 beats/minute
•	RTS < 11
•	Estimated blood loss of >1 litres
•	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

RR, respiratory rate; BP, blood pressure; RTS, revised trauma score; GCS, Glasgow Coma Score

METHODS

In cooperation with the central EMS dispatch center Rotterdam-Rijnmond, the South-West Netherlands Trauma Center prospectively collected data of all A1 ambulance runs in the greater Rotterdam area between April 1, 2003 and July 1, 2003. The following data were documented: date, alert time, information of the distress call and caller, information gathered by the ambulance nurse at the accident scene, and the name of the hospital to which the patients were transported. Whether an HMMT was dispatched, along with information concerning a possible cancellation, was also retrieved. Whenever possible, data from the ambulance dispatch center were linked to the HMMT database.

Every separate distress call resulting in an A1 ambulance run was compared to the HMMT dispatch criteria, and the need or justification of HMMT dispatch was determined. Only caller information, without later on-scene data, was used in this assessment. When HMMT dispatch was determined to be just, the case was classified as having a PD indication.

On-scene information provided by the ambulance nurse was also compared to dispatch criteria. When a positive indication for HMMT dispatch was found here, the case was classified as (also) having an SD indication.

Primarily these indications were determined for all A1 calls within UPD because then HEMS dispatch was factually possible. Secondly a similar analysis of A1-runs outside UDP was performed to determine future use of HEMS when round the clock dispatch is achieved.

RESULTS

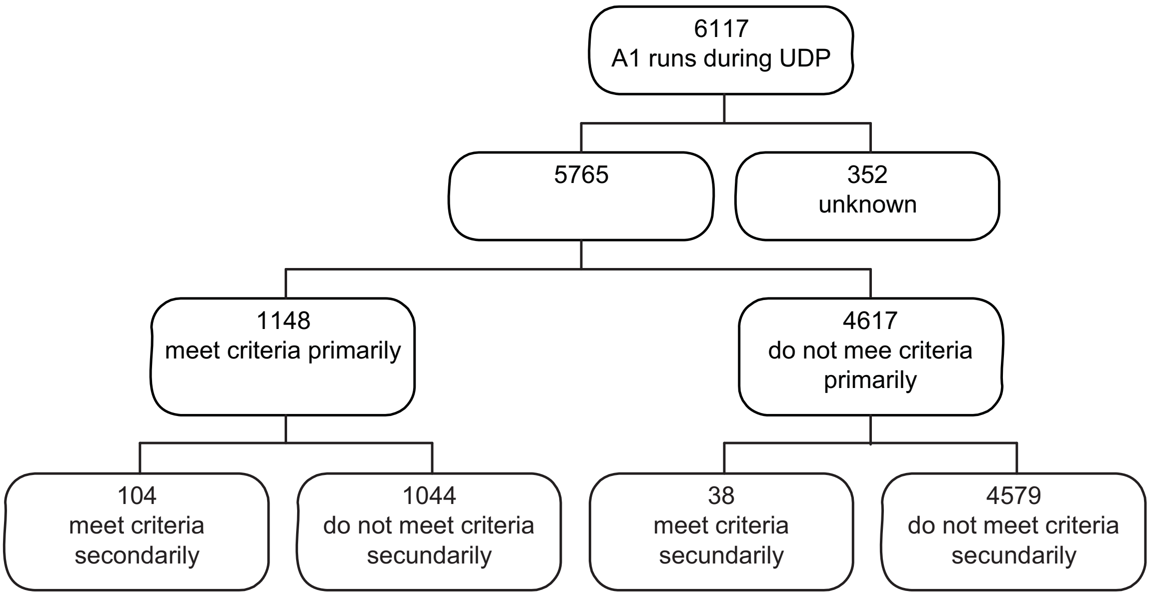
During the study period, there were 9497 documented A1 runs for the greater Rotterdam region. The population was divided into 2 groups; the first consisted of all A1 ambulance runs made within the UDP (Figure 2), which came to a total of 6117 (64.4%). The other group comprised A1 runs made outside UDP, totaling 3380 runs.

From the 6117, a total of 352 UDP ambulance runs were not well documented, so dispatch criteria could not be retrieved from the dispatch database. Of the remaining 5765 UDP ambulance runs, a total of 1148 met a PD criterion. Only 104 of these 1148 runs also met an SD criterion. From the 4617 UDP ambulance runs that did not meet the dispatch criteria primarily, eventually 38 runs qualified for HMMT dispatch secondarily.

Overall, out of 6117 calls a total of 1186 (1148 primary + 38 secondary = 19%) of the UDP ambulance runs qualified for HMMT dispatch (Figure 2). The emergency dispatchers honored 162 (14%) of these possible dispatches that met dispatch criteria (Table 2). This comes to a ratio of one actual HMMT dispatch for every 7 dispatch-justifying calls. Because round-the-clock availability of an HMMT is under discussion and is preferred by professionals and some health care policy makers, an inventory of theoretical 24-hour dispatch need was also performed. The latter was done by analysis of all A1 ambulance runs made outside the UDP, which came to a total of 3380 runs. After analysis of these cases, it was found that 479 (14%) qualified for HMMT dispatch.

The actual 162 HMMT dispatches in the studied period were reviewed and cross-referenced with dispatch criteria. All were deemed appropriate. Of these 162 dispatches, 77

Figure 2. Flowchart of analyzed A1 ambulance runs made within the UDP



were performed on primary request of the emergency dispatcher and 4 were requested by EMS on scene. The distribution of dispatch types of the remaining 81 dispatches that were initiated by another emergency dispatch center within the region, was similar. Finally, 30% of all dispatches were cancelled.

Table 2. Helicopter-MMT dispatches in the greater Rotterdam Rijnmond area over the period April 1st to July 1st 2003

	Total indications for helicopter-MMT dispatch	Within UDP	Outside UDP	Percentages of helicopter-MMT dispatches per indication (within UDP)
Trauma	1540	1113	437	156/1113 (14%)
Non Trauma	115	73	42	6/73 (8%)
Total	1655	1186	479	162/1186 (14%)

Presence of indications for primary and secondary helicopter-MMT dispatch, within or outside UDP, compared to real dispatches. UDP: Uniform Daylight Period

DISCUSSION

Recent studies indicated that the HMMT, a physician-staffed HEMS in the Netherlands, offers an increased chance of survival for severely injured patients of up to 3.5 times normal and could lead to reduced morbidity[5, 6]. The goal of this study was to assess the dispatch rates of the HMMT and determine whether this represented adequate or even optimal use of the facility. This was done by analyzing all A1 ambulance runs and cross-referencing information from each of them to determine whether HEMS dispatch had been appropriate.

The results showed that emergency dispatchers only implemented the HMMT in 14% of all calls meeting the formal dispatch criteria. This means strict adherence to dispatch protocols can lead to an increase in the number of dispatches by a factor of 7. This also means that a certain patient group remains deprived of the specific emergency treatment needed. During the study period, the dispatchers never declined a call because no aircraft was available.

Little literature has been published about the underutilization of HEMS assistance[8-10]. More is written about the use of trauma triage guidelines in general[11-13]. The American College of Surgeons Committee on Trauma suggested that overtriage up to 50% may be necessary to limit undertriage, which could be potentially life-threatening[14]. Wuerz et al[15] showed that physiologic triage criteria alone identify only 56% of trauma patients with an injury severity score (ISS) higher than 15. Whereas numerous reports describe mechanism of injury, indicators identified most patients with an ISS higher than 15 but have an high overtriage percentage[15-19]. The explanation given for undertriage and overtriage, as discussed in literature, was sought for shortcoming of the criteria used, not by possible lack of protocol adherence by the dispatchers. Though Gijsenbergh et al[8] conclude that repetitive training of dispatchers can result in increased dispatch sensitivity (a measure for undertriage) without decreasing dispatch specificity (a measure for overtriage).

The exact reasons for suboptimal protocol adherence are not clear and should be further investigated. The authors propose several possibilities, including the idea that dispatch criteria might be defined not clearly enough, or dispatchers and EMS personnel have not been familiarized well enough with these criteria. Also, the added value of HEMS dispatch might not be apparent to dispatchers. This might be attributable to a change in culture needed within the dispatch center community.

Finally, the lack of objective accountability by dispatchers and EMS personnel on the correctness of decisions regarding dispatches and criteria might contribute to inadequate use of protocol. Most of the abovementioned factors of influence can be counteracted by adequate training and documentation.

During this study, documentation of information regarding PD criteria was complete and reliable. Documentation of data by EMS personnel was not reliable enough to make any statement about correctness of the SD criteria. Data analysis showed that only 104 of 1148 ambulance runs that met PD criteria also classified secondarily. This suggests that if an HMMT would be dispatched for every A1 run that meets PD dispatch criteria, 9 of 10 dispatches would result in a cancellation as a result of secondary findings by the EMS personnel.

However, data recorded on scene by EMS personnel lack completeness and reliability and therefore distort the number of HMMT dispatches that actually qualify. This results in a structural underestimation of PDs that also qualify according to secondary criteria. The most important future steps that need to be taken to increase appropriate use of HEMS include training adequately and frequently, increasing the accuracy of documentation, and implementing a system in which the computer cross-references data input from emergency dispatchers with HMMT dispatch criteria. Subsequently, it will show whether dispatch is appropriate and help to increase protocol adherence and optimize quality of care for the severely injured patients.

CONCLUSION

The use of HEMS in the South-West Netherlands is far from optimal and does not foresee the actual need of prehospital HMMT assistance. This indicates inadequate use of health care resources and should be improved. Better protocol adherence could lead to an increase of PDs by a factor of 7. To achieve optimal use of the HMMT, more exchange of knowledge, training, and the use of standardized systems in which decisions need to be justified and documented should be implemented. Further study into the reasons for the suboptimal protocol adherence is warranted. In 14% of all A1 ambulance runs outside of UDP, an indication for HMMT dispatch existed. This stipulates once more the need for round-the-clock implementation of an HMMT.

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Prehospital Trauma Care

5

Helicopter Emergency Medical Services (HEMS): Impact on On-Scene Times

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ABSTRACT

Background This study compared prehospital on-scene times (OSTs) for patients treated by nurse-staffed emergency medical services (EMS) with OST for patients treated by a combination of EMS and physician-staffed helicopter emergency medical services (HEMS). A secondary aim was to investigate the relationship between length of OST and mortality.

Methods All trauma patients treated in the priority 1 emergency room of a Level I trauma center between January 2002 and 2004 were included in the study. To determine OST and outcome, hospital and prehospital data were entered into the trauma registry. OSTs for EMS and combined
EMS/HEMS-treated patients were compared using linear regression analysis. Logistic regression analysis was used to compare mortality rates.

Results The number of trauma patients included for analysis was 1,457. Of these, 1,197 received EMS assistance only, whereas 260 patients received additional care by an HEMS physician. HEMS patients had longer mean OSTs (35.4 vs. 24.6 minutes; $p < 0.001$) and higher Injury Severity Scores (24 vs. 9; $p < 0.001$). After correction for patient and trauma characteristics, like the Revised Trauma Score, age, Injury Severity Scores, daytime/night-time, and mechanism of trauma, the difference in OSTs between the groups was 9 minutes ($p < 0.001$). Logistic regression analyses showed a higher uncorrected chance of dying with increasing OST by 10 minutes (OR, 1.2; $p < 0.001$). This apparent effect of OST on mortality was explained by patient and trauma characteristics (adjusted OR, 1.0; $p = 0.89$).

Conclusions Combined EMS/ HEMS assistance at an injury scene is associated with longer OST. When corrected for severity of injury and patient characteristics, no influence of longer OST on mortality could be demonstrated.

INTRODUCTION

Trauma is the fourth overall cause of mortality and leading cause of death under the age of 29 years in the Netherlands[1]. As trauma patients in the Netherlands are mostly young adults (average age of 41 years[2]), trauma causes considerable losses of productivity, and hence causes social and economic damage[3]. The impact of injuries on health care costs in the Netherlands is similar to the costs of cancer and stroke[3, 4]. It is vitally important to determine the factors that influence the outcome for patients with multiple injuries, because reductions in mortality and morbidity could result in social and economic gains. Many studies have attempted to identify prehospital and in hospital factors related to the outcome of severely injured patients. One of these factors is time.

In trauma care, the timing of intervention is essential. Much of "the golden hour", the time after a trauma in which swift and adequate treatment is of vital importance to improving patients' outcomes, usually passes in the prehospital phase. Current prehospital trauma systems focus on delivering patients, without unnecessary delay, to hospitals within the golden hour. However, scientific evidence supporting these systems, based on the principle of "the golden hour", is lacking[5].

The influence of prehospital trauma care and the level of medical expertise needed (Pre-Hospital Trauma Life Support [PHTLS] vs. Advanced Trauma Life Support [ATLS]) are the subjects of discussions all over the world. On-site physician-provided ATLS is often associated with invasive, time-consuming interventions, leading to increased on-scene times (OSTs). Increased OSTs may be associated with increased mortality in severely injured patients[6, 7]. Other authors, however, found that specific prehospital ATLS procedures increase patients' chances for survival[8].

In the Netherlands, all emergency medical services (EMS) paramedics are PHTLS certified. Since 1997, prehospital trauma care has been expanded to include an ATLS-trained physician-staffed helicopter emergency medical service (HEMS). In contrast, in the United States, only 18% of HEMS units are physician-staffed[9].

For severely injured patients, HEMS dispatches in addition to the EMS, providing advanced trauma care at the crash. An HEMS physician at the scene may initiate interventions such as tube thoracostomy, intubation with anesthesia, and cricothyroidotomy[10].

HEMS have been shown to increase the chances of survival for these patients, especially in the case of blunt trauma[2, 11]. HEMS physicians are trained anesthesiologists or trauma surgeons. These physicians come in frequent contact with severely injured patients, both in the field and in the emergency room, giving them a high level of practical experience.

Currently, the Dutch HEMS teams (in Amsterdam, Rotterdam, Nijmegen, and Groningen) can reach about 80% of the Dutch population within 15 minutes, but only during daylight hours.

This study aimed to compare prehospital OST for patients treated by EMS only and for patients treated by a combination of EMS and HEMS. A secondary aim was to investigate the relationship between length of OST and mortality.

METHODS

All trauma patients aged 15 and older arriving in the emergency room between January 2002 and 2004 were included in this study. Victims of drowning, strangulation, and suffocation were excluded, as were patients with missing prehospital data. Prehospital (EMS) and inhospital data were entered into the trauma registry. With HEMS assistance, OSTs were obtained from the pilot time registry of the HEMS flight operator (ANWB-Medical Air Assistance).

The primary outcome of this study was OST. OST was defined as the time between the arrival of the first EMS unit and the patient's departure from the crash scene. Secondary outcome was mortality. Mortality was defined as death within the first month after trauma. The population consisted of two subgroups: an EMS-treated patient group and a combined EMS- and HEMS-treated (EMS/HEMS) patient group. The EMS/HEMS group consisted of all patients who, in addition to EMS care, received physician-staffed HEMS assistance at the crash scene. Because all patients in this study were transported to the emergency department by ambulance, HEMS assistance had no effect on transportation time, making it irrelevant to this comparison.

To obviate any bias in the comparison between the EMS and the HEMS groups, only variables unaffected by the presence of HEMS or EMS were used for analysis. Therefore, the Revised Trauma Score and the Glasgow Coma Scale (GCS) score, obtained upon the arrival of EMS before any prehospital intervention, were used to indicate the patients' vital condition. OSTs were compared between both subgroups.

Additional subgroup analyses were performed for three trauma and treatment modalities: "scoop-and-run" (OST <10 minutes), "stay-and-treat" (OST >10 x <50 minutes), and "entrapment" (OST >50 minutes).

Statistical Analysis

Mean OSTs between groups were compared using Student's *t* tests. A custom-fitted regression model was defined to compensate for the selection bias[2]. All commonly used predictive variables were evaluated for their contribution to the model. Finally, the variables Revised Trauma Score, age, Injury Severity Score (ISS), whether the trauma occurred inside or outside the uniform daylight period, and mechanism of trauma were found to have significant predictive value and were fitted into the model. In these regression models, factors were considered not to be affected by the presence of the HEMS, and were considered possible influences on mortality. The logistic regression models were used to analyze the influence of OST on mortality. Significance was defined as p <0.05. The software used for analysis was SPSS (version 12.1, SPSS, Chicago, IL).

RESULTS

During the 2 study years, EMS transported 1,774 patients to the high-care emergency room. Three hundred and seventeen patients were excluded, 313 because of incomplete prehospital data (predominantly OST). The mean ISS of excluded patients was 14. The majority of excluded patients (n = 309) belonged to the EMS group. The other four patients were excluded because they were victims of drowning, suffocation, or strangulation.

The number of trauma patients included for analysis was 1,457. Of these, 1,197 had received EMS care only, whereas 260 had received additional assistance by the HEMS physician. General characteristics are depicted in Table 1. All trauma-related parameters differed significantly between the groups: a lower mean GCS score was found in the EMS/HEMS group (10.3 vs. 13.8) and ISS was higher in the EMS/HEMS group, whereas the majority of patients had sustained blunt trauma in both groups. Hardly any patients with penetrating trauma were seen in the EMS/HEMS group.

Table 1. Demographics and injury characteristics for both patient groups

	EMS (n = 1,197)	EMS/HEMS (n = 260)	p
male (n =)	838 (70%)	205 (79%)	
penetrating trauma (n =)	147 (12%)	8 (3%)	< 0.001‡
blunt trauma (n =)	1,050 (88%)	252 (97%)	< 0.001‡
mean age (years)	35.1	39.2	
mean GCS	13.8	10.3	< 0.001†
mean ISS	9.1	23.6	< 0.001†

EMS indicates patients that were treated by ambulance personnel only. EMS/HEMS indicates patients treated by a combination of EMS and HEMS.
GCS: Glasgow coma score; ISS: injury severity score; †: student t-test;
‡: chi-square test

On-Scene Times

Mean overall OST was 26 minutes: 24.6 minutes for the EMS group and 35.4 minutes for the EMS/HEMS group ($p < 0.001$) (Table 2). When stratified into the scoop-and-run, stay-and-treat, and entrapment groups, differences in OSTs were lower. Mean ISS was significantly higher for the EMS/HEMS group in all three time-modality groups.

The overall difference in mean OST between the EMS and the EMS/HEMS group was 10.8 minutes (Tables 2 and 3). After adjusting for confounding variables, HEMS assistance was still associated with a 9.3-minutes longer OST. In trauma patients with an ISS > 15, an adjusted increase in OST of 9.3 minutes was observed. In subgroup analysis, HEMS assistance did not influence OSTs in both the scoop-and-run and the entrapment groups. The stay-and-treat group showed an adjusted average increase of 5.2 minutes associated with HEMS assistance.

Table 2. On-scene times and injury severity scores for pre-hospital trauma care, divided into the categories scoop and run, stay and treat, and entrapment

		EMS (n=1,197)	EMS/HEMS (n =260)	p
Mean OST overall (min)		24.6	35.4	< 0.001†
Mean ISS overall		9.1	23.6	< 0.001†
Scoop and run (< 10 min)				
	n	95	3	
	Mean OST (minutes ± SD)	6.4 (±2.0)	4.7 (±1.3)	ns†
	Mean ISS	11.5 (±11.8)	29.7 (±12.7)	0.01†
Stay and treat (10–50 min)				
	n	1,062	216	
	Mean OST (minutes ± SD)	24.8 (±9.3)	31.3 (±8.7)	< 0.001†
	Mean ISS	8.9 (±9.9)	23.7 (±15.3)	< 0.001†
Entrapment (> 50 min)				
	n	40	41	
	Mean OST (minutes ± SD)	61.8 (±16.6)	59.4 (±12.2)	ns†
	Mean ISS	9.6 (±11.6)	23.0 (±15.9)	< 0.001†

† = student t-test; SD = standard deviation; ns = not significant

Mortality

The number of patients who died as a result of their injuries was 117 (8%). Fifty-four (46%) of these patients received EMS assistance only, whereas 63 (54%) received EMS/HEMS care.

Three patients with an OST shorter than 10 minutes, 102 patients with an OST between 10 minutes and 50 minutes (stay-and-treat), and 12 patients classified as entrapped died. In all subgroups mentioned above, more patients died in the EMS/HEMS group than in the EMS group. After adjusting for the characteristics of the patient and the trauma, mortality was equal for the EMS and EMS/HEMS groups (odds ratio [OR], 1.0).

A 10-minute increase in OST was associated with an unadjusted higher chance of mortality (Table 4). However, after adjusting for severity of injury and patient characteristics (i.e., selection bias), the effect of prolonged OST on mortality disappeared.

Table 3. Differences (in minutes, with their confidence intervals) in on-scene times between the EMS and EMS/HEMS group (unadjusted and adjusted)

		Δ OST	95% CI	p
All patients				
	Unadjusted	10.8	[9.1 - 12.6]	< 0.001
	Adjusted	9.3	[9.3 - 11.2]	< 0.001
Patients ISS > 15				
	Unadjusted	11.3	[8.7 - 13.9]	< 0.001
	Adjusted	9.3	[6.7 - 12.0]	< 0.001
Scoop and run				
	Unadjusted	-1.8	[-4.1 - 0.6]	ns
	Adjusted	-0.6	[-3.3 - 2.1]	ns
Stay and treat				
	Unadjusted	6.6	[5.1 - 7.8]	< 0.001
	Adjusted	5.2	[3.7 - 6.7]	< 0.001
Entrapment				
	Unadjusted	-2.4	[-8.8 - 4.0]	ns
	Adjusted	-2.5	[-10.4 - 5.4]	ns

Adjusted: adjusted for revised trauma score, age, injury severity score, daytime/night-time, and mechanism of trauma; ns: not significant; CI: confidence interval; Δ OST: change in on-scene time.

Table 4. Influence of prolonged OST on mortality (per 10 minutes)

	OR	95% CI	p
Influence of longer OST on mortality, unadjusted	1.2	[1.0 - 1.3]	< 0.001
Influence of longer OST on mortality, adjusted*	1.0	[0.8 - 1.3]	0.89

* Adjusted for revised trauma score, age, injury severity score, daytime/night-time, and mechanism of trauma

DISCUSSION

Many factors influence the outcome of trauma care. HEMS assistance is often associated with longer OST. To investigate the effect of OST on the survival of patients with multiple injuries, we quantified prehospital EMS and HEMS OSTs and analyzed their effect on patient mortality. Because transportation time does not depend on HEMS presence in the Netherlands, and all patients in this study were transported by EMS, the OST was used instead of out-of-hospital time (OST + transportation time). HEMS assistance was found to be associated with prolonging OST by 11 minutes. However, patients in the EMS/HEMS group had a significantly lower mean GCS score, a higher mean ISS, and relatively more blunt trauma than did patients in the EMS group. When correcting for these patient and trauma characteristics, HEMS assistance was still associated with an increase in OST of 9.3 minutes. To determine which patient category (i.e., treatment modality) was most responsible for these prolonged OSTs, patients were divided into subgroups associated with the aforementioned treatment modalities. This showed the stay-and-treat category to be associated with the highest adjusted increase in OST, because of factors concerning HEMS dispatch (i.e., additional therapeutic interventions).

Looking at mortality, an increase in OST by 10 minutes seemed to be associated with a 20% greater chance of dying. However, after adjusting for patient and trauma characteristics (Revised Trauma Score, age, ISS, whether the trauma occurred inside or outside the uniform daylight period, and mechanism of trauma), the apparent effect of OST on mortality disappeared. Therefore, even though HEMS assistance leads to prolonged OSTs for specific patients groups, HEMS assistance does not lead to increased mortality. This suggests that the set of added therapeutic options brought to the scene by a physician does lead to increased survival and that the supposed negative effect of prolonged OST is neutralized.

Another interpretation of the data could be that the EMS obviates the need for HEMS by simply transporting sooner. Or formulated differently, longer OST to stay-and-treat does not improve outcomes but returns the mortality to that of the rapidly transported group. However, there is no reason to transport any sooner than currently indicated in the "stay and- treat" group because no increased mortality could be demonstrated. Furthermore, the Dutch EMS has to comply with Dutch regulations or law and cannot obviate the need for HEMS by simply transporting sooner. Strict dispatch criteria and protocols are to be maintained and deviations need to be explained or reported.

The effects of OST and out-of-hospital time on mortality have been studied before. In 2001, Lerner et al. studied the background of the golden hour and found little evidence to support the concept[5]. Several studies found that a decrease in out-of-hospital time resulted in improved patient survival[12-17]. However, these studies did not correct for the characteristics of the patient and the trauma, or the level of prehospital care (ATLS vs. PHTLS). Consequently, the actual influence of out-of-hospital time on individual patients remained unclear. Because outcome is influenced by a multitude of factors, it is essential in trauma care to correct for confounding variables. Other investigators have disputed the concept of the golden hour[18-20]. However, either these studies focused on patients with very long OSTs only, or they had a clear selection bias. The concept that shorter out-of-hospital times improve survival has not yet been demonstrated in studies of adequate size or appropriate statistical control[5], nor does the current study show such an effect.

It should be noted that the 313 patients excluded because of incomplete prehospital data (predominantly OSTs) were not the patients at risk of dying (mean ISS of 14). The majority of excluded patients belonged to the EMS group, because significantly more prehospital data were missing in this group. It is therefore unlikely that these exclusions biased our results.

Limitations of the Study

This study uses the ISS as a major determinant in the models. A weakness of the ISS is estimating the severity of neurologic injuries. Furthermore, the ISS could fail to differentiate severe injury from mismanagement of injury[21]. As the ISS mixes outcome data with the injury severity, ISS could incorrectly assign increased injury severity to the lesser injuries of mismanaged patients. However, it still remains the default method to indicate the severity of injury sustained. Hence, residual confounding may be present in the current "adjusted" analyses.

Another limitation is caused by limited data registration and the subsequent large number of patients not included for analyses. Limited power surrounds the conclusions concerning mortality with uncertainty. Further study is required before more definitive conclusions can be drawn on the complex issues associated with HEMS care. The differences in mechanism of trauma between both groups underline that in case of penetrating injury the treatment modality "scoop-and-run" is chosen, meaning that the EMS does not wait for the HEMS to arrive but rushes to the nearest Level I trauma center (as this is the treatment modality of choice in case of penetrating injury). Because the group with penetrating injuries was too small, separate analyses of patients with the blunt or penetrating injuries could not be made.

In conclusion, this study has demonstrated that EMS/HEMS assistance at the scene of the crash is associated with an increase in OST for specific patient groups, possibly because of additional prehospital therapeutic interventions. However, when corrected for severity of trauma and other patient characteristics, no influence of longer OST on mortality could be demonstrated.

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6

Prehospital Interventions: Time wasted or Time saved? An Observational Cohort Study of Management in Initial Trauma Care

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ABSTRACT

Objective Preclinical actions in the primary assessment of victims of blunt trauma may prolong the time to definitive clinical care. The aim of this study was to examine the duration of performed interventions and to study the effect of on-scene time (OST) and interventions performed before admission to hospital on hospital resuscitation time.

Methods 147 consecutive patients with high-energy blunt trauma aged >15 years were studied prospectively. Prehospital time intervals and interventions were documented and compared with hospital data collected from continuous digital video registration. Analyses were performed with correction for injury severity and type of prehospital medical assistance (emergency medical services (EMS) versus physician-staffed helicopter emergency medical services (HEMS)).

Results Primary survey and initial treatment were initiated and completed within 1 h of arrival of the EMS. 83% of this "golden hour" elapsed out of hospital and 81% (n=224) of all interventions (n=275) were carried out before admission to hospital. An increase in the number of prehospital interventions was associated with an increased OST (p<0.001).

Subanalyses showed no such correlation in the HEMS group. The HEMS group had a longer mean OST than the EMS group (p<0.001) with relatively more prehospital interventions (p<0.001) and a shorter mean in-hospital primary survey time with fewer in-hospital interventions. Overall, OST and the number of prehospital interventions were not related to in-hospital primary survey time and interventions.

Conclusion For most trauma patients the initial life- and limb-saving care is achieved within the "golden hour". Prehospital treatment occupies most of the golden hour. More prehospital interventions were performed with HEMS than with EMS only, but the higher number of interventions did not result in a longer OST with HEMS. Although the numbers of subsequent in-hospital interventions may be lower, no reduction in time in hospital may be expected from the interventions performed before hospital admission.

INTRODUCTION

Efficient time management and adequate acute treatment are considered crucial in the initial care of trauma victims. The period immediately following a trauma during which patients should receive life- and limb-saving care is often referred to as the "golden hour"[1]. The chances of survival increase when the time between the actual injury and the definitive care is kept to a minimum[2, 3]. Thus, trauma care systems are designed to provide rapid coordinated medical care to injured patients[4].

In the Netherlands the out-of-hospital trauma care is provided by emergency medical services (EMS). EMS teams are staffed with a highly trained nurse who supplies basic emergency care. In addition to the EMS, physician-staffed helicopter emergency medical services (HEMS) provide advanced trauma life support (ATLS)-based medical care[5] and professional overall on-scene management. HEMS are dispatched according to specific criteria. The primary dispatch criteria are based on suspicion of a high-energy trauma or other life-threatening trauma, and secondary dispatch criteria are based on the condition of the patient[6]. Because of relatively short distances in the Netherlands, HEMS activation is not related to distance and patient transportation to an appropriate emergency department is predominantly (85–98%) performed by ambulance, escorted by the HEMS physician when indicated.

In the Netherlands the involvement of the HEMS seems to reduce mortality and to enhance survival chances compared with situations were only EMS assistance is provided, especially for patients with severe blunt trauma[7]. However, the on-scene presence of a physician and subsequent increase in the number of time-consuming interventions may prolong the prehospital on-scene time (OST).

Primary in-hospital care should continue (H)EMS-initiated treatment following the internationally implemented ATLS guidelines[5] and may benefit from the interventions that were already performed on-scene.

Several studies have investigated the effect of the time interval within the "golden hour" on patient outcome[2, 7-9]. However, to our knowledge, no studies have investigated the actual time frames and actions in this first period following a trauma. In addition, no studies have been published in which the interventions performed on-scene and their duration were correlated with the interventions and the time spent during in-hospital primary trauma care.

The objective of this study was to examine the time management and interventions of the initial (pre)hospital trauma care. In addition, we tested the hypothesis that an increase in the number of interventions performed before admission to hospital would result in a reduction in the time spent in the emergency room.

METHODS

Study design

A prospective cohort study was performed, documenting and evaluating the interventions performed before and after admission to hospital and the timerelated structure of initial trauma care in blunt trauma victims. The study setting was a level 1 trauma centre in the Netherlands (Erasmus MC, Rotterdam) and its related trauma care region with over 2.5 million inhabitants.

Selection of participants

From May to September 2003, all consecutive patients sustaining a high-energy blunt force trauma who were transported directly from the scene of the accident to the emergency department were enrolled in the study. Patients referred to the Erasmus MC from another hospital were not considered eligible for inclusion. Victims of penetrating trauma were excluded because of the specific injury characteristics and subsequent requirement for the "scoop and run" procedure. Patients under the age of 15 years and victims of drowning, strangulation or suffocation were also excluded.

Data collection and processing

The data on all trauma patients were prospectively documented into the Major Trauma Outcome Study (MTOS) compatible trauma registry. Prehospital time intervals, the number and types of interventions performed before and after admission to hospital (intubation, chest tube, first and second intravenous line insertion, extremity splint placement) and patient characteristics were recorded. The prehospital time interval was divided into OST and transport time. OST was defined as the time between arrival of the first EMS unit on the scene and departure of the patient from the trauma scene. Transport time was defined as the time interval between departure from the trauma scene and arrival at the emergency department.

Dispatch centre records, ambulance registration forms and HEMS flight forms were manually collected and used to supplement registry data. The prehospital times were recorded in real time during the dispatch. The Revised Trauma Score (RTS) and Glasgow Coma Scale (GCS) were recorded on arrival of the first EMS unit but before treatment was initiated in order to avoid any bias.

The hospital resuscitation time (HRT) was obtained from continuous digital video registration. This allowed for a highly accurate calculation of the HRT that was blinded to prehospital data[10]. The interventions performed and the duration of the time intervals were scored using these videos. This enabled scoring of the number of interventions performed during the different steps of the ATLS principles (A, B, C, D and E) and the time needed.

The HRT was defined as the interval between briefing and the end of the secondary survey. It was subdivided into primary and secondary survey. Primary survey is the interval from briefing until the end of the exposure interval. Secondary survey is the time from the end of the exposure interval until the end of a complete and detailed physical examination including radiographs. In cases where the ATLS principle was not executed to completion, the end point of both the primary survey and HRT was defined as either the last finished ATLS interval "ABCDE", departure from the resuscitation room or death.

Two subanalyses were performed. To assess the effect of injury severity, patients with an injury severity score (ISS)<16 were compared with those with an ISS ≥16[11]. In addition, data for patients receiving additional HEMS assistance were compared with data for the EMS group.

Outcome measures

Primary outcome measures were prehospital and in-hospital time intervals. Secondary outcome measures were the number and types of interventions performed before and after admission to hospital.

Data analyses

All analyses were performed using the SPSS Version 11.5. Data on time management are displayed as median time with first and third quartiles. Comparisons between groups were made using the X^2 test for categorical variables and the Mann-Whitney U test for continuous variables. Data were stratified according to ISS (<16 vs ≥16) and the presence of HEMS (EMS group vs combined EMS-HEMS group) to determine any additional effect of injury severity and HEMS assistance on time management and interventions performed. Linear regression analysis was performed to determine the correlation between prehospital and hospital interventions and the total trauma resuscitation time.

RESULTS

Characteristics of study subjects

During the 4-month study period 192 patients with suspected blunt high-energy trauma were admitted to the emergency department of a level 1 trauma centre. Forty-five of these 192 patients were excluded from the study: 29 were aged,15 years, 4 were referred from surrounding hospitals, 3 sustained penetrating trauma and prehospital data could not be retrieved for 9 patients. Data for the remaining 147 patients were analyzed. Of these, 45 were multi-trauma patients with an ISS of ≥16 and 102 had an ISS of <16. A total of 40 patients were assisted by combined EMS-HEMS. When patients were treated by both an EMS and a HEMS unit, the EMS team always arrived on the scene first.

The demographic characteristics of the patients are shown in Table 1. HEMS assistance was provided relatively more frequently in the multi-trauma group (21/43). Patients in the EMS-HEMS group were more severely injured, as represented by lower GCS and RTS values and higher ISS values. In addition, patients in this group experienced physical entrapment relatively more often than patients in the EMS group. Unadjusted mortality was higher for multi-trauma patients and for patients receiving additional HEMS assistance.

Table 1. Demographic characteristics of 147 patients who suffered high energy blunt trauma

Characteristics	**Overall (n=147)**	**ISS<16 (n=102)**	**ISS≥16 (n=45)**	**p**	**EMS (n=107)**	**EMS+HEMS (n=40)**	**p**
Male (n)	107	75	32		74	33	
Median GCS	14 (10-15)	15 (14-15)	9 (4-14)	<0.001‡	15 (13-15)	13 (5-15)	0.002‡
Median RTS	12 (11-12)	12 (12-12)	10 (8-12)	<0.001‡	12 (11-12)	11 (9-12)	0.001‡
Median ISS	9 (4-19)	5 (4-9)	26 (20-31)	<0.001‡	8 (4-14)	18 (7-29)	<0.001‡
Physical entrapment (n)	11	6	5	0.17†	5	6	0.03†
HEMS assistance (n)	38	19	19	<0.001†	-	-	-
Mortality (n)	9	0	9	<0.001†	3	6	0.006†

EMS, emergency medical services; GCS, Glasgow Coma Scale; ISS, Injury Severity Score; RTS, Revised Trauma Score; † Chi-squared Test; ‡ Mann-Whitney. Data are given in medians with first and third percentiles in parentheses.

Table 2. Performed prehospital and in-hospital interventions subdivided according to injury severity (ISS) and HEMS involvement

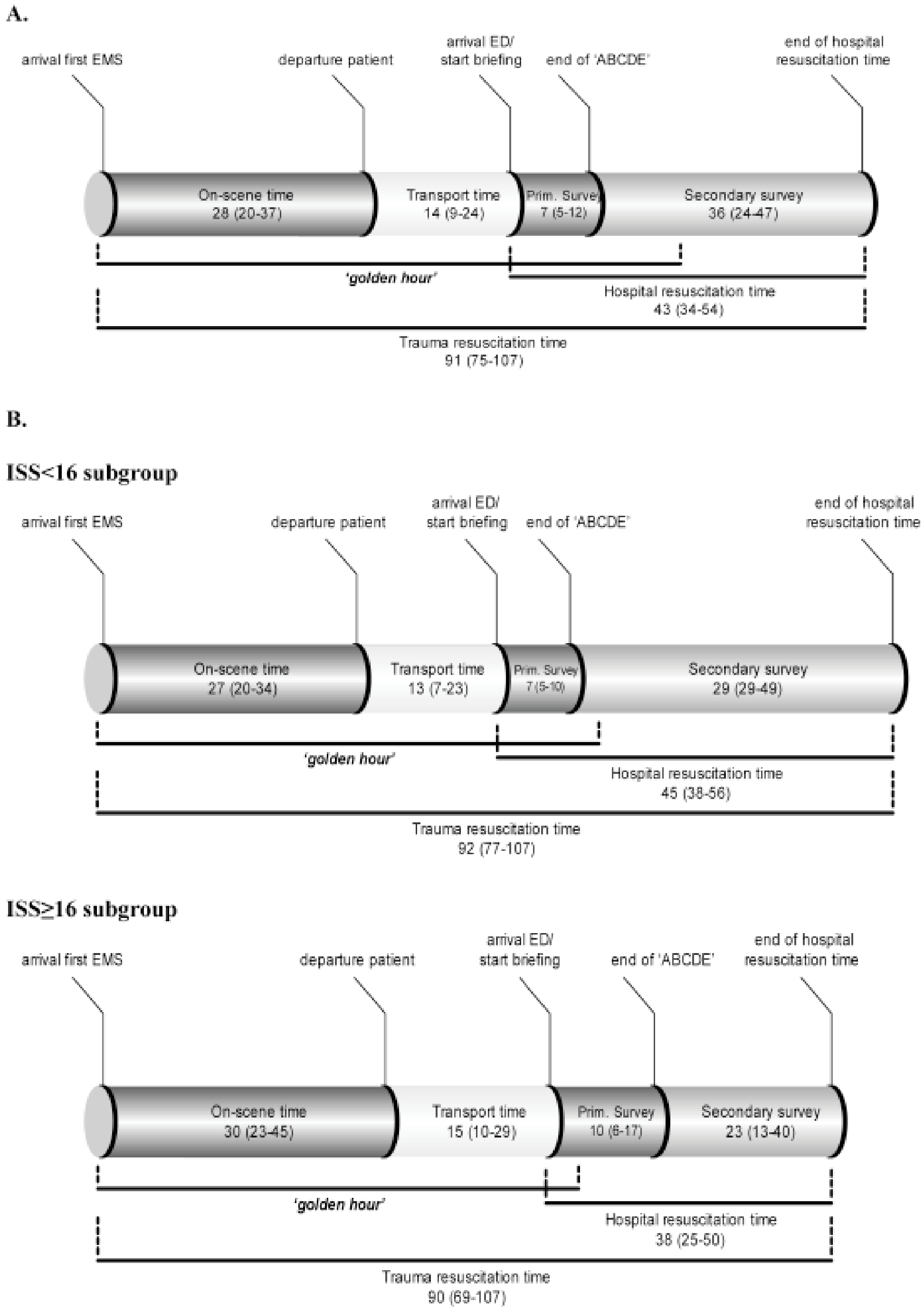
	Total N (%)	**ISS < 16 N (%)**	**ISS ≥ 16 N (%)**	**EMS N (%)**	**EMS+HEMS N (%)**
Total number of patients	147	104	43	107	40
Total number of interventions	275 (100)	166 (100)	109 (100)	171 (100)	104 (100)
Prehospital Interventions	224 (82)	139 (84)	85 (78)	132 (77)	92 (89)
Intubation	16 (6)	2 (1)	14 (13)	2 (1)	14 (14)
Chest drainage	5 (2)	0 (0)	5 (3)	0 (0)	5 (5)
Insertion first I.V.	142 (52)	101 (61)	41 (25)	102 (60)	40 (39)
Insertion second I.V.	45 (16)	24 (15)	21 (13)	17 (10)	28 (27)
Extremity splint immobilisation	16 (6)	12 (7)	4 (2)	11 (6)	5 (5)
Hospital interventions	51 (19)	27 (16)	24 (19)	39 (23)	12 (12)
Intubation	9 (3)	1 (1)	8 (7)	7 (4)	2 (2)
Chest drainage	6 (2)	0 (0)	6 (6)	3 (2)	3 (3)
Insertion first I.V.	5 (2)	3 (2)	2 (2)	5 (3)	0 (0)
Insertion second I.V.	16 (6)	12 (7)	4 (4)	13 (8)	3 (3)
Extremity splint immobilisation	15 (6)	11 (7)	4 (4)	11 (6)	4 (4)

ISS, Injury Severity Score; (H)EMS, (Helicopter) Emergency Medical Services; I.V., Intravenous line

Main results

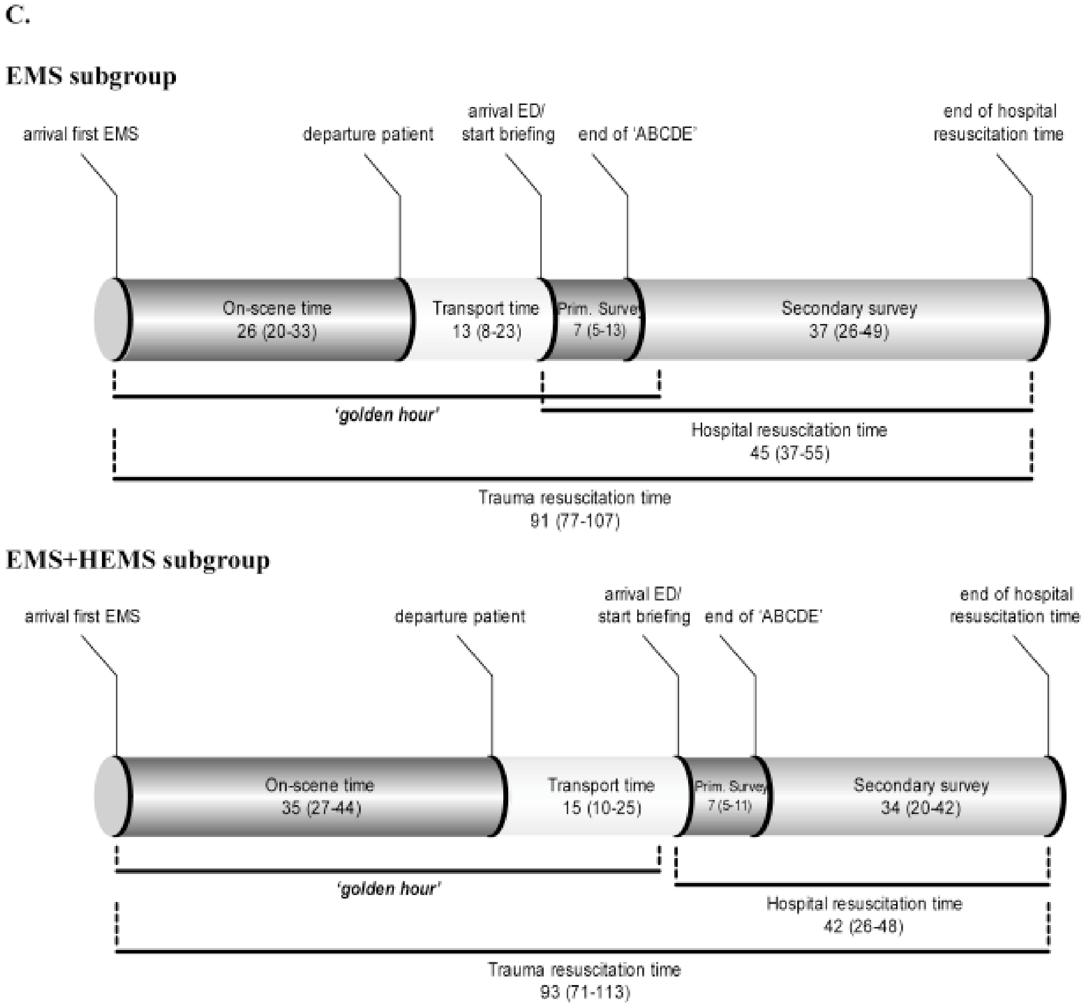
The distribution of the various time intervals is shown in fig 1A. The median trauma resuscitation time (TRT) was 91 min, subdivided into a median OST of 28 min, transport time of 14 min, primary survey time of 7 min and secondary survey time of 36 min. On average

Figure 1. (A) Overview of time intervals during trauma resuscitation in the total study. (B) Overview of time intervals during trauma resuscitation for patients with injury severity scores (ISS) <16 versus ≥16. (C) Overview of time intervals during trauma resuscitation according to type of prehospital assistance.



EMS, emergency medical services; HEMS, physician-staffed helicopter emergency medical services. Data are given as median time, with the 1st and 3rd percentile given in parenthesis.

Figure 1. (A) Overview of time intervals during trauma resuscitation in the total study. (B) Overview of time intervals during trauma resuscitation for patients with injury severity scores (ISS) <16 versus ≥16. (C) Overview of time intervals during trauma resuscitation according to type of prehospital assistance.



EMS, emergency medical services; HEMS, physician-staffed helicopter emergency medical services. Data are given as median time, with the 1st and 3rd percentile given in parenthesis.

and within all subgroups, the initial assessment and treatment including the primary survey were completed within the first hour after arrival of the first EMS unit at the trauma scene.

When stratified according to injury severity (fig 1B), the multi-trauma group had no difference in prehospital time intervals but did have a longer in-hospital primary survey interval (p=0.001) and a shorter in-hospital secondary survey interval (p<0.001). The HEMS-assisted group (fig 1C) had a longer mean OST (p<0.001) and a shorter mean in-hospital primary survey time than the group treated by EMS only.

The prehospital and in-hospital interventions performed during the "golden hour" are shown in table 2. A total of 275 interventions were performed in the 147 patients included in the study. Of these, 81.5% were performed before admission to hospital and 18.5% were performed in the emergency department. Most of the prehospital interventions were

Table 3. Number of prehospital interventions per patient and relation with the duration of prehospital on-scene time and in-hospital primary survey

Prehospital interventions (N)	Patients (N)	On-scene time (min)	Primary survey time (min)
0	6	22 (16-19)	7 (5-10)
1	84	25 (20-31)	7 (5-14)
2	36	31 (24-41)	8 (5-10)
3	19	34 (27-43)	7 (5-16)
4	2	55*	11 (4-12)

Data are given in medians with the first and third percentiles in parentheses. * No percentiles could be calculated; the individual data were 44 and 65 min.

intravenous line insertions and most of the in-hospital interventions consisted of insertion of a second intravenous line and extremity splint immobilization. The numbers of prehospital and in-hospital interventions were higher in the multi-trauma patients (ISS ≥16) than in the group with an ISS <16. The number of prehospital interventions was higher in the HEMSEMS group than in the EMS group (p<0.001) and the number of in-hospital interventions was lower. Relatively more prehospital intubations, chest tube placements and second intravenous line insertions were performed in the HEMS group. The five prehospital interventions (intubation, tube thoracotomy, first and second intravenous line insertions and extremity splint placement) were analyzed in relation to the OST. There was a signifi-

Table 4. Effect of separate prehospital intervention on the time used for the in-hospital corresponding ATLS-step

Prehospital intervention	N	In-hospital ATLS interval (s)	P
Airway interval			
Intubation	16	15 (9-34)	ns†
No intubation	131	12 (7-22)	
Breathing interval			
Thoraxdrainage	5	44 (35-57)	ns†
No thoraxdrainage	142	36 (24-56)	
Circulation interval			
First I.V.	142	45 (22-85)	ns†
No first I.V.	5	28 (19-202)	
Circulation interval			
Second I.V.	45	60 (35-108)	0.001†
No second I.V.	102	38 (18-73)	
Exposure interval			
Extremity splint	16	233 (166-1270)	ns†
No extremity splint	131	202 (80-460)	

ATLS, advanced trauma life support; IV, intravenous line; ns, not significant; † Mann-Whitney.
Data are given in medians with the first and third percentiles in parentheses.

cant association between prehospital intubation (p=0.05), chest tube placement (p=0.005) and second intravenous line insertion (p=0.001) and an increase in OST.

Table 3 shows the relation between the number of prehospital interventions (range 0–4) and the prehospital and in-hospital time intervals. An increased number of prehospital interventions was associated with an increased OST (p<0.001). Subanalyses for the EMS and HEMS groups showed no such association for the HEMS group.

No relation was found between the number of prehospital interventions and the duration of the in-hospital primary survey. An increase in transport time was correlated with an increased number of on-scene interventions. Each single prehospital intervention and the duration of the corresponding hospital ATLS interval was given in seconds (table 4). In-hospital time intervals were fairly constant despite performance of on-scene interventions.

DISCUSSION

This study has objectively assessed the time intervals and interventions performed in the initial care of 147 patients with blunt trauma. The effect of prehospital interventions and subsequent time spent at the trauma scene on resuscitation time in the emergency department has been studied for the first time. The median time interval from the arrival of an EMS unit at the trauma scene until the end of the primary survey was 49 min, delivering life- and limb-saving treatment within the first hour after arrival of medical assistance. This finding is in line with the worldwide assumption that definitive care must be established preferably within the "golden hour" to improve patient outcome[5].

As expected, the number of prehospital interventions was associated with an increase in the OST in both EMS- and HEMS-assisted patients. However, the concept that an increased OST should result in a decrease in hospital primary survey time was not supported. The results indicated a short primary survey time in the emergency department, which was fairly constant and not affected by interventions performed before admission to hospital. A more detailed analysis dividing the hospital primary survey into time frames for the single ATLS intervals (ABCDE) showed exact time intervals with far greater accuracy than the existing literature. Although some differences were statistically significant, the clinical relevance is limited.

An explanation for both findings concerning the primary survey time could be a more efficient, systematic and simultaneous ATLS approach of the emergency department trauma team. This might minimise the time required for ABCDE, even when more interventions are needed. The number of prehospital interventions prolonged the OST, but no such association was found when HEMS had been involved. On average, the presence of the HEMS crew was related to an increased OST (fig 1C). This may be due to the relatively higher number of time-consuming physical entrapments in the HEMS-assisted group, the reassessment time by the HEMS team and an overall more extensive treatment in addition to the five interventions documented in this study. The higher number of more severely injured patients in the HEMS group requiring more interventions did not increase the prehospital time intervals.

In agreement with the findings of the present study, both van Olden et al[9] and a meta-analysis by Carr et al[12] of 49 studies on prehospital times in 20 states in the USA showed an average prolonged OST when HEMS had been involved. Furthermore, a study by Sampalis et al[13] and a meta-analysis by Liberman et al[14] showed that prehospital advanced life support resulted in increased OST. However, no study or meta-analysis has investigated blunt trauma victims separately.

As reported by Hedges et al[15], the present study showed a relation between longer patient transport times and number of interventions, suggesting that longer distances to the hospital result in more interventions being performed on scene. This infers that (para) medics tailor their on-scene intervention strategy to transport distance. The finding by Petri et al[16] of a shorter OST in severely injured patients suggests that this may be another factor guiding the actions of (para)medics during on-scene management.

Limitations of study

No precise definition of the "golden hour" was found in the literature, suggesting that it is a concept rather than a stringent period of time. The measurement starting point chosen for this study was the arrival of the first EMS unit. This was chosen primarily because this point could be determined objectively and also because, from this time point, the prehospital medical interventions are supposed to affect the in-hospital resuscitation times and interventions. For logistical reasons the actual time at which the trauma occurred could not be retrieved reliably in about 30% of cases. For cases in which the trauma time and the EMS response time were documented accurately, a median time interval of 6 min passed between the emergency call to the dispatch centre and the arrival of the first EMS at the accident scene. The prehospital time intervals recorded in this study would thus increase overall by 6 min. Still, the "golden hour" would have expired after the initial treatment including the primary survey at the emergency department.

Because of the aforementioned unreliable documentation and the focus of the investigations on the influence of OST and prehospital interventions on the HRT rather than on the clinical outcome, the currently used starting point seems justified. If emergency surgery was needed or when a patient died, not all ATLS steps were completed. A moderate effect of this early termination on the HRT in the group of severely injured patients cannot be ruled out. Likewise, these patients were more likely to need more (radio)diagnostic modalities resulting in a longer HRT. This could result in bias towards in-hospital times in sicker patients, although the number of cases with unfinished ATLS steps was limited (n=17).

This study did not report on clinical outcome. The only objective outcome parameter obtained was 30-day mortality. Since the number of deaths was low owing to the heterogeneity of the injuries, this parameter could not be used for further analyses or for interpretation of the results.

CONCLUSION

(H)EMS achieve life- and limb-saving care within the "golden hour" but this occupies 83% of the first hour after a traumatic injury. A number of factors appear to affect the decisions concerning the medical treatment and subsequent time spent on the initial treatment. Clearly, the time necessary for treatment is predominantly determined by the number of interventions that need to be performed before admission to hospital, combined with the level of prehospital care. The number of prehospital interventions is increased when HEMS are involved compared with EMS only, but the higher number of interventions does not result in longer OST in the HEMS group. However, although the numbers of subsequent interventions performed in hospital may be lower, performance of interventions before admission to hospital does not seem to result in a reduction in the time in hospital. This study of the time frames in initial trauma care might serve as a basis for further research into the consequences of interventions and time management on patient outcome.

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7

Prehospital Chest Tube Thoracostomy: Effective Treatment or Additional Trauma?

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ABSTRACT

Background The use of prehospital chest tube thoracostomy (TT) remains controversial because of presumed increased complication risks. This study analyzed infectious complication rates for physician-performed prehospital and emergency department (ED) TT.

Methods Over a 40-month period, all consecutive trauma patients with TT performed by the flight physician at the accident scene were compared with all patients with TT performed in the emergency department. Bacterial cultures, blood samples, and thoracic radiographs were reviewed for TT-related infections.

Results Twenty-two patients received prehospital TTs and 101 patients received ED TTs. Infected hemithoraces related to TTs were found in 9% of those performed in the prehospital setting and 12% of ED-performed TTs (not significant).

Conclusion The prehospital chest tube thoracostomy is a safe and lifesaving intervention, providing added value to prehospital trauma care when performed by a qualified physician. The infection rate for prehospital TT does not differ from ED TT.

INTRODUCTION

Management of trauma patients has been subject to many changes during recent years. To achieve a higher standard of care, further standardization was implemented. Nowadays, trauma patients all over the world are assessed and treated either in accordance with the Advanced Trauma Life Support–based protocol for physicians as set forth by the American College of Surgeons or according to the Pre-Hospital Trauma Life Support system in the case of ambulance nurses in the field[1].

Alterations and additions to assessment and treatment of trauma patients have been effectuated both clinically and at the accident site. In The Netherlands, one of these additions to trauma care for severely injured patients in the prehospital phase is the introduction of the helicopter mobile medical team, a physician-staffed Helicopter Emergency Medical Service (HEMS). One of the benefits is the fact that a highly trained surgeon or anesthesiologist can perform procedures, such as administration of analgesics and general anesthetics and insertion of a tube thoracostomy (TT), that ambulance nurses are not allowed to execute. Although the beneficiary influence on survival of the Helicopter Mobile Medical Team has been established, little is known about the benefits or disadvantages achieved by the use of the separate interventions in the prehospital phase of trauma care[2, 3].

The subject of this study is the treatment of pneumoand/ or hemothoraces by the use of TT, which is the initial treatment of choice for significant pneumothorax, massive hemothorax, and hemopneumothorax[1]. TT has become a standard procedure in emergency departments, whereas in the prehospital phase, its use remains controversial. Some authors have proposed that the use of TT in the prehospital phase reduces mortality and is a safe and effective tool with low associated morbidity[4, 5]. Schmidt et al. also stated that the risk for infections does not increase simply because of environmental factors, whereas others consider intrapleural and wound infections to be more likely when chest tubes are placed in less sterile environments, such as accident scenes[5-7].

The primary objective of this study was to compare the infectious complication rate between emergency department (ED) and prehospital TT. Secondary objectives are the assessment of misplacements and analysis of TT indications.

PATIENTS AND METHODS

The setting was the Erasmus MC University Medical Center Rotterdam (EMC), a Level I trauma center and teaching hospital with more than 1,200 beds. ED resuscitation of trauma victims is a multidisciplinary Advanced Trauma Life Support–based effort. Direct patient care is provided by residents in surgery, anesthesiology, and emergency medicine. Extended trauma care at the accident site can be provided by physician-staffed HEMS. These physicians are well-trained anesthesiologists or trauma surgeons.

Over a 40-month period, all consecutive trauma patients that were given a chest tube either by the Rotterdam HEMS or in the ED and subsequently admitted to the EMC were prospectively enrolled in this study. Patients who received a chest tube in another hospital or who died within 48 hours directly after trauma were excluded, after it was confirmed that none of these patients died as a result, directly or indirectly, of chest tube placement. Patients were subdivided into two groups: those who had a TT placed in the prehospital setting and those who had a TT placed in the ED. All TTs were performed by blunt dissection of the subcutis and intercostal muscles, after incision of the skin at the fourth or fifth intercostal space, anterior to the midaxillary line. The pleura was opened using a blunt instrument. No trocars were used because of the increased risk for iatrogenic complications[8].

Empyema-like intrapleural infections are related to chest tube placement, but pulmonary infections can arise through a large number of paths.7 Therefore, primary outcome was defined as empyema-like intrathoracic infections or an infected tube insertion site (extrathoracic). These were diagnosed by the diagnostic triad of positive infection parameters in the blood, suspicious chest radiograph, and positive bacteriologic culture. Blood samples were taken at days 7 and 14 after TT, and infectious parameters were deemed positive when two values of C-reactive protein greater than 30 mg/L, erythrocyte sedimentation rate greater than 30 mm/h, or white blood cell count greater than 10 x 10^9/L were found. All bacteriologic cultures from thoracic fluid or the tube insertion site were analyzed for microbiologic infection by the department of microbiology and the presence of infectious agents was determined. Subsequently, all chest radiographs were reviewed by a senior radiologist.

Misplacements were defined as chest tubes placed outside of the pleural cavity. Patient demographics and type of injury were prospectively entered, as was TT indication, clinical course, and outcome, The Injury Severity Score was calculated[9].

Statistical Analysis

Statistical analysis was performed retrospectively for the purpose of this study. All calculations regarding TT-related infections and complications pertained to the number of drained hemithoraces instead of patients. All data were collected in a Microsoft Access 97 database and analyzed using the SPSS version 10.0 software. Analysis was performed using Student's t, Fisher's exact, and Mann-Whitney tests, and means are given ± SD with a 95% confidence interval.

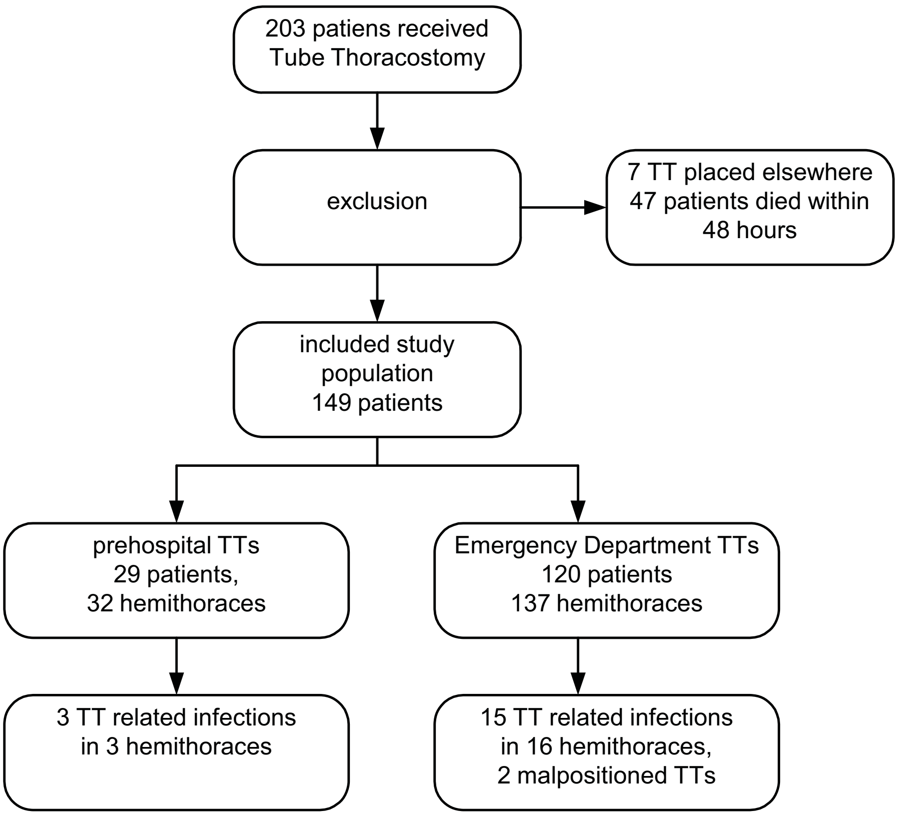
RESULTS

From October 2000 until February 2004, a total of 203 patients (Fig. 1) received TTs in either the prehospital setting or the ED of the EMC. Seven patients received TTs in other hospitals and 47 patients died within 48 hours after admission. All 54 were excluded. The resulting 149 patients, receiving 194 chest tubes placed in 169 hemithoraces (129 unilateral, 20 bilateral), were admitted to the EMC, and enrolled into this study. The mean Injury Severity Score for included patients was 23.3, ranging from 9 to 54. The patient population was then categorized into two groups: 29 patients with chest tubes (in 32 hemithoraces) placed in the prehospital setting, and 120 patients with chest tubes placed in the ED (in 137 hemithoraces) (Table 1). Two patients received TTs in the prehospital setting and, on arrival to the ED, received another chest tube contralaterally. They were analyzed in both the prehospital and ED groups, with the corresponding hemithorax.

Indications for TT

The indications for TT of the included patients in both groups are listed in Table 1. Overall, the main indication for the use of TT was a clinically significant (i.e., desaturation of the patient below 95% SaO_2) pneumothorax (84 of 169), for both the prehospital (12 of 32) and the ED

Figure 1. Flowchart of included patient population. The number of infections is depicted per moment of TT performance (at the accident site or in the Emergency Department)



(72 of 137) situations. The relative number of pneumothoraces was larger in the ED (p=0.13), whereas decompressed tension pneumothoraces were in the prehospital setting more of-

ten considered as an indication for TT (11 of 32) compared with the ED group (10 of 137) (p<0.0001). For penetrating trauma, the main TT indication was the presence of a hemothorax. With blunt trauma, more TTs were performed for pneumothorax in the ED (44 of 64) than in the prehospital setting (12 of 28) (p=0.04).

A total of seven needle decompressions were performed in the patient population that received prehospital TT (22%). In the ED population, 10 needle decompressions were documented (7%), of which 6 had been performed in the prehospital setting.

Table 1. General characteristics, TT indications and complications for both the prehospital and ED study groups

	Overall		Blunt trauma		Penetrating trauma	
	PH (n= 29)	ED (n= 120)	PH (n= 28)	ED (n= 64)	PH (n= 1)	ED (n= 56)
General						
Male	22	101	21	50	1	51
Mean age (years ± SD)	38.0 (±18.0)	36.1 (± 15.4)	38.8 (±17.8)	42.2 (±17.2)	16 [a]	29.7 (±9.7)
Mean ISS	29.3 (±11.7)	22.1 (± 10.4)	30.0 (±11.2)	26.3 (± 9.9)	9 [a]	16.6 (±8.1)
Hemithoraces (n= 169)	32	137	31	73	1	64
Drains (n= 194)	32	162	31	86	1	76
Indications (per hemithorax)						
Tension pneumothorax	11/32	10/137†	11/31	6/73		5/64
Flail chest	2/32	6/137	2/31	6/73		
Hemothorax	7/32	48/137	6/31	17/73	1/1	31/64
Pneumothorax	12/32	72/137	12/31	44/73‡		28/64
Complications (per hemithorax)						
Infections	3/32	16/137	3/3	14/137		2/64
Malpositioning	0	2/162		2/86		

Data are given for the entire population and then subdivided into penetrating and blunt trauma groups.
[a] Values cannot be called mean; TT= Tube Thoracostomy; PH= Pre-hospital; ED= Emergency Department; ISS®= injury Severity Score; †=p<0.0001, Mann Whitney test; ‡= p<0.05, Mann Whitney test.

Infectious Complications

In 39 instances, antibiotics were given before TT was performed; 2 of 29 times in TTs performed in the prehospital setting and 37 of 120 times in those performed in the ED (p=0.008). None of these patients developed complications. Related to chest tube insertion, a total of 19 infected hemithoraces did develop, 3 in the prehospital group and 16 in the ED group (Table 2): 2 local infections at tube insertion site, 8 true empyemas, and 9 empyema-like intrathoracic infections. Associated with chest tube insertion, empyema will typically culture gram-positive Staphylococ-

Table 2. Overview of data concerning patients with positive laboratory infection parameters and bacterial cultures

Pt	Group	Indication	Gender	Age (yrs)	ISS	Hosp (days)	ICU (days)	Trauma	Causative agent	Radiological Diagnosis	Treatment
1	PH	Ptx	m	29	17	25	19	B	Staph Aureus, E. Coli	Wound infection	AB
2	PH	Htx	f	24	41	114	29	B	Pseudomonas aer	Pleural fluid	AB
3	PH	FC	m	25	38	19	14	B	Klebsiella pneum	Pleural fluid	AB
4	ED	TPtx	m	31	25	20	1	P	S. Aureus	Empyema Thoraces (CT)	Thoracotomy + AB
5	ED	TPtx	m	65	34	21	1	B	S. Aureus, Pseudomonas aer	Pleural fluid	AB
6	ED	Htx	m	21	19	25	1	P	Hafnia alvei, Serratia marc	Empyema Thoraces	Thoracotomy
7	ED	Htx	m	54	34	92	15	B	S. Species, Pseudomonas aer	Pleural fluid	AB
8	ED	Htx	m	18	25	40	18	B	S. Aureus	Empyema Thoraces	Thoracotomy
9	ED	Htx	m	68	22	34	/	B	S. Aureus	Empyema Thoraces	Thoracotomy
10	ED	Htx	m	50	26	14	/	B	S. Aureus	Pleural fluid	AB
11	ED	FC	f	75	29	105	30	B	B. cereus	Pleural fluid	Drainage
12	ED	FC	m	65	45	74	31	B	S. Aureus	Empyema Thoraces	Thoracotomy
13	ED	Ptx	f	31	25	22	1	B	S. Species	Pleural fluid	Drainage
14	ED	Ptx	m	65	29	7	2	B	S. Aureus	Abscess rib	AB
15	ED	Ptx	m	42	10	24	9	B	S. Aureus	Empyema Thoraces bilateral, intrahepatic chest tube	Thoracotomy + AB
16	ED	Ptx	f	63	41	108	38	B	S. Aureus	Abscess entry wound + thoracic wall	Incision and drainage
17	ED	Ptx	m	37	27	19	3	B	S. Aureus	Empyema Thoraces	TT + AB
18	ED	Ptx	m	33	34	25	13	B	S. Aureus	Pleural fluid	AB

Pt=patients; ED= Emergency Department, PH= prehospital; TPtx= tension pneumothorax, Ptx= pneumothorax, Htx= hemothorax, FC = flail chest; ISS® = Injury Severity Score; Hosp stay = length of hospital admission (days); ICU= Intensive Care Unit admission (days); Trauma, B=blunt, P=penetrating. AB= AntiBiotics.

cus aureus[10, 11]. When looking at S. aureus–related infections only, data showed a total of 1 of 32 prehospital and 12 of 137 infections (p=0.47). One patient from the ED group developed bilateral empyema from infection with S. aureus. The main indication for TT placement in the group with infectious complications was pneumothorax (8 of 19), followed by hemothorax (6 of 19).

Another 49 patients from the entire population had laboratory infection parameters that were considered positive but did not have positive cultures of fluid from drain exits or pleural fluid. Two of these patients did have fluid collections that were suspected of having empyema thoraces, but when drained fluid was cultured, no microorganisms were found.

Tube Malpositioning

In total, none of the TTs performed in the prehospital setting and 2 of the ED-performed TTs (2 of 162) needed replacement after being diagnosed as malpositioned. One was found to be placed intrahepatically, causing an undrained hemithorax that led to empyema thoraces in both hemithoraces. One ED-placed chest tube was positioned subcutaneously.

Intensive Care Unit and Hospital Stays

The mean stay of patients in hospital, in the intensive care unit (ICU), and the duration of drainage (primary TT) are shown in Table 3. Duration of drainage was longer for patients that received ED TT than prehospital TT, with 4.3 and 4.1 days, respectively (p=0.663). Conversely, mean ICU and total hospital stay was longer for patients that had TTS performed in the prehospital setting. Mean hospital stay was longer for patients that developed infectious complications (p<0.0001, Mann-Whitney).

DISCUSSION

Performance of tube thoracostomy is often the definitive treatment for severe thoracic injury and may be a lifesaving intervention in the initial care for severely injured patients. Indications are well defined[1], but in many prehospital programs, TT is not included in the therapeutic arsenal because of assumed added risks of complications[12]. By comparing complication rates between TTs performed in the prehospital setting and those performed in the ED, this study intended to determine the possible added risk of using TT by physicians in the field and to compare outcome to the literature. Emphasis must be placed on the fact that the Dutch HEMS is physician-staffed, where other studies comparing complications between emergency departments and the field are based on flight nurse–staffed HEMSs[13-16].

Potential causes for thoracic empyema include iatrogenic infection of the thoracic pleural cavity during chest tube placement. A total of 19 infected hemithoraces did develop, 3 after prehospital TT and 16 after ED TTs, which did not differ significantly (p=1.0). When associated

Table 3. Mean hospital and ICU stays in days, and duration of chest tube drainage, for prehospital and ED performed TT groups

	Prehospital n= 29 patients, 32 hemithoraces	ED n= 120 patients, 137 hemithoraces
Hospital stay (days)	21,5 (± 23,3)	19,1 (± 21,9)
ICU stay (days)	8,3 (± 10,3)	5,7 (± 11,2)
Drainage time (days)	4,1 (± 3,3)	4,3 (± 2,9)

ED: Emergency Department, ICU: Intensive Care Unit.

with chest tube insertion, empyema will typically culture gram-positive S. aureus[11, 17]. The current study showed 1 of 32 prehospital and 11 of 137 ED infections (p=0.47) resulting from S. aureus, with an overall empyema incidence of 4%. Studies analyzing clinically placed TTs showed similar incidences. Millikan et al. found a 2.4% incidence of empyema[7] and, more recently, Deneuville found an incidence of 2%[18]. One study pertaining to TTs performed in the prehospital setting by physician-staffed HEMS found no intrapleural infections after emergent TT in the field in 63 patients[5], which does not correspond to our results, showing an infection rate of 9% in TTs performed in the prehospital setting. In 47 cases (32%), antibiotics were given before TT placement. Although prophylactic administration of antibiot-ics is part of both TT protocols and its benefits in prevention of empyema has been established[19], there seems to be either a suboptimal protocol adherence or a problem with its registration. In the ED, the prophylactic administration of antibiotics (37%) was documented significantly more often then in the prehospital setting (10%) (p=0.008).

A secondary outcome measure was tube malpositioning. When computed tomographic scanning is used, tube malpositioning can be found in up to 26% of performed TTs.19 This study showed only two cases (1%) of tube malpositioning. However, because radiography, which only detects a small percentage of tube malpositioning[20], is the standard for establishing TT position, improperly placed chest tubes may have been overlooked. For the same reason, retained hemothorax, which is a well-defined risk factor in the cause of infectious complications such as empyema thoraces[10, 21], cannot be diagnosed with high sensitivity either.

The main indication for TT placement, in concordance with others[5], was a clinically significant pneumothorax. Significantly more tension pneumothoraces were diagnosed and treated in the prehospital setting than in the ED. A possible explanation lies in the urgent nature of the tension pneumothorax and the subsequent need for immediate treatment in the prehospital setting by needle decompression as a lifesaving intervention. This does mean, however, that these patients are given a TT in the emergency department for a simple pneumothorax, because the tension component has been cleared.

An interphysician discrepancy may exist. Flight physicians for the Dutch HEMS are surgeons or anesthesiologists who received extensive additional training in prehospital trauma care. Physicians performing TTs in the ED of the EMC, a teaching hospital, are most often first- or second-year residents in surgery, supervised by an attending trauma surgeon. Insufficient experience of individuals involved in trauma care is, to some extent, a reason for significant morbidity and extended hospital stay resulting from TT[18]. More malpositioned tubes did in fact occur when the lesser experienced physician in the ED performed TT, though not significantly. Length of stay in the hospital and ICU did not significantly differ either. To what extent infectious complications as defined here can be linked to physician inexperience remains unclear. Many other factors surrounding individual cases confound this comparison. Duration of drainage has been shown not to correlate with the development of empyema[10]. Our results showed no difference in duration of drainage or in incidence of infectious complications between the TTs performed in the prehospital setting and those performed in the ED.

In conclusion, the results of this study show that the rate of infectious complications did not differ for TTs performed in the prehospital setting and those performed in the ED. Neither did the main indication for placement of a chest tube (i.e., pneumothorax). Reduction of the incidence of chest tube-related complications may be obtained by additional training of physicians and better protocol adherence to antibiotic strategies. In light of current findings, the authors state that prehospital use of tube thoracostomy by qualified professionals does not introduce additional risk of complications compared with the in-hospital situation and therefore is a lifesaving and valuable addition to prehospital care for the severely injured patient.

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8

Inventoring the Need for Mobile Medical Team Assistance in the Evening and Night

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ABSTRACT

Background The aim of this study was to gain insight into the quantitative and qualitative aspects of Mobile Medical Team (MMT) dispatch during nightly hours, between 19.00 and 7.00 hours.

Method In a descriptive cohort study all patients were included for which MMT assistance was summoned for in the Southwestern area of the Netherlands in 2005, between 19.00 and 7.00 hours. For the included patients (pre) hospital data were prospectively documented and analysed.

Results During the study period MMT assistance dispatched 235 times during the evening and night. Sixty-nine of these dispatches were cancelled. In 67% of cases the nocturnal dispatch was activated following the nature of the accident and in 33% of cases it was based upon the condition of the patient. Sixty-three per cent of the dispatches occurred between 19.00 hours and midnight. The median Injury Severity Score was 10 (4-25) with an overall one-month mortality rate of 16%. Twenty-three per cent of the patients were intubated by the MMT.

Conclusion This study shows that there is a substantial need for specialised medical assistance in addition to the ambulance, between 19.00 and 7.00 hours. Qualitatively, the need for assistance during the evening and night equals that during daytime. MMT assistance during nightly hours is potentially live saving. Extrapolation of the regional results produces an estimated yearly need of 502 effective MMT assistances in the Netherlands, between 19.00 and 7.00 hours.

INTRODUCTION

A joint venture between the VUmc in Amsterdam and the Algemene Nederlandse WielrijdersBond (ANWB) was founded May 1, 1995. The ANWB Medical Air Assistance (MAA) helicopter company enabled the provision of medical care by a helicopter Mobile Medical Team (MMT) to (trauma) patients on the scene. The team, consisting of a physician, a nurse, and a pilot, was transported by helicopter. As a supplement to Basic Trauma Life Support (BTLS) they provided Advanced Trauma Life Support (ATLS) [1] and an expansion of (invasive) therapeutical options on the scene of an accident [2, 3].

The added therapeutical options consist of the administration of specific medication, Advanced Airway Management, thoracic drainage, and the performance of surgical interventions. Moreover, by regularly dispatching a small group of (para)medics a large expertise was built within a short amount of time. Management of seriously injured trauma patients on the accident scene was a key issue. Analyses of these first prehospital experiences suggested a survival benefit by MMT assistance compared with regular ambulance care, which was most pronounced for roadtraffic casualties [3, 4]. Based upon these results, the trauma helicopter was introduced nationwide in the Netherlands, with helicopter stations in Amsterdam, Rotterdam, Nijmegen, and Groningen.

Budgetary restrictions and legislation limited the MMT dispatch to the Uniform Daylight Period (UDP), maximized to the time between 7.00h and 19.00h. The MMT had to be available at any time during these hours. Outside the UDP, from 19.00h until 7.00h, the ambulance personnel could ask for a Medical Assistance Team. This team was compiled *ad hoc*, generally in a nearby hospital, and consisted of a surgery resident, an anesthesiology resident, and an emergency nurse. The team was than transported to the accident scene by the police. Due to limited exposure and large changes in personnel, Medical Assistance Team faced situations with which they had insufficient experience or for which they had not been trained. As a consequence, the added value of this construction became subject of debate. Since the residents had to leave the hospital upon an assistance call, the continuity of the in-hospital management was compromised. These undesirable local circumstances together with a nationwide request for continuous high-quality prehospital care resulted in a pilot study that started January 15, 2005 in the Southwestern area of the Netherlands. For the first time, a complete and professional Mobile Medical Team was available 24 hours a day for 7 days a week. Between 7.00h and 19.00h this MMT was transported by helicopter, from 19.00h until 7.00h the MMT traveled by MMT-bus. During the UDP approximately 900 requests are submitted for MMT assistance in the Southwestern area of the Netherlands area, a region with 4.5 million inhabitants. In contrast to this established number, only estimates exist for the need of similar medical assistance during the nocturnal period [5].

The aim of this study was to gain insight into the need for MMT assistance between 19.00h and 7.00h, to be expressed both quantitatively (*i.e.*, the number of requests) and qualitatively (*i.e.*, type of accidents and treatments given). The nationwide need for MMT availability in the evening and night will be calculated from the results.

METHODS

Population

This pilot represents a descriptive cohort study. Patients for whom MMT assistance was requested in the Southwestern area of the Netherlands in the time period between January 15 2005 and January 15 2006 were included in the study. The MMT dispatch had to have taken place between 19.00h and 7.00h.

Data collection

Prehospital patient and dispatch data were collected from a prospective MMT registry and from databases of the Dispatch centers located in the study area. If necessary, supplemental data were retrieved from the ambulance forms. Hospital data were retrieved from the Rotterdam Trauma Registry, supplemented with data from medical records. The following data were collected for each patient: accident scene, trauma mechanism, patient characteristics, interventions performed prehospital, transport times, prehospital times, the hospital the patient was transported to, and vital signs such as the Revised Trauma Score RTS [6], Glasgow Coma Scale [7], and the blood pressure.

Criteria for MMT dispatch are well-defined[5]. They include criteria based upon the nature of the accident (primary dispatch criteria), and criteria based upon the patient's condition (secondary dispatch criteria). Upon an emergency call, the central dispatcher decides if primary MMT dispatch is warranted or not. In addition, the ambulance personnel may request MMT assistance upon inspection of the patient's condition and vital signs. This is called a secondary dispatch. To gain insight into dispatch motives, the criteria on which each dispatch was based on were recorded.

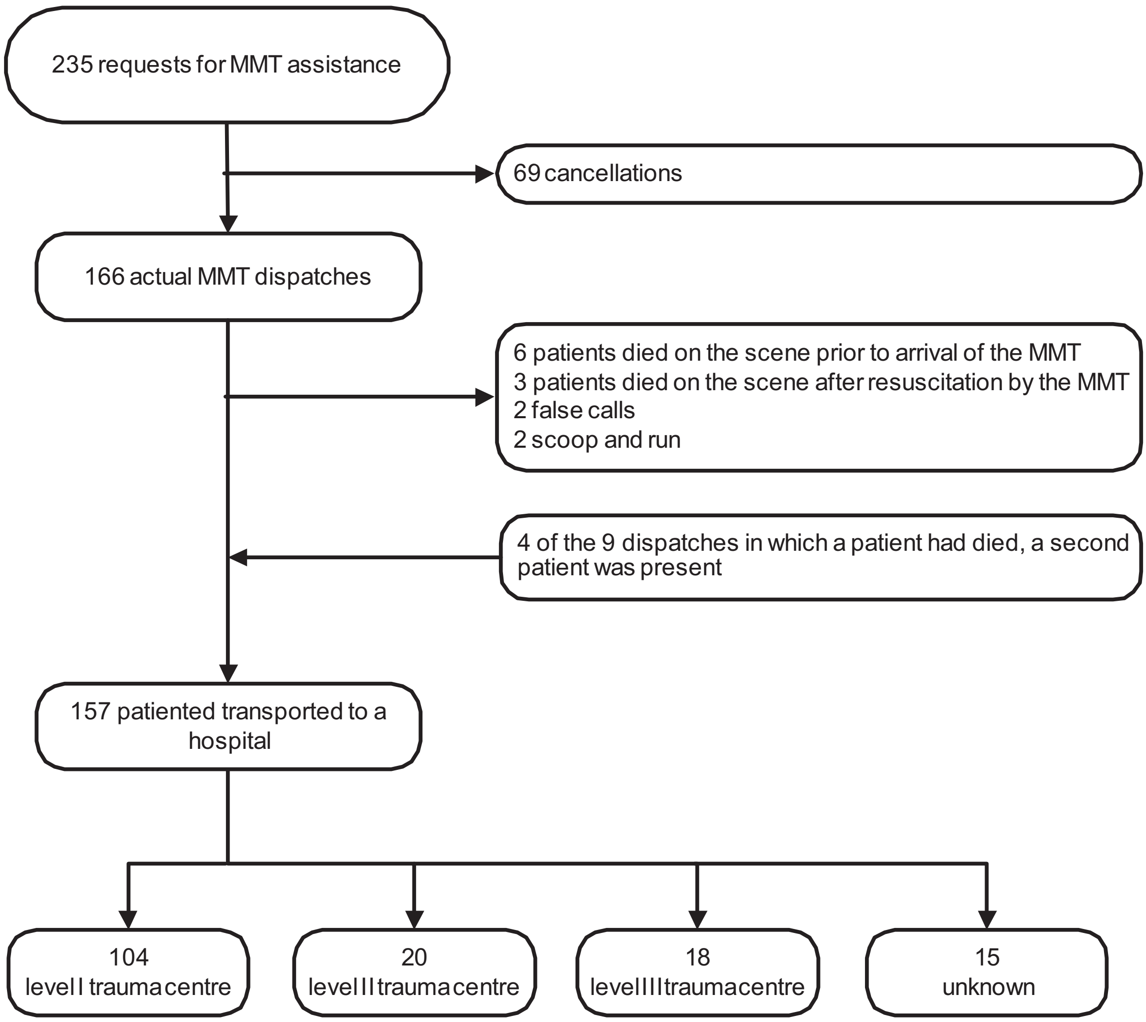
Statistical analyses were performed using the Statistical Package for the Social Sciences® for Windows, version 11.5 (SPSS, Chicago, Illinois, USA). Descriptive statistics was used for analysis of the demographic data.

RESULTS

In the study period, 235 requests for MMT dispatch in the Southwestern area of the Netherlands were received in the time frame 19.00 to 7.00h. Sixty-nine of these 235 requests were cancelled. Cancellation was mainly due to a limited injury severity of the patient. In few cases the patient had already died on the scene (Figure 1).

Overall, 166 real dispatches took place between 19.00 and 7.00h. On six occasions the patient was reported dead on arrival before arrival of the MMT, and in three cases resuscitation was unsuccessful. In addition, no patient was found on the scene on two occasions. Two times, the EMS team had performed a 'scoop and run' procedure, and had left the accident scene prior to arrival of the MMT. In 4 out of 9 dispatches in which the patient had died, a second patients required medical assistance on the scene. A total number of

Figure 1. Flow diagram, showing requests for nocturnal MMT assistance (19.00h-7.00h) during the 1 year study period



The level represents the trauma care capacity of the hospital.
Level I: Trauma centre with 24 hours/day (neuro)surgical capacity (Erasmus MC, Erasmus MC-Sophia, Sint Elisabeth Ziekenhuis, University Medical Centre Utrecht);
Level II: Non-academic regional hospital with extended trauma care capacity (Sint Franciscus Gasthuis, Medisch Centrum Rijnmond-Zuid);
Level III: Regional hospital with limited trauma care capacity (Vlietland Ziekenhuis, Ruwaard van Putten Ziekenhuis).

157 patients were transported to a hospital. Of these, 104 (66%), 20 (13%), and 18 (11%) was transported to a level I, II, or III trauma centre, respectively. For 15 patients (10%) the hospital of destination could not be traced.

The 166 actual dispatches were mainly trauma related (86%; Table 1). The median age of the entire study population was 33 years. The majority (74%) was male. The median GCS was 14 (1st and 3rd percentile, 3-15), and 49 patients had a score of 12 or less. Of the 143 trauma related dispatches, 114 (80%) had a median Injury Severity Score (ISS) of 10 (1st and 3rd percentile, 4-25). Thirty-eight patients (23%) were intubated upon administration of anesthesia. Thoracic drainage was performed in six patients, which relieved one patient from a pneumothorax. Twenty-six patients eventually died, including the 9 patients who died on the scene as mentioned above. Another 17 patients died in the hospital within 30 days. Of these, 12 patients died due to neurological injury, two bled to death upon penetrating thoracic injury, two died as a result of blunt thoracic injury, and one patient who was 83 years of age died of pneumonia. These 17 patients had a median ISS of 25 (1st-3rd percentile, 35-75). All patients who were transported to regional hospitals (N=65) arrived at the Emergency Department alive, however their condition at one month after the accident is unknown.

Table 1. Demographic data, vital signs, interventions performed and mortality of patients receiving assistance of the Mobile Medical Team (N = 166) between 19.00h and 7.00h

Item	Result	
Trauma (%)	86	
Gender (% male)	74	
Age (years)	33	(23-49)
RTS	12	(8-12)
GCS	14	(3-15)
ISS*	10	(4-25)
Intubation (%)	23	
Thoracic drainage (%)	4	
Mortality (%)	16	

Data are given either as percentage, or as median with the 1st and 3rd percentile given between brackets. RTS, Revised Trauma Score; GSC, Glasgow Coma Scale; ISS, Injury Severity Score; *, Restricted to trauma related dispatches.

In the Southwestern area of the Netherlands, 27 categories of MMT dispatch are used (Table 2). Of all dispatches during the evening and night, 76% (N=112) were based upon criteria reflecting the nature of the accident. In most cases there high-energy injury was suspected, or there had been a fall from height. In 48% of the nocturnal HEMS assistances that were requested on the basis of the patient’s vital signs, the patient had diminished consciousness in combination with disturbed vital signs, resulting in a low RTS score. Figure

2 shows an overview of the categories of incidents for which MMT assistance had been requested. Nearly 49% of cases were traffic casualties, 13% were victims of acts of violence.

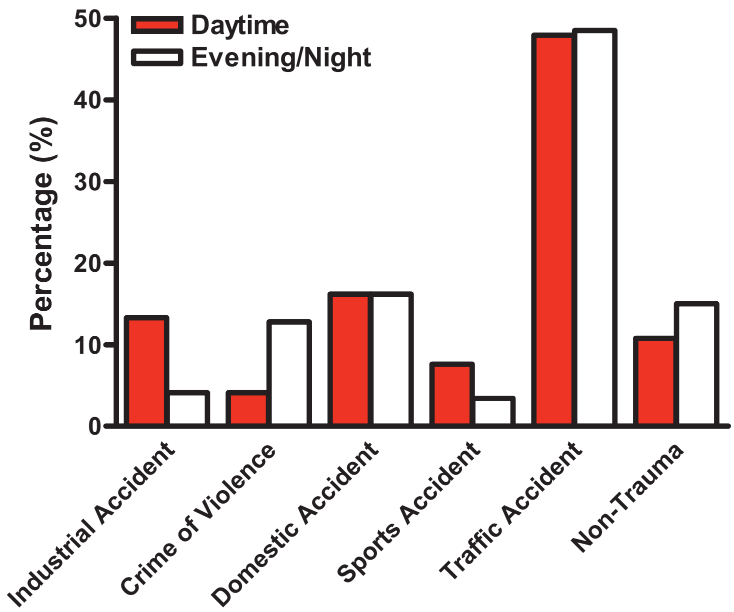
In order to gain additional insight into the distribution of MMT requests over time, the times of the actual dispatches that took place between 19.00h and 7.00h were put on a time chart (Figure 3a). Cancellations were excluded. Of all nocturnal MMT dispatches, 63% took place between 19.00h and midnight. Looking at the distribution during the

Table 2. Criteria for (nocturnal) dispatch of the MMT in the Southwestern area of the Netherlands

Dispatch criterion	Number (N=166)
Based upon the nature of the accident	
1 High-energy trauma: high-speed (>30 km/h (>19 mph) for motors or motor driven bicycles; >50 km/h (>21 mph) for cars) moving vehicle accident	67
2 Frontal collision on hardened road outside urban area	1
3 Train accident, airplane accident	6
4 Fall or jump from height >6 meters	26
5 Liberation from a wreck	2
6 Overwhelming with debris, including head and/or chest	0
7 Electricity or lightning accident	0
8 Drowning	2
9 Multiple (>4) casualty incident	0
10 Multiple (>1) casualty incident, including 1 fatality	1
11 Patient ejected from vehicle	0
12 Explosion	0
13 Exposure to hazardous materials	0
14 (Large) Fire in confined space with entrapped patients	1
15 Burn wounds 15% TBSA or > 10% TBSA with additional injuries	0
16 Diving accident	0
17 Pedestrian struck ≥ 20mph or launched	6
Based upon patient characteristics	
18 Seriously disturbed breathing frequencies, <10 of >30 per minute	3
19 Thoracic injuries with a saturation <96%, despite O_2 administration	0
20 Shock: Systolic BP <95 mmHg or pulse >120 bpm	1
21 RTS<11	26
22 Estimated blood loss >1 liter	0
23 Unconsciousness (GCS<9)	2
24 Signs of paralysis or paresthesia	0
25 Penetrating injury to head, neck, chest, or abdomen,	19
26 Fracture of femur, pelvis, or spinal cord	0
27 Open fracture to the extremities	3

Patients were classified in one group only. TBSA, Total Body Surface Area; BP, blood pressure; bpm, beats per minute; RTS, Revised Trauma Score; GCS, Glasgow Coma Scale.

Figure 2. Type of accident for which MMT assistance was requested during the evening and night (open bars)



For discussion purposes and to allow comparison, the data collected during daytime (7.00h to 19.00h; dark bars) of the study period were given as well.

week revealed that the number of requests for nocturnal MMT assistance is lowest in the middle of the week (Figure 3b). This number rises to reach a peak in the weekend (*i.e.*, Friday to Sunday). The need for a nocturnal MMT during the three weekend days (53%) almost equals that observed during the four weekdays (*i.e.*, Monday to Thursday).

The need for a nocturnal MMT remains relatively constant throughout the year, with a peak in May and lower request numbers in January, April, and September (Figure 3c).

Due to an accurate registration, the transport times had been registered for 164 of the MMT dispatches (99%; Table 3). The average time to reach the accident scene was 15 minutes, and the on scene time approximated 24 minutes. The average overall time from the emergency call until arrival at the hospital was 57 minutes.

DISCUSSION

Like many studies in traumatology this pilot study also has its limitation. For example, the limited sample size does not allow regression analysis, as a result of which it is not possible to make sound statements on possible survival benefits. The data regarding survival benefit are crucial for making a cost-effectiveness analysis of a nocturnal MMT that is kept in readiness. Such an analysis could convince policy-making agencies that the dispatch of a noctural MMT is justified. The added value of a MMT that is kept in readiness during

Figure 3. Distribution of the 166 nocturnal MMT dispatches during the (a) day, (b) week and (c) year

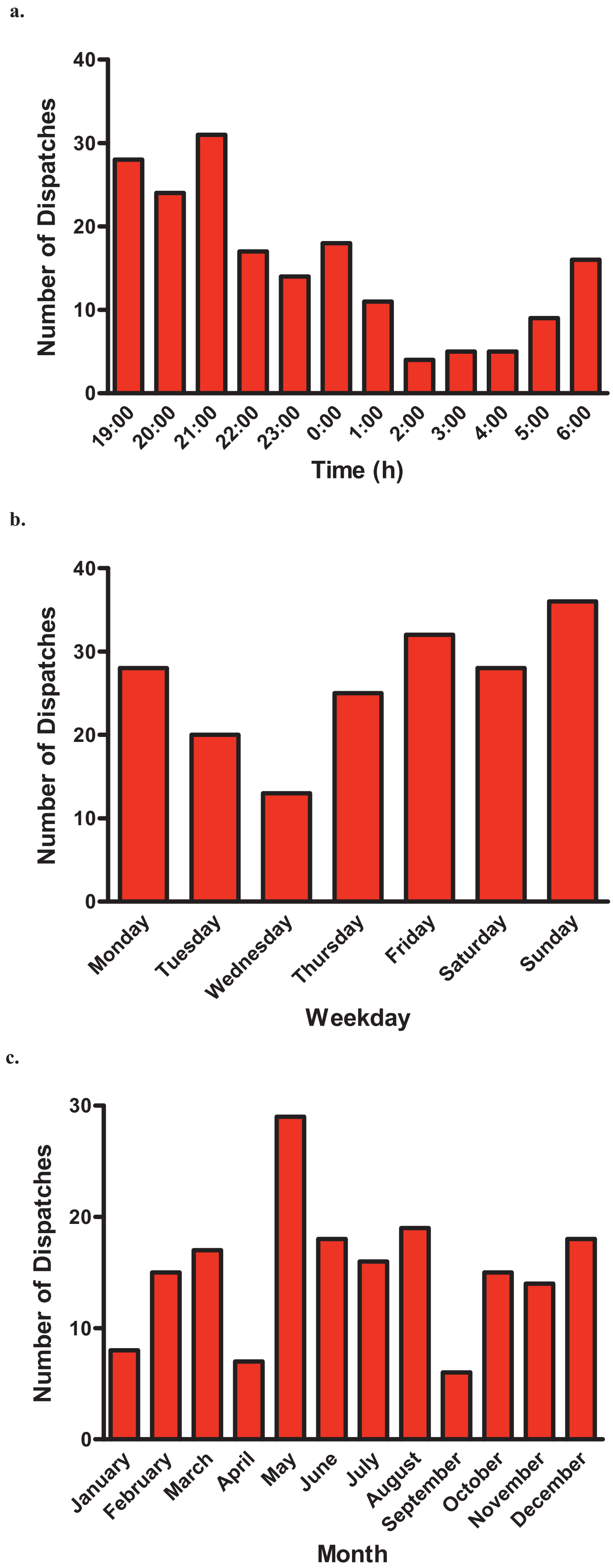


Table 3. Timing of 164 nocturnal MMT-dispatches (19.00h-7.00h)

	N	Time (hours)
Time from emergency call to departure	164	0:01:27 (± 0:00:57)
Time from emergency call to arrival at the accident scene	164	0:14:39 (± 0:07:32)
On scene time	164	0:23:43 (± 0:22:31)
Time from departure from the accident scene to arrival in the hospital	157	0:17:43 (± 0:14:24)
Total time from emergency call to arrival in the hospital	157	0:56:42 (± 0:31:06)

The average time is presented, with the Standard Deviation is given within brackets.

the evening and night is more than a possible survival benefit alone. An available MMT has been well trained to manage, care and treat politraumatized patients. They provide additional prehospital care at the accident scene professionally and rapidly. [2, 3, 8-10] In addition to methodological shortcomings of this study, 15 patients had been transported to regional hospitals to could not be tracked down. Moreover, it was virtually impossible to find out if paitents who were transported to regional hospitals were still alive at one month after the trauma.

For reasons of discussion and comparison, analogous data available of MMT dispatches during the UDP (7.00 to 19.00h) were used. During the study period, there were 235 requests for MMT assistance during the evening and night. Most of these nocturnal dispatches were effectuated based upon criteria regarding the nature of the accident. The number of secondary dispatches during the evening and night was relatively high compared with the number during the day (33% versus 5%; Figure 1). Traffic casualties represent the largest group for which MMT assistance was requested, both during the day as during the evening and night (Figure2). There is high similarity between dispatch-related data collected during the nightly hours compared with those collected during daytime hours: 29% cancellations in the evening and night versus 34% during the day; 23% intubations in the evening and night versus 24% during the day; 4% thoracic drainage in the evening and night versus 3% during the day. In addition, the population characteristics (gender, age, RTS, and GCS) were comparable for both groups.

Acute intubation of the patients was required in at least 38 patients (23%). In addition, a chest tube was placed in 6 patients (4%). In one patient this was performed to relieve a tension pneumothorax. In these cases, the actions of the MMT had been potentially live saving.

The need for a nationwide coverage of a MMT that is kept in readinees during the evening and night was extrapolated from the results of the current study. In 2005, the MMT assisted 794 times in the Southwestern area of the Netherlands. Of these, 166 assistances (21%) took place between 19.00h and 7.00h. Therefore, the proportion of dispatched during the day versus during the evening and night is 3.78:1 (*i.e.*, 628:166). Nationwide, the MMTs had assisted 1898 times during the day. These day combined project towards a nationwide need for 502 MMT assistances (*i.e.*, 1898/3.78) between 19.00h and 7.00h. Herein, cancellations have not been taken into account.

Due to large differences in study design, type of victims (*i.e.*, blunt *versus* penetrating injury), scenery (*i.e.*, rural *versus* urban area), country (*i.e.*, trauma system), and composition of the MMT teams, it is not realistic to compare these Dutch data with data of other countries. In order to make a well-founded decision on the nationwide introduction of a MMT that is kept in readiness during the evening and night, policy-makers fully depend upon local and national studies performed in the Netherlands. The Ministry of Public Health, Welfare and Sports has taken the first step towards the structural formation of a MMT during the evening and night. Since November 1, 2006 a helicopter MMT is allowed to dispatch 24 hours a day and 7 days a week from Nijmegen with a 'nationwide' range. The additional MMTs (*i.e.*, Amsterdam, Groningen and Rotterdam) are being transported by helicopter during the daylight period. Until midnight these teams are being transported by ground transportation. With this stragegy, the quality of care for the serverely injured on the scene is warranted during the hours where the need for MMT assistence is highest. The first results of the nocturnal helicopter MMT pilot in Nijmegen are expected in the near future.

In conclusion, there is a demonstratable need for specialized medical care in addition to the care provided for by ambulance teams. This need is the most apparent between 19.00h and midnight. The qualitative need for care during these hours is comparable with that during the day.

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(Cost-)Effectiveness Analysis of Helicopter Emergency Medical Services

9

Beneficial Effect of Helicopter Emergency Medical Services on Survival of Severely Injured Patients

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ABSTRACT

Background In Rotterdam, the Netherlands, a helicopter-transported medical team (HMT), staffed with a trauma physician, provides additional therapeutic options at the scene of injury. This study evaluated the influence of the HMT on the chance of survival of severely injured trauma victims.

Methods This was a 2-year prospective observational study of consecutive adults who suffered multiple trauma (Injury Severity Score (ISS) 16 or more) and presented to the Erasmus Medical Centre emergency ward. The effect of the HMT was quantified by an odds ratio (OR), adjusted for confounding variables in logistic regression models.

Results Complete data for a total of 346 patients were available for analysis. Two hundred and thirty nine patients were treated by ambulance personnel alone and 107 received additional HMT assistance. Patients in the HMT group had significantly lower Glasgow Coma Scale scores (mean 8.9 *versus* 10.6; $P = 0.001$) and a higher ISS (mean 30.9 *versus* 25.3; $P < 0.001$). The unadjusted OR for death was 1.7 in favour of the group treated by ambulance staff only (OR for survival 0.61 (95 per cent confidence interval (c.i.) 0.37 to 1.0, $P = 0.048$)). After adjustment, however, patients in the HMT group had an approximately twofold better chance of survival (all injuries: OR 2.2 (95 per cent c.i. 0.92 to 5.9), $P = 0.076$; blunt injuries: OR 2.8 (95 per cent c.i. 1.07 to 7.52), $P = 0.036$).

Conclusion The presence of the HMT may increase chances of survival for patients suffering multiple trauma, especially for those with blunt trauma.

INTRODUCTION

On-scene clinical management and assessment of trauma patients is a challenging task. Not only is time essential (the 'golden hour', first coined by Cowley et al.[1]), but the evaluation of patients often takes place under difficult circumstances, with basic diagnostic procedures and a limited set of therapeutic options available. Advanced Trauma Life Support (ATLS®)[2] (American College of Surgeons) and Pre-Hospital Trauma Life Support (PHTLS®) (National Association of Emergency Medical Technicians, USA) principles state the importance of a structured approach to stabilizing the patient's vital functions. Airway management, respiratory and circulatory support are the primary focus of initial care.

In the Netherlands, the application and execution of specific therapeutic options for patient resuscitation are restricted to physicians. For several years, Dutch paramedics have had the option to request the additional presence of a physician as part of a ground-transported medical team (GMT) to assist in the treatment of the severely injured at the scene. Practical constraints, however, limit the additional value of the GMT for several reasons. First, transport by road limits the effective radius of action and increases the amount of time before arrival. Second, GMT members are recruited from senior residents who are on duty at the moment the request is made, and the need to abandon regular duties increases the time needed for team formation. Finally, there is a large pool of potential GMT members so individual residents have limited opportunity to develop the routine and skills equivalent to those of ambulance paramedics. A Dutch ambulance paramedic is called to a scene with severely injured patients only three times a year on average, and has limited experience in resuscitation and initial treatment of this specific trauma group.

In 1995 helicopter-transported medical teams (HMTs) were introduced in the Netherlands, enabling the delivery of a trauma team to the scene of an accident in addition to the ambulance crew(s). These teams consist of a specially trained physician and a paramedic. They add advanced airway management, rapid sequence intubation, placement of chest tubes, administration of specific medication and limited surgical interventions to the on-scene therapeutic spectrum. Currently, there are four active Dutch HMT services that operate during daylight hours and cover approximately 75 per cent of the Dutch population within 15 min[3].

The HMT service has been designed to enable a trauma team to arrive as quickly as possible at the scene of injury. The team supplements, but does not replace, the emergency medical service (EMS). Although patient transport by helicopter offers a possible time benefit, it suffers the disadvantages of noise, disorientation and limited space. Only 2–15 per cent of patients are therefore transported by helicopter after on-scene treatment in the Netherlands.

The HMT has a low 'activation threshold' and is usually dispatched at the same time as the EMS and arrives within minutes of the ambulance. The criteria for dispatching the HMT

Table 1. Summary of the criteria for the primary deployment of the Rotterdam helicopter-transported medical team for trauma patients

Category	Criterion
General	Place difficult to reach for ambulances
	(>20 min to reach injury scene)
	If, in professional opinion of dispatcher, the HMT provides additional value
Mechanism of trauma	Motor vehicle accidents with estimated speed of > 30 km/h
	Frontal collisions outside the built-up area of a town
	Fall from > 6 meters or third floor
	Entrapment in vehicle
	Death of other occupant
	Ejected from vehicle
	Explosions
	Near drowning or diving accidents
	Exposure to toxic chemicals
	Inhalation trauma or severe burns
Patient condition	Penetrating injuries to head, neck or trunk
	Pelvic, spinal or femur fracture
	Comatose (Glasgow coma score of 8)
	Systolic blood pressure <95 mmHg or pulse>120 per min
	Major estimated blood loss (>1 litre)
	Respiratory distress

Ambulances, while on scene, can always request assistance (secondary deployment).
HMT, helicopter-transported medical team.

on a primary call are listed in Table 1. Alternatively, ambulance paramedics at the scene can request a secondary deployment of the HMT when faced with severely injured entrapped victims. Owing to budget restrictions Dutch HMTs cannot currently operate after sunset. Because of this, ambulance personnel must depend on delayed arrival of a less experienced GMT for additional assistance at night.

The purpose of this study was to evaluate the possible beneficial effect of the HMT on the survival of severely injured trauma victims.

PATIENTS AND METHODS

The Erasmus Medical Centre, Rotterdam is a university hospital with more than 1200 beds. It has full 24-h (neuro)surgical capabilities and functions as the sole level 1 trauma centre for a population of 2.3 million inhabitants in the south-west of the Netherlands. Patients

Table 2. Erasmus Medical Centre Rotterdam trauma protocol inclusion criteria

Disturbed physical variable	Revised Trauma Score <12
	Respiratory rate <10 or
	>29 breaths/min
	Systolic blood pressure <100 mmHg
	Glasgow Coma Scale <13
	Pulse >140 beats/min
Penetrating injuries	Head, Neck, Thorax, Abdomen, Pelvic or Inguinal region
Specific blunt injuries	Injuries in more than two regions
	Fractures of two or more long pipe bones
	Second- or third-degree open fracture
	Fracture of femur
	Unstable fracture of pelvic ring
	Spinal injuries
High-energy trauma	Automobile crash >50 km/h
	Major damage to vehicle
	Bicycle, moped or pedestrian hit by automobile
	Fall >4 m
	Death of other crash victim

The inclusion criteria are designed to include all patients with reasonable chance of severe injury, likely to require the attention of the trauma team.

participating in the study were trauma victims who presented directly to the emergency ward between October 2000 and October 2002.

Survival was the main outcome variable. Only severely injured patients, with an Injury Severity Score (ISS)[4] of 16 or more, were evaluated. Injuries were coded using the Abbreviated Injury Scale, revision 1990 (AIS-90)[5]. Patients succumbing to injuries deemed as inevitably fatal (AIS-90 code 6), victims aged less than 15 years of age, those pronounced dead on arrival, and those who presented after drowning accidents or strangulation were excluded. Patients were categorized as deceased if they were coded as such in the hospital registry within 3 months after admission.

Research data were extracted from the Rotterdam Trauma Registry and from the original ambulance charts. Patients were treated according to the hospital trauma protocol if they had either a sub-optimal Revised Trauma Score (RTS)[6] <12, a specific severe injury or had suffered high-energy trauma (Table 2). All patients aided at the scene by the HMT were included in the EMS + HMT group. Patients treated by EMS services alone or who received additional care from the GMT were included in the EMS group.

Only variables not affected by the presence of the HMT were included in the evaluation. The RTS and Glasgow Coma Scale (GCS)[7] score attained on arrival of the ambulance, as documented by the ambulance paramedic, were used to indicate the vital condition of the patient. Age and specific details of injuries were extracted from the trauma registry.

Regression model and statistical analysis

A custom-fitted regression model was used to compensate for possible confounding variables. In a previous study[8] conducted for the general Rotterdam trauma population, the New Injury Severity Score (NISS)[9] was found to be preferable to both the ISS and the Anatomical Profile (AP)[10-12] in terms of calibration and discriminating power. In this study an identical evaluation was performed to determine the best injury severity indicator within this selected multitrauma population. The prehospital RTS was used, which should not be transformed blindly into the weighted RTS[13]. The components of the RTS and the actual GCS value were therefore included in the model as separate terms. Mechanism of trauma was categorized as either blunt or penetrating, and age was entered as the actual value in years.

Working at night is likely to be a negative predictor of survival, as it influences the mechanism of injury, temperature and time between injury and admission to hospital. To compensate for this the variable 'time of day' was added. During the study period the HMT was limited to daylight departure only.

A preliminary analysis was performed to ascertain the optimal injury severity scale by comparing the predictive abilities of the ISS, NISS, and parts A, B and C of the AP score[8]. The remaining predictive variables were evaluated for their contribution to the model using the best injury scale. The influence of the HMT was evaluated by including a dummy variable, indicating whether the HMT was present, after which the model was refitted. The resulting regression coefficient was used to compute the corresponding odds ratio (OR) and confidence interval (c.i.). The model was refitted for additional analyses within subgroups of patients with blunt injuries only and a GCS of 8 or less, and/or significant cranial injuries (ISS-cranial ≥ 9). Finally, a sensitivity analysis regarding the influence of the HMT was made by omitting all patients admitted at night.

The performance of the logistic regression models was evaluated by their discriminative ability, indicated by the area under the receiver–operator characteristic curve (AUC), and the level of calibration, indicated by the Hosmer–Lemeshow statistic (HL).

Analysis was performed with the SPSS® version 10.1 (SPSS, Chicago, Illinois, USA) and the R[14] statistical packages. The survival curves were created by a nonparametric smooth of the actual outcomes by the LOWESS function in R. Differences between groups were evaluated by the non-parametric Mann–Whitney *U* test and Pearson's 2 test. Two-tailed *P* values are presented.

RESULTS

Between October 2000 and October 2002 a total of 1102 patients, aged 15 years or older, were treated according to the Erasmus Medical Centre trauma protocol, and admitted to the hospital owing to severe trauma. All patients had experienced either a high-energy trauma, presented with a suboptimal RTS score or were diagnosed with a specific set of injuries indicative of the high-energy nature of the trauma. Four hundred and twenty-nine patients met the multitrauma inclusion criterion (ISS 16 or more). Eighty-three of the 429 patients were excluded from this study: 55 patients were referred from surrounding hospitals and did not present directly to the study hospital, seven presented without the intervention of either an ambulance or helicopter crew, four were diagnosed with inevitably fatal injuries (AIS-90 injury severity weight = 6), and prehospital data could not be retrieved for 17 patients.

A total of 346 patients remained for analysis. Baseline characteristics are shown in Table 3. Ambulance paramedics presented 239 patients to the emergency department, on nine occasions assisted by a GMT. The remaining 107 patients (30.9 per cent) were treated at the scene jointly by the EMS and HMT. The mean time spent on-scene was 8 min shorter for the EMS group (23.2 *versus* 31.2 min for the EMS + HMT group). The mean scene-to-hospital time was 13 min for both groups, as patients are generally transported by EMS.

Table 3. Demographic data of 346 patients who suffered multiple trauma

	Overall	EMS	EMS + HMT	P
Total no. of patients	346	239	107	
No. during daylight hours	215	108	107	
Male	269 (77.7)	192 (80.3)	77 (72.0)	0.084*
Mean age (years)	41.1	40.2	42.9	0.236†
Glasgow Coma Scale	10.1	10.55	8.90	0.001†
Blunt Trauma (%)	298	195 (81.6)	103 (96.3)	<0.001*
Auto / Motor	93 (26.9)	56 (23.4)	37 (34.6)	
Bicycle / Moped / Pedestrian	100 (28.9)	63 (26.4)	37 (34.6)	
Fall	82 (23.7)	57 (23.8)	25 (23.4)	
Other	23 (6.6)	19 (7.9)	4 (3.7)	
Penetrating Trauma	48 (13.9)	44 (18.4)	4 (3.7)	<0.001*
Mean Injury severity Score	27.0	25.3	30.9	<0.001†
Mean New Injury severity Score	36.9	34.9	41.4	<0.001†
Prehospital Intubation	90 (26.0)	29 (12.1)	69 (57.0)	<0.001*
Prehospital chest drainage	11 (3.2)	1 (0.4)	10 (9.3)	
Deaths	95 (27.5)	58 (24.3)	37 (34.6)	0.047*

Values in parentheses are percentages. EMS, emergency medical service; HMT, helicopter-transported medical team. *Pearson ^{2} test; †Mann–Whitney *U* test.

Patients in the EMS + HMT group were more severely injured, and had worse GCS, ISS and NISS values (Table 3). The uncorrected mortality rate was significantly worse for those aided by the HMT. The incidence of penetrating trauma differed between the two groups. The overall unadjusted chance of survival was similar for patients who had penetrating and blunt injuries (OR 1.16 (95 per cent c.i. 0.58 to 2.3))

Construction of regression model

A model simultaneously estimating survival based on the ISS, NISS, and a weighted A, B and C variable as defined in the Anatomical Profile, determined that the NISS was the most important predictor. A model was then fitted with all the predictive variables and the NISS as indicator of injury severity. Neither patient sex nor time of day had predictive value for survival estimation ($P = 0.903$ and $P = 0.930$ respectively). RTS triage code for respiratory rate ($P = 0.129$) and mechanism of trauma ($P = 0.111$) were of modest influence but were kept in the final model. The remaining variables all had a significant influence on survival (RTS systolic blood pressure $P = 0.022$, GCS $P < 0.001$, age $P < 0.001$, NISS $P < 0.001$).

The final predictive model included the RTS code respiratory rate, RTS code systolic blood pressure, GCS, age, mechanism of trauma and NISS. This base model was found to be sufficiently calibrated (HL 11.8; $P = 0.160$) and good at discriminating (AUC 0.911).

Table 4. Unadjusted and adjusted odds ratios for survival of trauma victims

		EMS	EMS+ HMT	Unadjusted OR	Adjusted OR	P
All mechanisms	346	239	107	0.61	2.2 (0.92-5.9)	0.076
Daytime only	215	108	107	0.69	2.5 (0.92-6.8)	0.073
Penetrating injuries only	48	44	4	0.29	0.2 (0.01-5.8)	0.360
Blunt injuries only	298	195	103	0.63	2.8 (1.07-7.52)	0.036
Injury Severity Score (ISS)						
16-25	203	155	48	1.04	4.6 (0.78-27)	0.092
26-32	50	39	11	1.16	5.9 (0.19-190)	0.314
32-74	93	45	48	0.68	1.9 (0.46-7.7)	0.385
ISS-cranial >=9	201	129	72	0.53	3.0 (0.99-8.8)	0.052
ISS-cranial >=9 and ISS-other >=9	102	54	48	0.54	3.3 (0.77-13.9)	0.110
Glasgow Coma Scale <=8*	127	75	52	0.74	3.5 (0.82-15.1)	0.091

Values in parentheses are 95 per cent confidence intervals. Odds ratio (OR): odds of survival for those aided by the helicopter-transported medical team (HMT) divided by odds of survival among those treated by the emergency medical service (EMS). Values above 1 favour the HMT and those below 1 favour the EMS. Adjusted OR: OR for survival adjusted for age, vital scores, mechanism of trauma, daylight hours and injury severity. * Blunt injuries only.

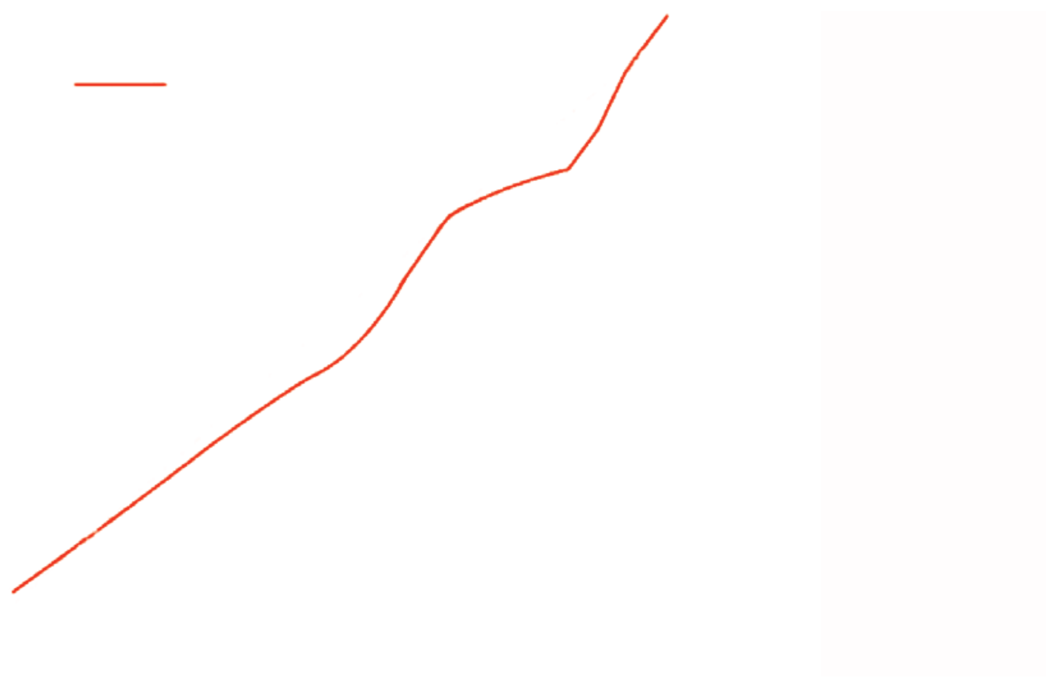
Influence of helicopter-transported medical team

Without correction for all the predictive variables, the chance of survival for those treated by ambulance personnel alone was higher than that for patients assisted by theHMT (OR 1.7 (95 per cent c.i. 1.0 to 2.7)). After correction for all other predictive variables, victims aided by the HMT had a better chance of survival (OR 2.2 (95 per cent c.i. 0.92 to 5.90; $P = 0.076$). A similar result was found in the sensitivity analysis within the daytime-only subgroup (Table 4). The effect of the presence of the HMT on survival is shown in Fig. 1. The observed survival was higher for all patients assisted by the HMT, particularly for those with a predicted survival chance of between 20 and 90 per cent.

Among those with blunt injuries only, the adjusted chance of survival was 2.8 times better for those assisted by the HMT than for those treated by the EMS only (Table 4). Again, the model was sufficiently calibrated (HL 12.6; $P = 0.131$) and discriminating (AUC 0.920).

The effect of the HMT was further evaluated for patients with different levels of injury severity. The models were refitted for the analysis of each subgroup (Table 4). Although none of the ISS subgroups showed a statistically significant improvement in survival, analyses for all patients and those with blunt injuries only showed a trend towards a beneficial effect of the HMT.

Figure 1. Estimated and observed survival for patients aided by the Emergency Medical Service (EMS) and those aided by both the EMS and Helicopter Medical team (EMS+HMT). The chance of survival was estimated by logistic regression for the relevant confounders, except for the presence of the HMT.



Additional analyses were performed within the subgroup of patients with blunt injuries only. For comatose patients (GCS 8 or less), the OR for survival was estimated at 3.5 in favour of those treated by the HMT, although this was not statistically significant (P = 0.091). The assistance of the HMT appeared beneficial, but did not have a statistically significant impact on survival of patients with severe cranial injuries, or those with severe cranial injuries combined with any other severely injured body region (Table 4).

DISCUSSION

Patients assisted by both the EMS and the HMT had sustained more severe injuries and had diminished vital signs. These differences were reflected in the unadjusted mortality rate. Standard injury stratification methods, such as Trauma Score and Injury Severity Score (TRISS)[15] and "A Severity Characterisation Of Trauma" (ASCOT)[16], are derived from American trauma populations with a significantly different injury severity distribution. These methods should not therefore be used directly to stratify within this highly selective multitrauma population[17, 18].

A custom-fitted logistic regression model compensated for the selection bias and, although it cannot be excluded that an important confounding factor was omitted, all commonly used predictive variables were included in the model. After statistical compensation, a reversal of the crude OR was observed. The adjusted OR for survival was estimated at 2.2 times in favour of those aided by the HMT. Even greater differences in survival odds in favour of HMT assistance were shown for subgroups of patients with blunt injuries only, diminished GCS scores or severe cranial injuries.

A similar result in Dutch trauma victims was found by Oppe and De Charro[19], who studied the impact of the Amsterdam HMT on trauma patients admitted to hospital. An OR for survival of approximately 2 in favour of the Amsterdam HMT group was seen among patients with survival chances between 0.50 and 0.88. However, patients with a lower chance of survival, for instance those with an ISS score of 25 or above, still appeared to have a 1.8 times better chance of survival ($P = 0.248$). It is therefore likely that some more severely injured patients also benefited from HMT assistance.

Other studies have produced less favourable data on the effectiveness of HMTs[20-23]. Differences between the services complicate the comparison between studies. In the USA, only 18 per cent of all HMTs are staffed by physicians[24], whereas all four Dutch HMTs are staffed by specially trained trauma physicians and nurses. Furthermore, in contrast to the North American system, Dutch patients are rarely transported by helicopter.

Brathwaite *et al.*[20] evaluated the effect of scene to trauma centre transportation of trauma victims by helicopter in 22 411 Pennsylvanian patients and found no clear differences in survival odds. Their study focused on the transportation mode (ground *versus* helicopter) and not on the level of care provided. Both services appeared to be staffed by paramedics and no apparent differences in treatment options were reported. The reported overall mean ISS of 19 among those transported by helicopter was less than the mean ISS of 30.9 in the present study. The authors admit that the lack of patients with an ISS in the range 16–60 reduced the clinical significance of their findings.

In an assessment of the London helicopter emergency medical service, which has a similar design to the Dutch service, Nicholl *et al*.[21] found no evidence that the service improved the chance of survival of trauma victims, when considering the overall helicopter caseload. An additional finding was that the HMT had a small beneficial effect among patients with 'severe injuries', similar to the present study. However, several authors have identified serious methodological flaws[25-27]in Nicholl's analysis.

Thomas *et al*.[26] have reviewed recent HMT-related articles and performed a retrospective study on the paramedic-staffed HMT in Boston, USA. Some 16 699 patient records derived from the general trauma population (overall mortality rate 3.8 per cent compared with 27.5 per cent in the present study) were available for logistic regression analysis. Similar to the Rotterdam study, the crude odds of death was 3.4 and the adjusted risk was 0.76 in favour of those treated by HMT (95 per cent c.i. 0.59 to 0.98) ($P = 0.031$). However, the Boston study did not compensate for any vital signs at the scene of accident in the regression analysis and also included interfacility transport in the study (approximately 50 per cent of all HMT flights).

The present study indicated a positive association between the involvement of the HMT and survival chances, but did not identify exactly how the benefit is derived. The Rotterdam EMS already delivers a high level of expertise at the scene of injury, and is capable, for example, of endotracheal intubation in unconscious patients (without paralysing agents) and needle decompression of a tension pneumothorax. The possible beneficial effect of the HMT is likely to originate from the additional expertise and therapeutic options brought to the scene. In particular, airway management is a key component of the advanced life support among severely injured patients; failure to achieve adequate airway patency has been identified as a major contributor to preventable death in trauma care[28-30].

Currently, less than a third of patients with multiple trauma presenting directly to the Erasmus Medical Centre have been assisted by the HMT at the scene of injury. The present results suggest that the focus of the service should be shifted towards more frequent involvement in the aid of severely injured patients, especially those with blunt injuries. An effective way of achieving this might be by enabling the HMT to continue its service after sunset, as nearly 40 per cent of the present study population was injured after dark.

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Helicopter Emergency Medical Services and Health-Related Quality of Life: Results from a Prospective Cohort Study of Severely Injured Patients

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Submitted

ABSTRACT

Background The aims of this study were to assess the health related quality of life (HRQoL) of severely injured patients, and to investigate a possible association with the type of prehospital care (Helicopter Emergency Medical Services (HEMS) versus Emergency Medical Services (EMS) assistance).

Methods A prospective cohort study was conducted in which all severely injured trauma patients presented at a level I trauma centre were included. After 12 months, the EuroQol-5D (EQ-5D) and Health Utilities Index (HUI2 and HUI3) were used to determine health status.

Results Follow-up assessments were obtained of 246 patients (response rate 68%). The overall population median EQ-5D utility score was 0.73. HUI2, HUI3, and EQ-5D VAS scores were 0.81, 0.65, and 70, respectively. Patients receiving HEMS assistance were more severely injured (median ISS 26 versus 20) compared with those receiving EMS assistance. No differences in HRQoL between the HEMS and EMS group could be demonstrated.

Conclusion HRQoL of survivors of severe injury has not returned to normal one year after trauma. The health status did not differ between HEMS and EMS assisted patients. HRQoL in this population was more related to co-morbidity and female gender than to the type of prehospital care received (HEMS versus EMS).

INTRODUCTION

Major trauma can be defined as an injury with an Injury Severity Score (ISS) of at least 16 or higher [1]. Major trauma is known to have a massive impact on both individual and community health: In the Netherlands, it has been shown that injuries of such a high level of severity lead on average to 25 years of healthy life lost per injured patient. Severely injured patients make an equal or higher contribution to the burden of disease compared to cerebrovascular accidents, chronic obstructive pulmonary disease or diabetes and depression [2].

Major trauma has such a large impact, because of the relatively young age of the average severely injured patient. The negative consequences of their trauma are often diverse and substantial. Under the age of 45 years, traumatic injuries are the leading cause of death [3]. In the long term, most survivors of major trauma still suffer from one or more permanent functional consequences. This has a negative impact on their health-related quality of life (HRQoL), which will remains far below the general population norms [2, 4, 5].

This considerable burden of mortality and disability resulting from major trauma needs to be addressed. Over the past decades, injury prevention has been very successful, but seems now facing its limits in the industrialized world [6]. Therefore, advances in trauma care are complementary to injury prevention and are becoming increasingly important [7].

The implementation of regionalized trauma systems and designated trauma centers has shown to improve survival rates of major trauma patients in particular [8-13]. Little is known, however, on the effects of advances in trauma care on HRQoL of major trauma survivors.

For major illnesses, improved health care has reduced mortality rates but has also resulted in a substantial increase in the burden of chronic disease. It has been shown, for example, that a sharp reduction in the case fatality rate of acute myocardial infarction has led to increasing numbers of patients with chronic heart failure and an increasing demand on health care [14-17]. Whether advances in trauma care lead to similar increases in chronic health consequences or have a net beneficial effect on HRQoL instead has not yet been studied.

Prehospital trauma care, the first link in the complex chain of trauma patient care, was upgraded in the Netherlands in 1995, when physician staffed HEMS were introduced in addition to nurse staffed Emergency Medical Services (EMS). Since then the Netherlands have a system of standard nurse staffed EMS and additional physician staffed HEMS. Because of logistic and topographical reasons HEMS in the Netherlands are primarily used to transport a physician to the scene of an accident. In only 5 % of all dispatches patients are transported by helicopter to a hospital. The presence of a physician significantly expands the scope of therapeutical options (i.e., invasive interventions or rapid sequence intubation) and experience at the scene of an accident. After introduction of HEMS in The Netherlands, a mortality reduction was observed for a subgroup of patients with major trauma in some studies [18, 19].

The aim of this study was to assess the health related quality of life of survivors of severe trauma, and to investigate a possible association with the type of prehospital care (HEMS assisted versus EMS assisted).

METHODS

Study population and design

From January 2004 till July 2006, a prospective cohort study was conducted, including all consecutive poly-trauma patients with an Injury Severity Score (ISS)[1] of 16 or higher and older than 14 years, that were presented to the emergency department of a level I trauma centre in a Dutch trauma region serving 4.9 million inhabitants. Patients that were pronounced Dead On Arrival (DOA) at the accident scene were excluded. Data were extracted from the Hospital Trauma Registry that documented the same variables as the Major Trauma Outcome Study database [20] (i.e., Age, Glasgow Coma Scale [21], Revised Trauma Score [22], Mechanism Of Injury, and injury specifics). Missing data were obtained from the original ambulance charts.

Outcome assessment

The EuroQol-5D (EQ-5D) and Health Utilities Index (HUI2 and HUI3) were used as generic measures to determine the HRQoL. The combination of the EQ-5D with the HUI3 is in accordance with international guidelines for conducting follow-up studies measuring injury-related disability [23]. The EQ-5D and HUI are complementary with respect to the domains of the International Classification of Disabilities, Functioning and health (ICF) stated by the World Health Organization [24].

The generic EQ-5D classification of health [25] covers the main health domains that are affected by injury, with particular focus on the participation level of the ICF. It allows for a proper description of a heterogeneous injury population and for discrimination among specific injuries [26]. Moreover, the EQ-5D has been recommended for (economic) evaluation of trauma care at a consensus conference [27]. In this classification, health is defined along five dimensions: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. Each dimension has three levels: no problem, moderate problem, and severe problem. Subsequently, a domain-related scoring algorithm based on empiric valuations from the U.K. general population and subsequent statistical modelling is available by which each health status description can be expressed into a utility score (EQ-5D) [28]. This summary score ranges from 1 for perfect health to 0 for death, and can be interpreted as a judgment on the relative desirability of a health status compared with perfect health. The second part of the EQ-5D consists of a vertical Visual Analogue Scale (VAS). This calibrated scale is marked 100 at the top, labelled *best imaginable health state* and 0 at the bottom, labelled *worst imaginable health state* [25].

The HUI is a self-administered health-status questionnaire consisting of 15 questions, which classifies respondents into either the HUI Mark 2 (HUI2) or HUI Mark 3 (HUI3) health states [29]. It covers the main health domains that are affected by injury, with particular focus on functional capacities. Results of the questionnaire are converted by an algorithm, into the levels of the complementary HUI 2 and HUI 3 classification system [30], in order to form 7- and 8-element health-state vectors, respectively. From these vectors, single-attribute and overall health-state utility scores are calculated using the respective HUI2 and HUI3 utility functions [31], with preferences derived from the general public.

At twelve months after trauma admission all included patients received the written questionnaire by mail. In absence of response patients received a phone call one month after the mailing in order to stimulate participation and increase the response rate.

Socio-demographic, injury, and health care related characteristics

From the literature, potential determinants of functional outcome were identified [32-34]. These determinants of functional outcome were grouped into socio-demographic (age and gender, education level, household composition, and co-morbidity), injury (ISS, Revised Trauma Score (RTS), and injury location), and health care related characteristics (HEMS or EMS service). Education was divided into primary school level or higher, household composition into households existing of a single person or more persons, and co-morbidity was divided into a group without a co-morbidity, a group with only one co-morbidity and a group with two or more co-morbidities. A co-morbidity condition was defined as a previous disease at the time of trauma according to the patient or the family.

The injury diagnosis was verified at the individual level with information from the hospital discharge register according to the Abbreviated Injury Scale, 1990 Revision, update 1998[35]. Patients treated by nurse-staffed Emergency Medical Services only were included in the EMS-group. All patients receiving combined EMS and physician staffed Helicopter Emergency Medical Services assistance on-scene were included in the HEMS-group.

Statistical Analysis

The statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 12.0 (SPSS, Chicago, IL, USA). A non-response analysis was performed by multivariable logistic regression. Age, sex, ISS, RTS, mechanism of injury, health status (EQ-5D summary score), and HEMS or EMS service were tested as possible determinants of non-response. All significant variables ($p<0.05$) were used to adjust for response bias. Subsequently, the respondents were weighted with the inverse probability of response resulting from the final model. The Kolmogorov-Smirnov test was used to test for normality of the data. The Levene's test was applied to assess homogeneity of variance between groups. Since not all outcome measures showed normal distribution or equal variance, all items were regarded as non-parametric for the statistical analysis. For continuous data, e.g., age, ISS, GCS, EMV, and RTS the Mann-Whitney U-test was used to assess the difference between HEMS and EMS groups. For dichotomous data, e.g., gender, mechanism of injury, mortality, and prehospital intubation, the chi-square test was performed to compare HEMS with EMS. Socio-demographic and injury related characteristics were tested as predictors of HRQoL in univariate and step-forward multivariable regression analyses. To determine differences in health-related quality of life (EQ5D and HUI) between EMS and HEMS assisted patients, the non-parametric Mann-Whitney U-test was conducted. Differences regarding the mean utility scores were tested with a one-way Analysis of Variance (ANOVA). P-values < 0.05 were considered to indicate statistical significance.

RESULTS

Dring the study period of 30 months, 524 poly-trauma patients (ISS>15) over 14 years of age were admitted to the Emergency Department of the study hospital. Of these patients, 162 (30.9%) died within 30 days after hospital admission and the remaining 362 survivors were included in the prospective cohort study on HRQoL. One year follow-up measurements of 246 patients (response rate 68%) were obtained (Table 1). Of the 116 patients that did not participate, 107 patients were untraceable, 1 could not be included since the patient had insufficient knowledge of the Dutch or English language to properly communicate about the investigation, and the remaining 8 patients were unwilling to participate.

Table 1. Characteristics of the study population (patients surviving major trauma at 12 months follow-up) by type of prehospital care (EMS versus HEMS)

	Overall	EMS	HEMS	P-value
N	246	145	101	
Male[1]	162 (66)	92 (63)	70 (69)	NS+
Age[2] (year)	40 (23-57)	43 (25-65)	31 (21-53)	0.002++
Blunt Trauma[1]	238 (97)	142 (98)	96 (95)	NS+
Glasgow Coma Score[2]	14 (7-15)	14 (9-15)	10 (3-15)	<0.001++
Revised Trauma Score[2]	12 (10-12)	12 (11-12)	11 (8-12)	<0.001++
Injury Severity Score[2]	22 (17-29)	20 (16-25)	26 (20-37)	<0.001++
Prehospital intubation[1]	43 (18)	9 (6)	34 (34)	<0.001+
Co-morbidity[11]	90 (37)	63 (43)	27 (27)	<0.05+

+ Fisher's exact test, ++Mann-Whitney U-test

[1], patient numbers are displayed, with the percentages given within brackets; [2], data are displayed as median, with the first and third quartile given within brackets; EMS, nurses assisted Emergency Medical Services; HEMS, physician assisted Helicopter Emergency Medical Services.

Table 2. Health-related quality of life of severely injured patients at 12 months after trauma by sociodemographic, physical and injury related factors

Determinants	Subgroup	N	EQ-5D Median	HUI2 Median	HUI3 Median	EQvas Median
Total study population		246	0.73	0.81	0.65	70
Sociodemographic						
Gender	Male	162	**0.80**	**0.83**	0.68	**74**
	Female	84	**0.69**	**0.77**	0.50	**68**
Age	<55	176	0.76	0.82	**0.68**	**72**
	≥55	70	0.69	0.78	**0.49**	**69**
Education	Primary	45	0.73	0.78	0.44	70
	Higher	181	0.73	0.81	0.66	70
Household composition	Alone	69	**0.69**	0.77	0.59	**68**
	Not alone	166	**0.78**	0.81	0.68	**73**
Physical						
Co-morbidity	None	155	**0.80**	**0.85**	**0.73**	**76**
	1	67	**0.60**	**0.76**	**0.47**	**66**
	≥2	23	**0.64**	**0.61**	**0.31**	**55**
Injury related						
ISS	<25	145	078	0.81	**0.68**	73
	≥25	101	0.72	0.80	**0.59**	70
Injury localization						
Head	<3	65	0.69	0.82	0.66	68
	≥3	181	0.76	0.80	0.64	73
Face	<3	240	0.73	0.80	0.65	70
	≥3	6	0.72	0.73	0.48	76
Chest	<3	146	0.74	0.80	0.65	71
	≥3	100	0.73	0.80	0.63	70
Abdomen	<3	213	0.73	0.81	0.65	70
	≥3	33	0.76	0.82	0.65	70
Extremities	<3	185	0.76	0.81	0.67	71
	≥3	61	0.69	0.78	0.55	70

Utility scores of the EuroQol-5D (EQ-5D) and Health Utility Index (HUI2 and HUI3) were calculated as described in the Material and Methods. These scores range from 0 for death to 1 for perfect health; the EQvas score ranges from 0 for the worst imaginable health state to 100 for the best imaginable health). Median scores are displayed.

The first row displays the median scores for the total study population. In all subsequent rows, utility and VAS scores of subgroups based on the determinants sociodemographic, physical and injury related factors were compared. Results printed in bold indicate a statistically significant difference in utility or VAS score between the indicated determinants (Mann-Whitney U-test, $p<0.05$). For co-morbidity, pairwise comparison was made for all three groups. Statistical significance was reached when comparing absence of co-morbidity versus either one or multiple co-morbidities. ISS, Injury Severity Score.

Patient characteristics

One hundred and sixty-two patients (66 %) were male (Table 1). The median ISS of this study population was 22, with a median age of 40 years. The vast majority of patients (97%) sustained a blunt force trauma. Patients in the HEMS group were significantly younger than in the EMS group (median age 31 versus 43 years). Patients in the HEMS group were on average more severely injured (median ISS of 26 versus 20) and had more disturbed vital parameters (median GCS 10 versus 14 and median RTS of 11 versus 12). In the HEMS population relatively more patients were intubated compared with the EMS group (34% versus 6%). The patients in the HEMS group had significantly less co-morbidity (27%) than in the EMS group (43).

Description of health-related quality of life one year after trauma

The median EQ-5D utility score of 0.73 of the total population of major trauma patients was far below the Dutch general population norms (EQ-5D summary measure 0.88)[36] (Table 2). A median EQvas score for the total population was calculated of 70. The median HUI2 and HUI3 scores for the total population were 0.81 and 0.65, respectively. Gender and co-morbidity were significantly and consistently associated with worse EQ-5D and HUI outcomes. Females reported worse 1-year follow-up health states compared with males. This difference was statistically significant for EQ-5D, HUI2 and EQvas. In all generic measures used, 1 or more co-morbidities were associated with worse HRQoL. The observed associations between the other included variables and HRQol were less consistent. Patients with a higher age (≥55) had significantly worse HUI3 and EQvas scores. A household composition of more than one person was associated with a better-reported HRQoL on the EQus and Eqvas. Only the HUI3 showed a association of higher ISS (≥25) with reduced HRQoL. There were no differences between the EMS and HEMS group in any of the EQ-5D or HUI2/HUI3 summary scores (Table 3).

Table 3. Health-related quality of life of severely injured patients at 12 months after trauma by type of prehospital care (EMS versus HEMS)

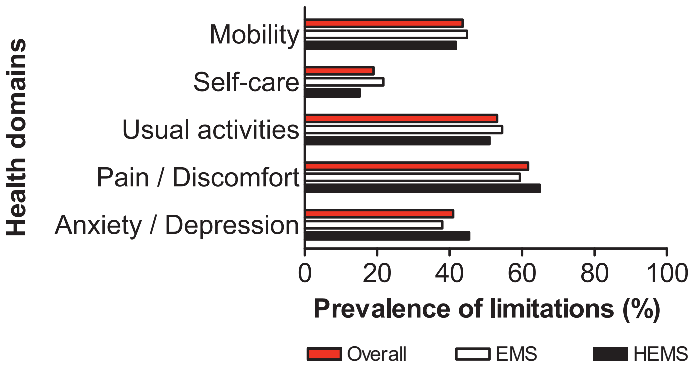
	Overall	EMS	HEMS	P-value
EQvas (median)	70 (57-85)	70 (58-84)	70 (51-90)	0.89
EQ-5D (median)	0.73 (0.62-0.85)	0.73 (0.59-1.0)	0.76 (0.62-0.85)	0.78
HUI2 (median)	0.81 (0.65-0.94)	0.83 (0.64-0.94)	0.80 (0.66-0.92)	0.61
HUI3 (median)	0.65 (0.33-0.84)	0.66 (0.33-0.86)	0.64 (0.33-0.82)	0.40

Utility scores of the EuroQol-5D (EQ-5D) and Health Utility Index (HUI2 and HUI3) were calculated as described in the Material and Methods. These utility scores range from 0 for death to 1 for perfect health; the EQvas score ranges from 0 for the worst imaginable health state to 100 for the best imaginable health). Median scores are displayed.

Data are presented as median, with the first and third quartile given within brackets. The Mann-Whitney U-test was used to compare scores in the EMS versus HEMS groups.

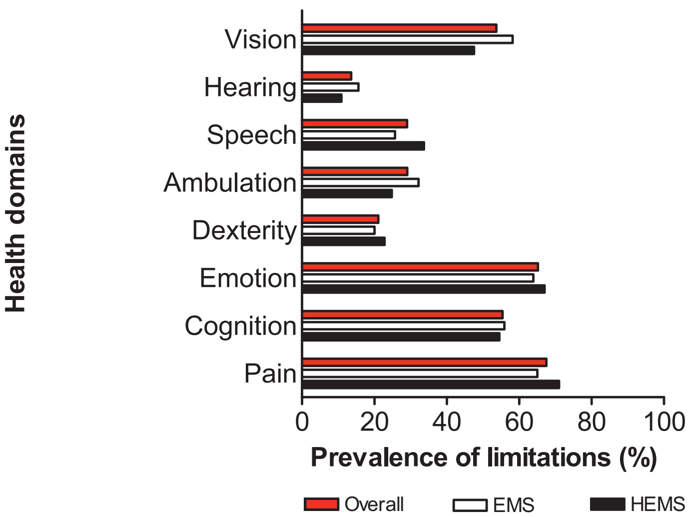
One year after trauma, the prevalence of physical and physiological limitations for the total patient population was high on all dimensions of both EQ-5D (44% for mobility, 19% for self-care, 53% for usual activities, 62% for pain and discomfort, and 41% for anxiety and depression) (Figure 1a) and HUI3 (54% for vision, 14% for hearing, 29% for speech, 29% for ambulation, 21% for dexterity, 65% for emotion, 55% for cognition, and 68% for pain) (Figure 1b).

Figure 1a. Prevalence of physical and physiological limitations (moderate or severe) of the EQ-5D health domains by type of prehospital trauma care (EMS versus HEMS)



The percentage of patients with limitations in any of the health domain is shown. Differences between the EMS and HEMS group were tested with the Chi-square Test. No significant differences were found.

Figure 1b. Prevalence of limitations (mild to severe) of the HUI3 health domains by type of prehospital trauma care (EMS versus HEMS)



The percentage of patients with limitations in any of the health domain is shown. Differences between the EMS and HEMS group were tested with the Chi-square Test. No significant differences were found.

Differences between the EMS and HEMS group on all the separate dimensions of EQ-5D and HUI3 were inconsistent, small, and not significant. On some dimensions (e.g., mobility, self care and ambulation) the prevalence of limitations was slightly lower in the HEMS group compared with the EMS group, whereas for other dimensions (e.g., pain, anxiety/depression and emotion) the reverse was observed.

Multivariable analyses

A multivariable regression analysis was conducted to further explore the influence of the type of prehospital care (HEMS versus EMS) and sociodemographic and injury related factors on health status one year after trauma (Table 4).

After adjustment for confounders, including age, gender, co-morbidity and injury severity, the functional outcome of patients assisted by HEMS or EMS showed no differences on any of the separate dimensions of the EQ-5D. In comparing HEMS with EMS, the odds ratios (OR) were ranging from 0.6 (95% CI 0.2-1.3) for the dimension self care to 1.8 (95% CI 0.9-3.6) for the dimension anxiety/depression.

Post trauma problems concerning anxiety or depression were significantly influenced by sociodemographic determinants and co-morbidity. The female gender, a higher educational level and a household consisting of one person led to more problems concerning anxiety and depression. Females were also more likely to experience limitations due to pain and physical discomfort.

Absence of co-morbidity was an independent predictor for less mobility related limitations (OR =0.5), limitations for usual activities (OR=0.4), pain or discomfort (OR=0.2) and anxiety or depression (OR=0.3). Patients with a higher ISS (≥25) were more likely to report limitations concerning mobility, self-care and usual activities. Patients who sustained severe chest injuries showed less problems on several health domains, compared to patients with severe injuries of other body regions. This association was only significant for less limitation in self-care. As to be expected, severe injuries to the extremities were significant independent predictors of limitations in mobility.

Comparable results as shown for the EQ-5D were found in a separate multivariable regression analysis with the HUI as outcome measure (data not shown). In this analysis too, no significant differences on any of the separate functional outcome dimensions of the HUI were found between patients assisted by HEMS or EMS. The absence of co-morbidity was a significant independent predictor for fewer limitations concerning the HUI-dimensions ambulation (OR=0.3), emotion (OR=0.5), cognition (OR=0.3) and pain (OR=0.4). Comparable to the results found with the EQ-5D, the HUI showed that females were more likely to experience problems concerning pain compared with men (OR=0.4). Patients with a higher ISS (≥25) were more likely to report limitations concerning ambulation (OR=2.6) and dexterity (OR=2.9). As to be expected, severe injuries to the extremities were independent predictors of dexterity (OR=4.1).

Table 4. Odds ratios of determinants of limitations of functional outcome after major trauma assessed by multivariable logistic regression analyses

	EQ-1 Mobility	EQ-2 Self-care	EQ-3 Usual activities	EQ-4 Pain / discomfort	EQ-5 Anxiety / Depression
HEMS	0.9 (0.5-1.6)	0.6 (0.2-1.3)	0.8 (0.4-1.5)	1.4 (0.7-2.8)	1.8 (0.9-3.6)
Sociodemographic					
Male	1.0 (0.6-1.9)	0.9 (0.4-1.9)	0.8 (0.5-1.6)	**0.4 (0.2-0.8) +**	**0.4 (0.2-0.8) ++**
Age <55 years	0.7 (0.4-1.5)	0.8 (0.3-1.9)	1.0 (0.5-2.1)	1.5 (0.7-3.1)	1.3 (0.6-2.6)
Primary education	2.0 (1.0-4.2)	1.5 (0.6-3.7)	1.2 (0.6-2.6)	0.7 (0.3-1.5)	**0.4 (0.2-1.0) +**
Living alone	1.6 (0.8-3.0)	1.1 (0.5-2.5)	1.7 (0.9-3.3)	1.7 (0.8-3.5)	**2.3 (1.2-4.6) +**
Physical					
No co-morbidity	**0.4 (0.2-0.8) +**	0.5 (0.2-1.2)	**0.4 (0.2-0.8) ++**	**0.2 (0.1-0.5) ++**	**0.3 (0.1-0.5) ++**
Injury related					
ISS ≥25	**2.3 (1.1-4.9) +**	**5.1 (2.1-12.8) ++**	**2.6 (1.2-5.6) +**	0.9 (0.4-1.9)	1.0 (0.5-2.1)
Injury localization					
Head ≥3	0.8 (0.3-2.0)	0.4 (0.1-1.1)	0.6 (0.2-1.4)	0.4 (0.1-1.1)	1.2 (0.5-3.1)
Face ≥3	0.9 (0.1-5.5)	0	4.7 (0.5-44.2)	1.9 (0.3-12.9)	1.7 (0.3-10.4)
Chest ≥3	0.6 (0.3-1.3)	**0.3 (0.1-0.9) +**	0.7 (0.3-1.5)	1.2 (0.5-2.8)	0.9 (0.4-1.9)
Abdomen ≥3	0.8 (0.3-2.2)	1.0 (0.3-3.0)	0.7 (0.3-1.9)	0.8 (0.3-2.4)	1.5 (0.5-4.3)
Extremities ≥3	**2.3 (1.0-4.9) +**	1.6 (0.6-4.0)	0.8 (0.4-1.8)	1.6 (0.7-3.9)	0.9 (0.4-2.0)

Step-forward multivariable regression analysis was performed to determine the odds of developing posttraumatic problems in each of the five domains of the EQ-5D (EQ-1 to EQ-5). Odds ratios were calculated for potential high-risk groups based on sociodemographic, physical, or injury related factors. Odds ratios are displayed with the 95% confidence interval between brackets. Bold fonts indicate that the association is statistically significant; $^{+}$=<0.05. $^{++}$=p<0.01.

DISCUSSION

One year after trauma, the average day-to-day function of major trauma patients has not returned to normal in the current study population. Health-related quality of life, as measured by the summary scores of both the EQ-5D and HUI remained far below general population norms. The prevalence of specific limitations in this population was very high, with 40-70% of patients still suffering from problems with mobility (44%), usual activities (53%), pain (62-68%), anxiety/depression (41%), emotion (65%), and cognition (55%) after one year.

Since this was the first study applying the HUI, we could add prevalences of problems among major trauma patients with dexterity (21%), cognition (55%), and emotion (65%) to the literature.

In this study the advances in trauma care, which may lead to an increase in chronic health consequences or may have a beneficial effect on HRQoL instead, have been subjected to evaluation. Specifically the effect of an advancement of pre-hospital trauma care, i.e., assistance of physician staffed Helicopter Emergency Medical Services (HEMS) at the scene of the accident was explored.

No difference in outcomes between patients receiving more or less advanced pre-hospital trauma care has been found. Differences in the summary scores of EQ-5D and HUI between the physician assisted HEMS group (advanced prehospital trauma care) and the nurse assisted EMS group (less advanced prehospital trauma care) were small and not significant. Moreover, differences between those groups in all specific health dimensions were small, not significant and inconsistent.

Multivariable analysis showed that HEMS assistance was not independently and significantly associated with HRQoL. Health-related quality of life at one year after major trauma was far more influenced by personal factors than by the level of pre-hospital care, as reflected by the significant and consistent negative effects of female gender and co-morbidity on the (dimensions of the) EQ-5D and HUI.

Our main findings, as summarized above, are based upon a prospective cohort study of severely injured survivors in a Dutch trauma region. This study was designed according to international guidelines for the conduction of follow-up studies measuring injury-related disability [23]. First of all, in this study the internationally accepted case definition for major trauma (ISS>15 [1]) was used and no prior exclusions of patients based on social characteristics (e.g. language, ethnicity) were made.

As recommended, HRQoL was measured with EQ-5D and HUI in order to cover all health dimensions of the ICF that are relevant for patients with (major) trauma. In previous studies [5, 37], determinants of long-term functional consequences of major trauma have demonstrated good performance of EQ-5D in major trauma survivors, in terms of discriminative power and sensitivity to change. Nevertheless, some limitations of EQ-5D were identified (e.g. lacking information on dexterity and cognition), that have been addressed in this study by additionally applying the HUI.

The validity of our descriptive results is supported by the consistency of results on the EQ-5D and HUI, respectively. The prevalence of pain (i.e., the single dimension with full overlap between both measures) was comparably high on both the EQ-5D (62%) and HUI (68%). High prevalence's of limitations on all health domains were consistently found on both measures.

Since well-validated instruments were used, the reported high prevalence of health related limitations in this study is a good reflection of the health situation of major trauma patients after one year. Beyond the overall description of HRQoL of major trauma survivors, a comparison on several outcome measures between the physician staffed HEMS assisted population and the nurse-staffed EMS group was made. It must be considered, that this comparison is hampered by limitations of the study design. By necessity, an observational study was conducted, i.e., a design which can hardly ever provide evidence on therapeutic effectiveness [38]. In theory, a (cluster) randomized controlled trial would be preferable to study the effectiveness of HEMS on HRQoL. But in practice, for ethical and societal reasons, this was not an option. Two observational studies had already shown improved survival rates among HEMS assisted patients in the Netherlands [18, 19]. Moreover, HEMS had already been nationally implemented prior to this study and had rapidly gained a position as publicly well accepted and highly appreciated health service [39]. In order to assess the influence of this health service on HRQoL we therefore had to rely on an observational design, which almost inevitably suffers from confounding by indication if therapeutic questions are addressed [38].

The comparison of patient characteristics of the HEMS group versus the EMS group identified significant differences, which are probably (partly) based on confounding by indication. Patients in the HEMS group were more severely injured and had more physiological disturbances on the one hand, but they were younger and were less affected by co-morbidities on the other. In the Netherlands, the decision to assign a patient to HEMS or EMS assistance is made by a trained health professional (usually with a nursing background) at a regional call center. In our trauma region, HEMS assistance seems more easily requested in case of accidents among younger patients with higher (expected) injury severity levels. These two types of confounders, that have opposite effects on HRQoL, may affect comparisons of HEMS with EMS. This implies that comparisons between HEMS and EMS should be interpreted with reason.

In the multivariable models, however, we were able to adjust the results for the most important confounders, including those related to differential indication. By linking the follow-up data with the Rotterdam trauma registry, our results could be adjusted for differences in both the age and injury severity distribution of the patients. Moreover, the collected data on socio-demographic factors and co-morbidity, allowed adjustments for these factors in the comparisons between HEMS and EMS. The extensive data collection facilitated adjustment for the most important factors with both an established effect on HRQoL and a relation with the indication process for HEMS assistance (injury severity, age and co-morbidity). This provides support for the main finding one year after trauma, i.e., that generic average HRQoL is not different in patients with HEMS or EMS assistance, and is far more influenced by personal factors (as reflected by the significant and consistent negative effects of female gender and co-morbidity) than by the level of prehospital care.

This negative influence of co-morbidity and female gender is consistent with previous reports. Numerous investigators have previously reported that co-morbidity is an important independent predictor of worse health outcomes after major trauma [34, 37, 40-42]. And the influence of gender as an independent predictor of worse functional outcome after major trauma has also been reported in different studies [5, 26, 43, 44]. Vles et al [5] hypothesized that the relation between adverse outcomes and the female gender could be related to physiological, psychological and social differences between males and females. We found that females experience worse generic HRQoL in the long term, mainly because of significantly more problems on psychological dimensions.

At one year after trauma, both in comparing the crude data and after adjustment for injury severity and other confounders (including age and co-morbidity) no statistical significant differences in HRQoL between HEMS and EMS assisted patients were found. This indicates that HEMS assistance neither leads to a shift from mortality to injury-related morbidity and disability nor to improved functional outcome in the long term. This result is consistent with the small amount of previous studies on this topic. Oppe et al.[19] found comparable EQ-5D summary scores of 0.67 and 0.71 for the Amsterdam population at 9 and 15 months, respectively. Overall, they found that the quality of life was lower for the HEMS population compared with the EMS group. However, after correcting for injury severity no differences in functional outcome remained. Similar results were found in the United Kingdom. Six months after trauma no differences in health status, measured by the Nottingham Health Profile, were found between EMS and HEMS assisted patients [45]. Also a small study performed in Finland using the SF-36 quality of life questionnaire, could not demonstrate an improved HRQoL by a physician staffed HEMS assistance [46].

In order to draw more definite conclusions on the effects of HEMS on functional outcome, further research is indicated. For this purpose (inter-) national studies on the effects of HEMS with much larger sample sizes should be performed. These studies should focus on the long-term effects of prehospital care on HRQoL and comply with the guidelines for conducting follow-up studies measuring injury-related disability as suggested by the European Consumer Safety Association is recommended [23]. Determinants should be identified that affect quality of life. More efforts are needed to improve the HRQoL of major trauma patients. The prevalence of reported limitations after major trauma is high and advanced prehospital trauma care alone seems not enough to achieve more acceptable outcomes.

CONCLUSION

Functional outcome and quality of life of survivors of severe injury has not returned to normal one year after trauma. The prevalence of specific limitations in this population is very high (40-70%) and does not differ significantly between HEMS and EMS assisted patients. Health-related quality of life at one year after major trauma was far more influenced by personal factors than by the level of prehospital care.

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11

Physician Staffed Helicopter Emergency Medical Services in the Netherlands: A Cost-Effectiveness Analysis

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ABSTRACT

Background The long-term health outcomes and costs of Helicopter Emergency Medical Services (HEMS) assistance remain uncertain. The aim of this study was to investigate the cost-effectiveness of HEMS assistance, as compared to Emergency Medical Services (EMS).

Methods A prospective cohort study was performed at a level I trauma centre. Quality of life measurements were obtained at two year after trauma, using the EuroQol-5D as generic measure to determine health status. Health outcomes and costs were combined into costs per quality-adjusted life year (QALY).

Results The study population receiving HEMS assistance was more severely injured than that receiving EMS assistance only. Over the study period HEMS assistance saved a total of 29 additional lives. No statistically significant differences in the quality of life were found between patients that were assisted by EMS or HEMS. Two years after trauma, we found a mean EuroQol -5D utility score of 0.71 versus 0.70, respectively. The incremental cost effectiveness ratio for HEMS assistance instead of EMS assistance was €28,537 per QALY. The sensitivity analysis showed a cost-effectiveness ratio between €16,000 and €62,000.

Conclusion In the Netherlands, the costs of HEMS assistance per QALY remain below the acceptance threshold. Therefore, HEMS should be considered as cost-effective.

INTRODUCTION

In most western countries Helicopter Emergency Medical Services (HEMS) are available to provide on scene assistance to trauma patients [1]. HEMS can be requested by dispatch centre or by regular Emergency Medical Services (EMS) that are already at the accident site. The type and quality level of care provided by HEMS may differ depending on local (regional and national) circumstances, needs and appointments. Depending on these conditions HEMS may be staffed with physicians, flight nurses or paramedics [2]. As these professionals have different levels of certifications they will provide different therapeutic options to patients at the accident site. The utilization of HEMS may also differ due to topographical and infra-structural diversities (urban area, rural area or inaccessible areas)[3].

HEMS are used to cover long distance patient contacts and to transport advanced life support to the scene of an accident after which a patient is transported to a hospital by ambulance or helicopter. Due to a limited amount of conclusive literature, the health effects of HEMS remain uncertain. However, published reviews have reported positive effects of HEMS assistance on survival (e.g. survival benefits), which has also been observed in the Netherlands [4-8].

Another important question is the price of this care. It is well known that prehospital trauma care provided by HEMS is relatively expensive. In an era where healthcare cost savings have a high priority for governments, expensive treatments modalities and health services are observed attentively.

Studies into the cost-effectiveness of HEMS are limited [4, 8-10]. So far only two studies on survival, quality of life in combination with costs per Quality Adjusted Life Year (QALY) have been published [9, 11]. These two studies are reporting costs per QALY for HEMS of €7,300 up to €37,700 (US$9,300-US$47,900) [9, 11] The use of costs per QALY as an outcome measure is important and allows to compare the efficiency of different types of health-care service with each other. It also may support decisions to restrict investments to services with costs per QALY below a predefined "acceptance threshold". The acceptance of cost per QALY is however not an absolute figure. Policy makers and healthcare economists have proposed that costs varying from €25,000 up to €75,000 (US$31,800 - US$95,300) per QALY may be considered as acceptable [12-14].

In 1995 HEMS were introduced in the Netherlands. A cost effectiveness study was connected to this introduction [11]. Since than the Dutch trauma system has been developed and is covering the entire country [15]. The organization of the trauma system as well as the level of training of HEMS physicians, nurses and the physicians in the trauma centre has improved since than. Because of this development a well-designed study was necessary to measure the effects of HEMS on survival and Quality of life (QoL). This cost-effectiveness analysis is presented in this report. The study hypothesis was that the costs per QALY for Helicopter Emergency Medical Services in the Netherlands are below the acceptance threshold.

METHODS

Study population and design

For the survival and costs calculations data were collected from January 1st 2003 till December 31st, 2006. During this four year study period a prospective cohort study was conducted, in which all consecutive poly-trauma patients with an Injury Severity Score (ISS)[16] >15 and aged >13 years, who were admitted to the emergency department of a level I trauma centre, were included. Patients identified as Dead On Arrival (DOA) at the scene of the accident were excluded from this study.

Data were extracted from the Trauma Registry that includes the same variables as the Major Trauma Outcome Study database [1] (i.e., Age, Glasgow Coma Scale (GCS) [17], Revised Trauma Score (RTS) [18], Mechanism Of Trauma, and injury specifics). Missing data were additionally obtained from the original ambulance charts. All patients receiving on-scene EMS and HEMS assistance were included in the HEMS-group. Patients treated by EMS services only were included in the EMS-group.

Survival calculations

The estimated survival was calculated using the Trauma Injury Severity Score (TRISS) method that includes the "predicted mortality"[19]. The TRISS (logistic regression-based) method is the multivariable approach of choice [20]. The coefficients used in the TRISS model are derived from the Major Trauma Outcome Study (MTOS)[1]. To compare case mix between the regular MTOS population and this study population a so-called M-statistic must be calculated. Although M does not follow a specific distribution, it is generally considered acceptable to apply uncorrected TRISS when M is 0.88 or higher [21]. Since the value of the M in our population was 0.38 a custom fitted regression model was used to calculate a predicted survival. The construction of the logistic regression was analogous to the method described by Frankema et al [7]. After evaluating variables for their contribution to the model, the following variables were finally included in the regression model; RTS-Systolic Blood Pressure, RTS-Respiratory rate, RTS-Glasgow Coma Scale, Injury Severity Score (ISS)[16], mechanism of trauma, age, gender and type of care (HEMS or EMS). The performance of the regression model in terms of goodness-of fit was tested with the Hosmer Lemeshow (HL) statistic and for its discriminative value by calculating the area under the ROC curve. The regression model was used to calculate the lives saved by HEMS assistance.

Quality of Life measurements

The EuroQol-5D (EQ-5D) was used as generic measures to determine health status two year after trauma. The EQ-5D is generally recommended for economic evaluation of trauma care at a consensus conference [22]. A domain-related scoring algorithm based on empiric valuations from the U.K. general population and subsequent statistical modelling is available by which each health status description can be expressed into a utility score [23]. This summary score ranges on a scale from1 to -.059 (1 and 0 indicate full health and death, respectively), and can be interpreted as a judgment on the relative desirability of a health status compared with perfect health. Death was defined as deceased within 30 days after trauma. At 24 months after trauma admission all included survivors from 2003 until 2005 received a written questionnaire by mail. In absence of response patients received a phone call one month after the mailing in order to increase participation.

Cost Calculations

Medical costs were calculated by multiplying the volumes of health care use with the corresponding unit prices in 2006. The costs per in-hospital patient day (including intensive care stay), emergency department costs, operation costs, costs of diagnostics, and outpatient department visit costs were included in the direct medical cost were calculated. Cost volumes were recorded with hospital information systems, and the patient questionnaire. Included in the questionnaire were also questions related to long-term medical care. These medical costs consisted of rehabilitation costs. In The Netherlands a detailed 'fee for service' system is used for the remuneration of medical interventions and diagnostic procedures [24], enabling calculation of micro costs. Therefore, medical costs were calculated by multiplying the volumes of health care use per individual patient with the corresponding official Dutch unit prices for each diagnostic or therapeutic procedure. The costs of the HEMS itself were based on the actual cost as found in the balance of payments of 2003 until 2006.

Cost effectiveness analysis

Cost-effectiveness was assessed by calculating the incremental cost-effectiveness ratio, defined by the difference in average costs between the two prehospital emergency care approach strategies (HEMS versus EMS) divided by the difference in average health effects. The effect is expressed as quality adjusted life years (QALYs). A QALY takes into account the premature loss of life from deaths using years of life lost, and the period spent without full health for non-fatal conditions as measured by years lived with disability (YLDs). The QALY provide a means of combining the impact of fatal and non-fatal outcomes in a single measure. The incremental costs of HEMS consisted of the extra costs per HEMS treated patient compared with patients in the EMS-group.

Discounting

It is generally accepted practice in economic evaluations to discount future costs and benefits arising from health care interventions to reflect individuals' and society's time preference [25]. To compare the benefits that occur over time, it must be adjusted to relate to the 'present value' in which the costs are spent. A discount rate of 1.5% for the benefits was used, as recommended in the Dutch guidelines for economic evaluations (CVZ) in this study [26].

Statistical Analysis

The statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 12.0 (SPSS, Chicago, IL, USA). As the discount rates vary over time and across countries, we tested the impact of the use of different discount rates on the results obtained by sensitivity analysis .An annual discount rate of 0 and 3.5% for benefits was used since the guidance by NICE (National Institute for Health and Clinical Excellence 2004) recommends an annual discount rate of 3.5%.

RESULTS

The effect of HEMS on survival

During the study period (4 years) 781 patients were admitted to the emergency department of a level 1 trauma centre. The majority of patients were male (73%) and sustained blunt force trauma (91%) (Table 1). Patients in the HEMS group were younger (median age 36 versus 43 years), had more disturbed vital parameters (median GCS 3 versus 13 and median RTS 8 versus 12) and were more severely injured (median ISS 29 versus 22) compared

Table 1. Patient characteristics divided by HEMS and EMS

	Overall	HEMS	EMS	P-value
N	781	310	471	
Male[1]	567 (73)	233 (75)	334 (71)	N.S.[+]
Age[2] (year)	41 (25-62)	36 (23-57)	43 (27-66)	0.008[++]
Blunt Trauma[1]	713 (91)	289 (93)	424 (90)	NS[+]
Glasgow Coma Score[2]	11 (3-15)	3 (3-15)	13 (5-15)	<0.001[++]
Revised Trauma Score[2]	11 (8-12)	8 (8-12)	12 (9-12)	<0.001[++]
Injury Severity Score[2]	25 (18-33)	29 (22-38)	22 (17-26)	<0.001[++]
Prehospital intubation[1]	220 (28)	145 (50)	66 (14)	<0.001[+]
Mortality	228 (29)	100 (32)	128 (27)	NS[+]

[+] Fisher's exact test, [++]Mann-Whitney U-test. N.S., not significant.

[1], patient numbers are displayed, with the percentages given within brackets; [2], data are displayed as median, with the first and third percentile given within brackets.

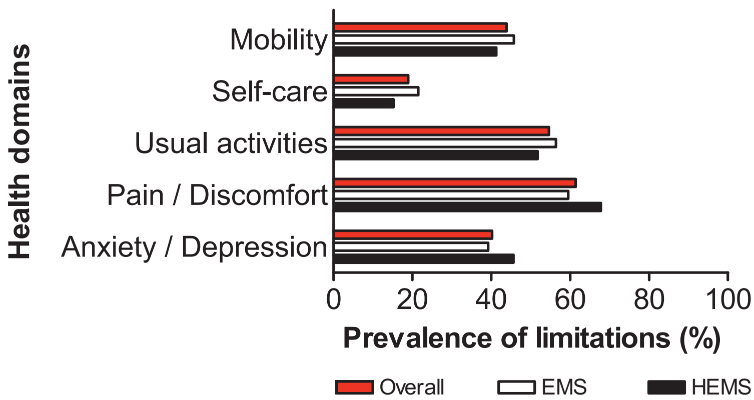
with patients in the EMS group. In the HEMS population relatively more patients were artificially ventilated compared with the EMS group (50% versus 14%). The unadjusted mortality for both groups was comparable.

The Hosmer Lemeshow (HL) statistic showed that the regression model had an appropriate goodness of fit (HL: $R^2 = 6$, $p = 0.650$). The area under the ROC curve was 0.90, indicating an excellent discriminative power. The survival analyses showed that that over the study period HEMS assistance saved a total of 29 additional lives.

Quality of life

Of the 781 poly-trauma patients (ISS>15) included in this study 654 (2003 until 2005) patients received a written questionnaire at 24-months after trauma. Of these 654 patients 454 survived their injuries. Follow-up measurements of 255 patients (response rate 56 %) were obtained. Of the 199 patients who did not participate, 194 patients were untraceable, 1 could not be included since they had insufficient comprehension or understanding of the Dutch language, 4 patients were unwilling to participate. The health status of patients that were finally included showed an EQ-5D summary score of 0.70 two years after trauma, which was far below the Dutch general population norm (i.e. 0.87) [27]. No statistically significant differences in the quality of life were found between patients that were assisted by EMS or HEMS. (Two years after trauma, we found a mean EuroQol -5D utility score of 0.71 versus 0.70, respectively. Two years after trauma, the prevalence of physical and physiological limitations for the total patient population was high on all dimensions of the EQ-5D (44% for mobility, 19% for self-care, 55% for usual activities, 61% for pain and discomfort, and 40% for anxiety and depression) (Figure 1). Differences between the EMS and HEMS group on all the separate health domains measured with the EQ-5D were not significant. On some dimensions (e.g., mobility, self care and usual activities) the preva-

Figure 1. Prevalence of physical and physiological limitations (moderate or severe) of the EQ-5D health domains two years after trauma by type of prehospital trauma care (EMS versus HEMS)



The percentage of patients with limitations in each health domain is shown. No statistically significant differences between the EMS and HEMS group were found (Chi-square test).

lence of limitations was slightly lower in the HEMS group compared with the EMS group, whereas for other dimensions (e.g., pain, anxiety/depression and emotion) the reverse was observed.

Costs

The average medical treatment costs for HEMS-assisted patients were €39,200 (Table 2). These costs mainly consist of costs for length-of hospital admission (€10,300) and intensive care cost (€16,100) (Table 2). The average costs for an ambulance-assisted patient were statistically significantly lower, namely €34,500 ($p=0.016$). This difference in cost was mainly caused by the difference in intensive care costs and the cost of diagnostic modalities. Finally this resulted in incremental costs for medical care of €4,700 (€39,200 – €34,500) per HEMS assisted patient.

Table 2. Average costs for medical treatment involved per poly trauma patient divided by type of prehospital care

	HEMS costs (€)	EMS costs (€)	P-value
Hospital stay (ward)	10,300	10,200	N.S.
Intensive Care stay	16,100	12,400	**0.003**
Out-patient clinic	2,400	1,900	N.S.
Emergency Department	1,500	1,500	N.S.
Surgery	3,400	3,100	N.S.
Diagnostics	3,600	2,800	**0.002**
Rehabilitation / nursing home	1,900	2,600	N.S.
Total	**39,200**	**34,500**	**0.02**

The Mann-Whithey U-test was used for statistical analysis.
N.S., not significant

Cost effectiveness analysis

The costs for the four years of HMS assistance summed up to a total of €11,314,972. These costs consist of €5,574,878 of personnel costs and €5,740,094 of material costs. The incremental costs of medical treatment care add up to a total €987,000 (210 surviving HEMS patients in four years times the incremental costs of €4,700 per patient). The total cost for HEMS assistance add up to €12,301,972 (actual HEMS cost of €11,314,972 plus the total incremental cost of €987,000). Based on these calculations, when using the recommended discount rate of 1.5%, the costs for HEMS are €28,327 per QALY (Table 3). A sensitivity analysis was performed to test the impact of the use of different discount rates, since they vary over time and across countries. The costs per QALY for HEMS when using a discount rate of 0.0% or 3.5% were €16,000 and €62,000, respectively.

Table 3. Model of the costs for HEMS per Quality Adjusted Life Year (QALY)

	Regression Model
Number of lives saved	29.0
Average life expectancy (years)	38.4
Total life years won	111205
QALY saved (utility = 0.7059)	785.3
QALY saved after discounting*	434.3
Total costs HEMS	€ 12,301,972
Costs per QALY	**€ 28,327**

For these calculations the EQ-5D summary score 0.7 was used to correct for Quality of life.
TRISS, Trauma Injury Severity Score.
* Discount rate of 1.5% as recommended in the Dutch guidelines for economic evaluations with t=38,4
Average life expectancy = mean life expectancy Netherlands – mean age research population.
Life expectancy per individual was calculated by using a life expectancy table of the general Dutch population (corrected for age and gender).

DISCUSSION

HEMS assistance is effective in saving lives of moderately and severely injured trauma patients. The study population receiving HEMS assistance was more severely injured than those receiving EMS assistance only. The incremental costs for intramural care were €4,700 for HEMS treated patients compared with patients treated by EMS only, which was mainly determined by the costs of the intensive care stay and the used diagnostics. Over the study period HEMS assistance saved a total of 29 additional lives. No statistically significant differences in the quality of life were found between patients that were assisted by EMS or HEMS. Two years after trauma, we found a mean EuroQol -5D utility score of 0.71 versus 0.70, respectively. The incremental cost-effectiveness ratio for the use of HEMS instead of EMS is €28,327 per QALY.

The multivariable method of choice to predict a possible survival benefit for trauma patients is the TRISS method [20]. The coefficients of TRISS are derived from the MTOS population. To use the TRISS method a study population should have a comparable distribution as the MTOS population. It is known that M-statistic for populations in Europe differs substantially from the MTOS population [21]. Even though comparable results were found with the TRISS method (HEMS saved 27.48 lives more than predicted by TRISS ($Z=4.47$, $p<0.001$; W-statistic = 8.86)) as with the regression model in this study, with a M-value of 0.38 no reliable conclusions could be drawn based on the TRISS method[21].

Functional outcome and quality of life of survivors of severe injury does not return to normal two year after trauma. The prevalence of specific limitations in this population is very high (40-70%) and differences between HEMS and EMS assisted patients in the EQ-

5D summary score and all specific health dimensions were small, not significant and inconsistent. In previous studies [28, 29] determinants of long-term functional consequences of major trauma have demonstrated good performance of EQ-5D in major trauma survivors, in terms of discriminative power and sensitivity to change. Since we used well-validated instruments, the reported high prevalence of problems in this study is a good reflection of the health situation of major trauma patients.

The sensitivity analysis showed that the choice for the discount rate highly influenced the outcomes of the cost-effectiveness analysis. Using a discount rate of 0.0% versus 3.5% resulted in a cost-effectiveness ratio between €16,000 and €62,000, respectively. Both of these figures are below the 'acceptance threshold' of €75,000 per QALY [12-14]. To put these results of costs per QALY more in perspective a comparisons can be made with costs for other treatment modalities in the Netherlands. An example of three regularly performed treatments in the Netherlands are a liver transplantation, heart transplantation and lung transplantation. The costs per QALY for these modalities are €35,100, €36,800 and €79,500, respectively [30].

The relatively low response rate of 56% could be regarded as a limitation of this study and may have affected the costs per QALY results. A large part of study population was untraceable since they were not living in the Netherlands, and consequently lost to follow-up. If the health status of the study population two years after trauma is compared with the quality of life measurements at one year in a comparable cohort during the same study period, the QoL two years after trauma is slightly lower than the quality of life reported one year after trauma (mean EQ-5D utility score 70 vs. 73). This finding has been reported before [31]. A possible explanation would be that patients with a disturbed health status are more likely to participate in the QoL measurements. This might entail that the low response rate could have influenced QoL score and that the actual health status of the total study population was in fact higher than measured. A better average health status would have resulted in lower costs per QALY.

CONCLUSION

With a calculated incremental cost for medical care of €4,700 (€39,200 – €34,500) per HEMS assisted patient, the costs per QALY for Helicopter Emergency Medical Services in the Netherlands remain below the acceptance threshold. Therefore, HEMS should be considered as cost-effective.

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Willingness to Pay for Lives Saved by Helicopter Emergency Medical Services

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ABSTRACT

Introduction Currently, policy makers in the Netherlands are discussing the possibility to expand the availability of Helicopter Emergency Medical Services (HEMS) from 12 hours to 24-hours a day. For this, the preferences of the general public towards both the positive effects and negative consequences of HEMS should be taken into account. Therefore, the willingness to pay (WTP) for lives saved by HEMS was calculated.

Methods A discrete choice experiment (DCE) was performed in order to explore the preferences of respondents towards (expansion of) HEMS availability. The attributes: costs (for HEMS) per household number of additional lives saved (by HEMS), number of noise disturbances (caused by HEMS) during daytime or nighttime were used. A written questionnaire was presented to 150 individuals by convenience sampling.

Result One hundred and thirty-six (91%) of the 150 individuals completed the DCE questionnaire. The marginal WTP for one additional life saved (in a month) was €3.43 (95% CI; 2.96-3.90) per month per household. Overall, the WTP for expansion to a 24-hour availability of HEMS can therefore be estimated at €12.29 (~US$17.50) per household per month.

Conclusion The WTP derived from this study is by far exceeding the 1-1.5 Million-euro necessary per HEMS per year for the expansion from a daytime HEMS to a 24-h availability in the Netherlands. Respondents are willing to pay for lives saved by HEMS in spite of increases in flights and concurrent noise disturbances. These results may be helpful for the decision-making process, and may provide a positive argument for the expansion of HEMS availability.

INTRODUCTION

In many western countries Helicopter Emergency Medical Services (HEMS) are available. Although the additional value of HEMS is often subject of debate, international literature demonstrates that HEMS assistance improves survival and outcome of severely injured patients[1-5]. HEMS, however, are a high-visibility, resource-intensive expense. Therefore, cost-effectiveness analyses may be determinative for the decision to introduce or expand HEMS in any national healthcare system. Cost-effectiveness analyses assess the balance between public investments (expressed in monetary terms) versus health gains (usually expressed as live years saved or quality-adjusted live years saved).

HEMS availability during day light hours (7.00-19.00h) was introduced in the Netherlands in 1997 after a pilot study demonstrating a positive balance between costs and health gains[3]. The Dutch trauma system is a well-developed system, with many parallels with other trauma systems (e.g. those of the US). Currently, policy makers are discussing a possible expansion of HEMS to a 24-hour a day availability. To support its decision, the Dutch government has recently started a pilot study to evaluate the cost-effectiveness of this expansion compared with ground transport. Decision-making on the expansion of HEMS, however, should take into account additional factors besides costs and patient outcomes. The Netherlands is a densely populated country with strict regulations on noise disturbance, in particular during nighttime. These regulations may conflict with expansion of HEMS availability for scene missions to nightly hours. Preferences of the general public on both the positive effects (in terms of lives saved) and negative consequences of HEMS (in terms of noise disturbances and costs) should therefore be considered.

Preferences of the general population can be elicited with several methods. One of those is called a discrete choice experiment (DCE), which identifies the wishes and preferences of a specific group of people. The willingness to pay (WTP) for (lifesaving) medical services can be calculated from a DCE, provided that costs are incorporated into that DCE[6]. Worldwide hardly any research has been performed to examine the attitude of the general public towards HEMS, including the marginal willingness to pay for lives saved by HEMS. We therefore conducted a DCE to determine the preferences of Dutch inhabitants towards HEMS availability and to calculate the willingness to pay for lives saved by HEMS. The results of this study may support the decision-making about the nationwide extension of HEMS during nighttime hours in the Netherlands.

METHODS

A discrete choice experiment (DCE) was performed in order to explore the preferences of respondents towards (expansion of) HEMS availability. Respondents had to fill out a questionnaire, choosing their preferred option from sets of scenarios. These scenarios consisted of a set of attributes that described HEMS as a service, *i.e.*, main characteristics of HEMS availability. The following attributes or main characteristics were chosen: costs (for HEMS) per household, number of additional lives saved (by HEMS), number of noise disturbances (caused by HEMS) during daytime, and number of noise disturbances (caused by HEMS) during nighttime (see Table 1). The attributes used were constant in each scenario, but varied over a range of levels. All scenarios in the questionnaire described hypothetical situations with differences in HEMS availability. The steps necessary to carry out a DCE are successively described below.

Table 1. Attributes and accompanying levels

Attributes	Levels			
Costs for HEMS per household each month (€)	1	5	15	30
Number of additional lives saved by HEMS each month	2	5	7	10
Number of noise disturbances caused by HEMS during daytime (between 07.00h and 19.00h) in one month	30	60	90	120
Number of noise disturbances caused by HEMS during nighttime (between 19.00h and 07.00h) in one month	0	10	20	30

Definition of attributes and levels

Attributes should cover the important aspects of HEMS dispatch, be meaningful, and avoid double counting of consequences. A scenario should include at least two attributes, but preferably not more than eight. Each attribute is quantified in levels. The levels of the attributes should be plausible, actionable and make respondents willing to make trade offs between combinations of the attributes[7,8]. In this DCE on the value of HEMS, respondents had to choose between two scenarios and an opt-out option within a choice set. Costs are expressed in euros (€1 = US$1.42). The following 4 attributes and levels were used (Table 1); 1) the costs per household each month (€1, €5, €15, and €30); 2) the number of additional lives saved each month (2, 5, 7, and 10 lives); 3) the number of noise disturbances produced by the helicopter during daytime (between 07.00h and 19.00h) in one month (30, 60, 90, and 120 flights); 4) the number of noise disturbances produced by the helicopter during nighttime (between 19.00h and 07.00h) in one month (0, 10, 20, and 30 flights). The attributes cover the aim of the HEMS presence (i.e., additional lives saved) and the main disadvantages (i.e., costs and noise disturbance). The levels were defined with data on the current situation, including the number of lives saved assessed in a previous study[3].

Experimental design

The questionnaire given to each respondent contained 16 choice sets, representing a fractional factorial array. As opposed to a full factorial design (which uses all possible combinations) a fractional factorial design refers to a selection of all possible combinations and levels. The fractional factorial design allows for analysis of the main effects (between 70% and 90% of the explained variance), which are the most important aspect of the decision-making process[9]. In the current study a fractional factorial design was used, containing 16 choice sets existing of two scenarios and an opt-out option. An example of a choice set is given in Figure 1. The two scenarios were presented as regions A and B, which had a different HEMS policy. Respondents were asked to pick the region they would prefer to live in.

The opt-out option offered the possibility to choose a region where no HEMS service is present. This option is the same in each choice set. It is important to include the opt-out option. Otherwise the value for an attribute could be higher than its actual value. If respondents chose the opt-out option, an additional forced choice had to be made between region A and B.

Data collection

A written questionnaire was presented to 150 individuals by convenience sampling. Study approval was obtained of the local Ethics Committee (equivalent of the Institutional Review Board). Relatives of personnel of non-clinical departments distributed the questionnaires among their social network. In this way a study population was approached with no direct link to the principal clinical investigators or the subject matter (i.e HEMS and/or trauma care). In the introduction of the questionnaire, objective background information on the subject of HEMS was presented. An example of a choice set was provided to explain the questionnaire. Next, the 16 choices were presented. One dominant choice set was included in the design in order to examine whether the respondents had understood the questionnaire correctly. This dominant choice set could be answered wrongly. This 'wrong' answer implied that respondents chose to pay much more for fewer lives saved and more noise disturbances during day and night. A sub-analysis was performed for those questionnaires in which the dominant choice set was answered correctly in order to test for a possible bias. The last part of the questionnaire consisted of questions concerning characteristics of the respondents and their attitudes towards HEMS. The attitude towards HEMS was measured on a five-point scale. The score 1 was a very positive attitude towards HEMS.

Data analysis

To get insight into the respondents' trade off behavior between attributes and levels the data were analyzed using a conditional logit model[9]. The results of the forced choice (between scenario A and B in case the opt out option was chosen) were used to determine the preferences of respondents, since it seems realistic that respondents in real life cannot

Table 2. Demographic characteristics of the 136 respondents versus the Dutch population

Characteristics Respondent	DCEP	DP
Mean age (years)	42	39
Male (%)	46	49
Highest education (%)		
Elementary school	4	5
Junior secondary school	7	19
Senior secondary (vocational) education	42	44
Higher vocational education	31	19
University education	16	12
Unknown	0	1
Net income household (%)		
< € 2000	30	37
€ 2 000 - € 3000	35	51
> €3 000	31	12
Missing	4	0
Household composition (%)		
No partner, no children	21	34
Partner, no children	40	29
Partner, one or more children	37	28
No partner, one or more children	2	6
Other	0	3

DCEP=population in the discrete-choice experiment;DP=Dutch population (LibermanM,Mulder D, Sampalis J.Advancedor basic life support for trauma: meta-analysis and critical review of the literature. J Trauma. 2000;49:584–99).

choose an opt out. The results of the unforced choice (between scenario A, B and the opt out) were used to calculate the WTP in order to avoid an overestimation of the WTP. The marginal WTP for the attributes 'lives saved', 'noise disturbance during daytime', and 'noise disturbance during nighttime' was calculated by dividing the coefficients of those attributes with the (negative) coefficient of the attribute cost per household. The marginal WTP therefore indicates the WTP per level change of that attribute. The confidence interval for marginal WTP was calculated using a boot strapping method. Analyses were performed using the Stata Statistical Software (release 9.0; Stata Corporation, Texas, USA).

RESULTS

One hundred and thirty-six (91%) of the 150 individuals who received a questionnaire participated in this discrete choice experiment (Table 2). The average age of the respondents was 42 years (range 18-82 years). Forty-six percent of the respondents were male.

The largest group of respondents (42%) had completed a secondary (vocational) education, followed by the group with a Bachelor degree (31%). The monthly net incomes per household were subdivided into three categories. These categories; < €2000 (30%), €2000 - €3000 (35%) and > €3000 (31%) were almost equally represented in the participating population. Five out of the 136 respondents (4%) preferred not to answer the 'income' question. Most respondents had a partner and no children (40%), closely followed by the group with a partner and one or more children (37%). In comparison with the Dutch population age and sex were almost equally distributed. The educational level and net income per household were higher in the study group, compared with the average Dutch population.

Table 3. Conditional logit outcomes for the forced choice, used to determine preferences of respondents

Attributes	Coefficient	Stand. error	Significance	95% Confidence interval	
Costs per household each month	- 0.06	0.00	<0.001	-0.07	-0.06
Life saved per month	0.32	0.02	<0.001	0.29	0.35
Noise disturbance during daytime per month (07.00-19.00h)	0.01	0.00	<0.001	0.01	0.01
Noise disturbance during nighttime per month (19.00-07.00h)	0.02	0.00	<0.001	0.01	0.02
Pseudo R^2			0.33		

Pseudo R^2, percentage of explained variance

Preferences of respondents

The attribute 'cost per household' had a negative coefficient, indicating that respondents preferred low cost for HEMS (Table 3). The positive coefficient for the attribute 'lives saved' showed a positive preference of respondents towards the number of additional lives saved due to HEMS availability. The attributes 'noise disturbance produced by the helicopter during daytime and nighttime', related to the expansion of HEMS, were also valued positively. This suggests that respondents had a positive attitude towards more noise disturbance. Although the coefficients were near to zero, these positive signs requested further analysis. Fourteen subjects answered the dominant choice set 'wrongly' and might have misunderstood the questionnaire. Excluding their data from the analysis did not change the positive preferences towards noise disturbance. The positive value of respondents towards the attributes noise disturbance may be explained by with their attitude towards HEMS. A subgroup analysis was performed for respondents with a very positive and respondents with a less positive attitude towards HEMS. The purpose of this subgroup analysis was to exclude the influence of the attitudes of respondents towards HEMS on the attributes noise disturbance during daytime and nighttime. The overall preference structure was similar for both groups.

Willingness to pay

The outcomes of the conditional logit model for the unforced choice were used to calculate the WTP (Table 4). In this model for the unforced choice the attribute 'noise disturbance during daytime' did not statistically significantly affect the WTP (p=0.059), unlike the other three attributes. Therefore, noise disturbance during the day was not included in the WTP calculation.

The marginal WTP for 1 additional life saved (in a month) was €3.43 (95% CI; 2.96-3.90) per month per household. Based upon a previous study it is estimated that 5.1 additional lives will be saved per 100 HEMS dispatches in the Netherlands[3]. In the Netherlands the annual number of HEMS dispatches during daytime is approximately 1900. Based on a pilot study, the expansion to a 24-hour availability of HEMS is expected to result in 500 additional dispatches each year (i.e., 41.7 dispatches per month)[10] on average, resulting in 25.5 additional lives saved per year (500 dispatches * 5.1 lives saved / 100 dispatches). Respondents were willing to contribute on average €0.12 (95% CI; 0.02-0.23) per month per additional noise disturbance, i.e. per additional flight, at night.

Table 4. Conditional logit outcomes for the unforced choice, used to calculate WTP

Attributes	Coefficient	Stand. Error	Significance	95% Confidence interval	
Costs per household each month	- 0.07	0.00	<0.001	-0.07	-0.06
Life saved per month	0.22	0.11	<0.001	0.20	0.25
Noise disturbance during daytime per month (07.00-19.00h)	0.001	0.00	<0.059	-0.00	0.00
Noise disturbance during nighttime per month (19.00-07.00h)	0.008	0.00	<0.002	0.00	0.01
Pseudo R^2			0.17		

Pseudo R^2, percentage of explained variance

Overall, the WTP for expansion to a 24-hour availability of HEMS can therefore be estimated at €12.29 (~US$17.50) per household per month ((€0.12 * 41.7 dispatches during nighttime per month) + (€3.43 * 25.5 lives saved / 12 months))).

DISCUSSION

In this study the preferences for HEMS availability were measured using a discrete choice experiment, where respondents made explicit trade-offs between costs, lives saved, and noise disturbance during the day and night. The results of this study revealed that respondents are willing to pay €3.43 per live saved by HEMS per household per month and €0.12 per additional HEMS flight during nighttime per household per month (that causes noise disturbance) in the situation of a future 24-hour HEMS availability. Based upon the results of the current study and the anticipated additional number of 500 HEMS dispatches per year, the WTP for HEMS expansion towards nighttime was estimated at €12.29 per household per month. This shows that respondents from the general Dutch population are willing to pay substantially for HEMS.

Limitations and future studies

These results, however, should be interpreted with great care. As each study design has strengths and weaknesses, this DCE has also a number of methodological limitations. First of all, it must be considered that stated preferences (and not revealed preferences) were measured, and that the results may not be representative for the general Dutch population. As the number of households with a high net income was overrepresented in our study population, the WTP for HEMS availability might have been overestimated.

In addition, we found some unexpected results also leading to an increased WTP for HEMS. Surprisingly, the attributes covering noise disturbance, both during daytime and during nighttime, were valued positively. Additional analyses showed that these positive preferences of noise disturbance could not be explained by the attitude of the respondents towards HEMS. Moreover, this could not be explained by potential misunderstanding of the questionnaire. The 14 subjects who answered the dominant choice set ‘wrongly’ might have misunderstood the questionnaire, but excluding their data from the analysis did not change the positive preferences towards noise disturbance.

The positive valuing of noise disturbance could imply that there is an unobserved systematic component in the chosen attributes. Respondents may associate the expansion of HEMS availability (i.e., additional lives saved and subsequent increased noise disturbance) with the possibility of improved quality of life or an extended life span. These characteristics were not included in the one-dimensional measure of effect ‘number of lives saved’. Another explanation could be that respondents unconsciously find the presence of a physician and the fast transportation element of trauma helicopters a reassuring thought. One could also hypothesize that our study sample had only little experience with noise disturbance and has therefore underestimated its impact. Especially, since HEMS is currently unavailable during nighttime in the studied region, the impact of noise disturbance during the night could be underestimated.

The discussion of how to interpret the positive valuing of noise disturbance raises the question whether or not it is appropriate to include this preference in the WTP. Because positive values for noise disturbance are counter-intuitive, one might argue that it is not appropriate to include a positive value in calculations of WTP and might prefer to ignore the result. However, although the coefficients of noise disturbance were near to zero (Table 3), their effect on WTP is substantial. Neglecting the positive preferences for noise disturbances (i.e. estimating these preferences at zero) in the calculations yields a WTP estimate for expansion of HEMS towards nighttime at €7 per household per month.

The current DCE was not set up to compare HEMS with other treatment programs. It is known that evaluation of a single program requires more cognitive exercise to evaluate the single option to judgment of respondents[11-13]. In joint evaluation (i.e., comparison with other programs) respondents can ask themselves which program they prefer and how much they prefer it. Future studies on willingness to pay for HEMS should therefore compare the WTP for HEMS with WTP for other treatment programs (i.e. kidney transplantation, chemotherapy etc) or a non-HEMS alternative (e.g. EMS). This might put the outcome in a more realistic perspective. This way, the respondents can make explicit trade-offs in a more realistic context, in comparison with a governmental (societal) perspective. Protiere and Luchine have shown for example that in comparison with programs for heart disease and breast cancer, the WTP for HEMS was valued lower[13,14]. They also demonstrated that WTP was influenced by the introductory information given to the respondents, stressing the importance of keeping this information as objective as possible. Olsen et al[15] showed that the WTP for HEMS and heart operations was equal and significantly higher compared to WTP for hip operations.

A straightforward comparison of the results of our study with other estimates on the willingness to pay to prevent fatal injuries is very difficult if not impossible, since the values obtained depend on the type of payment vehicle, elicitation format, initial level of risk and the anticipated risk decline[16]. To support decision-making in road traffic policy, the WTP for preventing one road traffic fatality with road safety measures in the Netherlands has been estimated at €2-10 million[16]. Assuming a WTP of €7-12 per household per month, 7 million households in the Netherlands and 25 lives saved per year, the WTP for preventing one fatal injury outcome by HEMS can be estimated at €23-40 million. The observed differences in WTP between road safety measures versus HEMS are probably due to both differences in study design and differences in target populations (general population with low injury fatality risk versus severely injured patients with high injury fatality risk).

CONCLUSION

In spite of methodological considerations, the results of this study show positive preferences of the general public towards expansion of HEMS. Though possibly slightly overestimated, the willingness to pay derived from this study is by far exceeding the 1-1.5 Million-euro necessary per HEMS per year for the expansion from a daytime HEMS to a 24-h availability in the Netherlands. Respondents are willing to pay for lives saved by HEMS in spite of increases in flights and concurrent noise disturbances. Utilizing these results in the decision-making process for the extension of HEMS during nighttime would provide a positive argument for the expansion of HEMS towards a nationwide service that is available 24 hours a day.

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General Discussion

In 1995 Helicopter Emergency Medical Services (so called Traumahelicopter) were introduced in the Netherlands. The first experience was evaluated in a cost-effectiveness study of this new trauma system. Since then no detailed analysis of the (cost-) effectiveness of HEMS in the Netherlands has been performed. The lack of knowledge of and insight into the important characteristics (health effects, effectiveness and efficiency, costs and benefits) of Helicopter Emergency Medical Services led to the work as described in this thesis. The various factors that determine the effects, costs and benefits of Helicopter Emergency Medical Services are the main topics of this thesis. One of the major outcome parameters used to quantify the effects of HEMS, though much disputed, is the mortality reduction for severely injured trauma patients.

An overview of the literature on the survival benefits of HEMS revealed a mortality reduction related to HEMS assistance, varying between 1.1 and 12.1 additional lives saved per 100 HEMS dispatches. 'Number of lives saved' was the most frequently used outcome parameter in HEMS studies. As opposed to relatively abstract parameters such as 'chances of survival' and 'odds ratio', the 'numbers of lives saved per 100 HEMS dispatches' (W-statistic) is a very comprehensible and an objective outcome parameter that allows for (inter-) national comparison.

A complicating factor when analysing previously published data was the use of different outcome parameters in different studies. Even if identical and appropriate outcome measures would have been reported in every study, comparison between studies should be addressed with great caution due to differences in geography, study setting, and trauma system. It is not valid to directly compare outcome studies performed in regions with diverse geographical distinctions (e.g,. urban versus rural areas). Likewise, data collected in a blunt trauma population do not necessarily apply to patients who have sustained penetrating trauma. In addition, HEMS assistance for particular dispatch criteria (e.g., trauma versus non-trauma) or dispatch mechanisms (e.g., auto launch) may reveal unique additional values and effects. The differences in the composition of the HEMS crew may be of significant influence on outcome; physicians are qualified and certified to provide different care than a crew of nurses alone. Besides these examples, more factors may affect outcome. Many of these additional factors influencing the outcome of acute care provided by HEMS are addressed in this thesis.

Whereas variations in e.g., geography, study setting, dispatch protocols and team structure are inherent to international HEMS studies, there is without a doubt room for improvement of future study designs. Appropriate and uniform prospective data analyses would make future international HEMS studies comparable and suitable for an analysis review. Comparison of similar results also requires correction for differences in injury severity (case-mix). If an existing regression model is to be used, the Trauma Injury Severity Score (TRISS) is still the method of choice [1]. The coefficients used in the TRISS model are derived from the major trauma outcome study (MTOS)[2] population. Use of the TRISS method is only warranted if the distribution of injury severity in the study population equals that of the MTOS population. M-statistics is used to describe (injury severity) case-mix variety. If the study population is not comparable with the reference MTOS population (i.e., M < 0.88), the TRISS model is not a valid method to predict the probability of survival for that particular population. This is likely the case in most studies executed outside the USA. Joosse et al showed that M-statistics in populations outside the USA are significantly lower than 0.88 due to differences in distribution of injury severity in the USA versus non-USA countries [3]. In our study the M-statistic showed to be below the threshold with M-value of 0.38. Therefore a logistic regression analysis was needed to correct for case mix.

One could argue that the mathematical assumptions underlying regression analysis might introduce a bias, causing limited under- or overestimation of the effects of HEMS on survival. Although such a bias cannot be ruled out, the models developed in our study had a excellent goodness of fit (i.e., Hosmer and Lemeshow of 5.97 with a P-value of 0.650, Area Under the Curve of 0.90) as well as an excellent area under the Receiver Operating Curve. Additionally, if you ask any HEMS physician to estimate in how many patients he or she has attributed to survival (saved a life), the numbers would be significantly higher. For instance, a HEMS physician arrives at an accident scene with multiple casualties. The physician is informed and reassured on the condition of the patients, and directed to the most severely injured patient. From a distance he notices a patient in severe respiratory distress, loosing consciousness due to an obvious tension pneumothorax. The EMS personnel did not diagnose this tension pneumothorax. The HEMS physician continued to perform a needle thoracocenthese that in this specific case saved the patients' life. Using a logistic regression analysis this will most likely not be accounted for as a life saved. There are innumerable examples of these interventions that influenced survival positively that remain unaccounted for. For that reason, it is more likely that the effect of HEMS on survival is underestimated in this study.

HEMS dispatch should be efficient, as air transport represents a concentrated allocation of in short supply healthcare resources. Excessive use of HEMS (*i.e.,* over-triage, or dispatches for patients with insufficient injury severity to potentially benefit from HEMS), leads to increased costs and unnecessary safety risks [4]. On the other hand, when HEMS is not or rarely dispatched to patients that could benefit from specialized medical care (*i.e.*, under-triage), patients are deprived from potentially lifesaving assistance. An appropriate balance must be found between dispatching HEMS too often (over-triage), which incurs unacceptable costs, or risking preventable mortality through insufficient use of HEMS (under-triage). This balance, fully depend on the sensitivity and specificity of the HEMS dispatch criteria used. The research outlined in this thesis **(Chapter 3**) revealed that only few studies have been performed into the validity of the HEMS dispatch criteria. The criterion 'loss of consciousness' seems promising with an acceptable accuracy. Mechanism of injury criteria generally lack accuracy, and will inevitably lead to significant over-triage. Again the comparison of different studies was complex due to (considerable) differences in study characteristics and outcomes measures. In order to obtain more conclusive and comparable results further assessment of the use of HEMS dispatch criteria is required. It was recommended that local and regional authorities' prospectively discuss triage (criteria), and strive to adjust guidelines based upon utilization review. Only then the level of evidence will rise above the level of evidence obtained from studies that are merely describing the outcome measures of over-triage. For that reason, a nationwide complete population-based trauma registry should be achieved. This should be a shared responsibility and obligation of all participants in (pre) hospital trauma care.

As described in this thesis, the dispatch procedure of HEMS in the South West Netherlands maybe further optimized; air transport dispatch was found to correspond inadequately with the patients' actual need for prehospital HEMS assistance. Emergency dispatchers only implemented HEMS in 14% of all calls meeting the formal dispatch criteria. Improvement will require more than only strict adherence to the current protocol. The latter would lead to a sevenfold increase of HEMS dispatches, with a concomitant risk of considerable over-triage. This suggests that, apart from the dispatch criteria, there is an unravelled component that prevents over-triage. Very likely the well known "gut feeling" of the dispatcher may play an important role, yet will present a challenge to qualify and quantify.

Other reasons for suboptimal use of adherence to dispatch criteria may well be insufficient communication, or perhaps prehospital providers consider the criteria as inadequate and choose not to use them. Recently, a pilot study was initiated in Rotterdam in order to analyse to what extent personnel applies the dispatch protocol for either primary dispatches (i.e., dispatcher centre personnel) or secondary dispatches (i.e., ambulance nurses/paramedics). In addition, dispatchers were asked to what extent they respect the currently applied HEMS dispatch criteria in terms of their usefulness and validity. Combining the outcome of this pilot study with current knowledge on accuracy of dispatch criteria should initiate an implementation study in which an improved set of dispatch criteria should be assessed for the validity and accuracy. The most important goal of such a study will be to create a set of more evidence based dispatch criteria and to create commitment and support of all participants that are involved in prehospital trauma care.

Despite current evidence, doubt concerning the added value of HEMS remains. The most common argument to dispute the conclusions of this thesis and other HEMS studies are that they all were not randomised controlled trails. HEMS critics frequently stress that the potentially lifesaving effect of HEMS in severely injured patients is based upon studies with an inadequate level of evidence, ranging from level V to level III studies at best. However, with the currently available evidence, no ethics committee or institutional review board would approve of performing a study in which patients would be allocated to a procedure in which they would be deprived of potentially lifesaving treatments. Such a study would be considered as unethical. Therefore, gaining data with levels of evidence I or II will not be feasible. This does not mean that the beneficial effect of HEMS compared with EMS cannot be established. Randomised controlled trials can be highly useful to demonstrate small differences in treatment effects. Observational studies can be as useful to demonstrate considerable differences between treatment effects. Therefore, it is not true by definition that observational data or data achieved from prospective cohort studies are invaluable. Blindly using the hierarchy in the level of evidence when valuing study outcomes may lead to unnecessary scepticism towards observational studies [5, 6]. As with every type of research, the data should be looked at attentively in order to determine if any potential bias might have affected the outcome. If so, this should be corrected where possible. When these basic rules are followed an observational trial can be as useful as randomised trails.

Opponents of HEMS are often suggesting that HEMS assistance results in a time delay, which may have a negative influence on the total treatment outcome. HEMS assistance at the scene of the accident is indeed associated with an extension of on-scene time (35.4 vs. 24.6 minutes; $p < 0.001$) (**Chapter 5**). This extra time is on the pre-hospital therapeutic interventions that are performed by HEMS doctors (**Chapter 6**). Especially, prehospital intubation ($p=0.05$) and chest tube placement ($p=0.005$) were related to significant increase of time spent at the accident location. Although additional treatment interventions performed by the HEMS team at the scene of the accident are more time consuming, no evidence has been found to support a direct connection between the length of on scene time and final treatment outcome.

Worldwide, pre-hospital trauma systems focus on delivering patients to hospitals within the golden hour, without any unnecessary delay. However, there is no evidence based support for this the principle of this 'golden hour' [7]. It is more important to know how this period was used and which life-saving measures were performed in this period. It is obvious that when no life-saving measures are taken even the "golden hour" is too long in severely injured patients. The discussion about the concepts of 'stay and play' versus 'scoop and run' is still vivid and poorly understood. More research and better definition are needed in order to provide conclusive evidence.

Not all patients will benefit from HEMS assistance. The research in this thesis provided evidence that patients with blunt trauma (mostly road traffic- and industrial accidents) are the most likely to benefit from HEMS assistance. This finding was confirmed also in other studies [8, 9]. For patients with penetrating injuries the 'scoop and run' strategy would be most beneficial. There are not many therapeutic options, which could be performed, without advanced medical equipment, outside the hospital. These patients should be transported to an appropriate hospital as fast as possible in order to receive advanced damage control care (e.g., operating theatre). This cannot be provided at the accident scene. HEMS assistance will, in these specific cases, results in an unnecessary time delay.

From time to time articles have been published, in general in non-scientific paramedical magazines in the Netherlands, discussing HEMS assistance and HEMS outcome research. Also, in these articles authors are proposing to expand the number of therapeutically options of EMS personnel, for instance rapid sequence intubation (RSI) and chest tube placement. The main argument being that if the budget for HEMS would have been spent to train EMS personnel how to perform RSI, additional survival could be gained using personnel already available. Furthermore, the authors of these articles and letters argue that most if not all HEMS efficacy studies have been performed by physicians with a personal interest in a positive effect of HEMS. This would make the available study results subjective and unreliable. Although these articles and letters lack scientific bases, they need to be taken seriously and addressed properly. Other possibilities to improve prehospital trauma care need to be discussed in order to improve final outcome. This will keep those who are involved in this process alert and engaged. From an academic point of view all these possibilities and suggestions need to be substantiated with valid, evidence based (clinical) research. The expansion of the scope of therapeutic options by the EMS personnel in the Netherlands with RSI is an example of a possibility.

An evaluation of literature shows evidence for a beneficial effect of prehospital intubations by EMS personnel. The success rate of prehospital RSI performed by paramedics ranges from 84 to 97 percent [10-13]. Even if this may seem to be highly successful, these results should be interpreted with care, as all these studies substantially differ in study population, trauma system, techniques used, and the number of attempts. These differences make it difficult to extrapolate the results to our trauma system in the Netherlands. Even in the USA, there are concerns about the success rates and number of attempts. It was suggested to limit the number of attempts to a maximum of three [14]. More than three attempts would inevitably result in a significant prehospital time delay and may reduce the chance of patient's survival. The element, that is needed to have a successful program that provides reliable prehospital RSI, is extensive training in airway management of a limited group of providers and close monitoring of the process [10, 13, 15]. There is, however, no conclusive evidence of the minimal requirements that needs to be fulfilled to get the certification to perform a safe RSI procedure. Warner et al [13] used a minimum of 12 uncomplicated endotracheal intubations per year as requirement for certification, with acceptable success rates. Based upon these numbers, it is not feasible, neither from an experience point of view nor from a cost point of view, to introduce RSI in EMS in the Netherlands. This is because of lack of exposure and related qualification of individual members of EMS. In the Netherlands approximately 800 severely injured patients need the endotracheal procedure on-scene each year. This would project to a maximum of 67 paramedics (800 / 12) that could maintain the experience needed to perform RSI. These 67 persons should cover all of the Netherlands during all days of the year just to meet the minimal qualifications, as opposed to the approximately 40 HEMS-physicians that are covering all of the Netherlands these days. The strong point of the actual HEMS physician included concept is that, besides more frequent pre-hospital experience with advanced airway management, the HEMS physician is also exposed to practice the in-hospital airway management and management of the severely injured patient.

There are no differences in health related quality of life between HEMS and EMS assisted patients at one and two years after trauma. This is an important conclusion of the research that is presented in this thesis (**Chapter 10**). This fact indicates that HEMS assistance neither leads to a shift from mortality to residual injury-related morbidity and disability, nor to worse functional outcome in the long term. In other words, the increased survival of severely injured patients does not result in increased morbidity. This is the evidence for a positive effect of HEMS involvement since the patients in the HEMS treated group were more severely injured and their vital parameters were more disturbed. One could hypothesize that more severely injured patients are more likely to have a higher disability rate and consequently a poorer functional outcome. This was not seen in the HEMS population in our study. Finally, the results of this quality of life study were used in a cost effectiveness analysis (**Chapter 11**). Obviously, the costs related to HEMS assistance were considerably higher compared with costs of EMS assistance. The costs-effectiveness analysis showed however that HEMS assistance is effective and efficient in saving lives of major trauma patients. The additional costs for the use of HEMS instead of EMS alone were calculated at €28,537 per QALY. This can be put into perspective by comparing the costs for HEMS with costs for other treatment modalities in the Netherlands. Examples of three regularly performed life savings advanced treatments in the Netherlands are the liver transplantation, heart transplantation and lung transplantation. The costs per QALY for these treatment modalities are €35,100, €36,800 and €79,500, respectively [16]. The costs of HEMS treatment of severely and moderate injured patients are below the 'acceptance threshold' for economical acceptability in the Netherlands. The HEMS is a cost-effective treatment concept in the Netherlands.

Furthermore, the "Willingness to Pay" study showed a positive acceptance of the general public towards the expansion of HEMS, even when the costs and noise disturbance are taken into account. The willingness to pay by the general public (€12.29 per household per month) was by far exceeding the 1-1.5 Million-euro necessary per HEMS location per year for the expansion from a daytime HEMS to a 24-h availability in the Netherlands. This is another positive argument for the expansion of HEMS towards a nationwide service that is available 24 hours a day.

In conclusion, the work outlined in this thesis demonstrated that, despite the fact that the current available HEMS dispatch criteria lack validity and are still insufficiently investigated for specificity and sensitivity (**Chapter 3**), (inter-) national studies overall show positive effects of HEMS on survival (**Chapters 2, 9 and 11**). Subsequently, the dispatch procedure of HEMS in the South West Netherlands should also be further optimized (**Chapter 4**). It was demonstrated that HEMS assistance at the scene of the accident was associated with increased on-scene times (**Chapters 5 and 6**). No evidence was found to support a direct link between the on scene time and final outcome. And although patients in the HEMS population were more severely injured, HEMS assistance does not lead to an increased number of survivors with functional limitations or decreased health-related quality of life (**Chapter 10**). The most important conclusion of this thesis is that Helicopter Emergency Medical Services in the Netherlands proof to be cost-effective (**Chapter 11**).

This thesis attempts to cover the most important factors connected with HEMS in the Netherlands, despite the fact that the subject is too extensive and complex to be covered in one thesis. Therefore more research will be needed in the field of (prehospital) trauma care to come to study results on efficiency and effectiveness, to come to an optimal organisation, which is providing acute trauma care under time pressure in different and difficult circumstances. These HEMS related topics need constant monitoring of (pre-) hospital trauma care that will finally lead to improvement in organisation and patient's outcome. For this effort, the commitment and dedication of all partners in the chain of trauma care is needed.

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Summary

In 1995, the first Helicopter Emergency Medical Service (so called Trauma helicopter) was introduced in the Netherlands. Since then, the national organisation of the trauma system, including HEMS and trauma centres, and the trauma related training of HEMS physicians and trauma surgeons, has improved considerably.

Since the nationwide introduction of HEMS in 1999 no evaluation has been performed to measure the effects of HEMS on trauma care in the Netherlands. This fact, in combination with the lack of randomised controlled trials for HEMS assistance, both in the Netherlands and world wide, is still a subject for debate. The discussion about the value of and necessity for HEMS is therefore ongoing. The lack of information relating to the costs, effects and benefits of HEMS highlighted the need to undertake the research outlined in this thesis.

The effect of Helicopter Emergency Medical Services (HEMS) on the outcome and, in particular, on the survival of trauma patients, is often the subject of discussion. **Chapter 2** provides an overview of literature on the survival benefits of HEMS. Sixteen studies, with varying methodological rigour, assess the effects of HEMS on trauma survival, and report estimates of the number of lives saved per 100 missions. Evaluation of the four most methodologically sound studies revealed an average estimated mortality reduction of 2.7 additional (*i.e.*, over ground EMS) lives saved per 100 HEMS dispatches for severely injured patients. Overall, previously published data indicate a clear positive effect on survival associated with HEMS assistance. In order to provide conclusive scientific evidence uniform statistics and comparable outcome parameters should be used in further research. This will help end the ongoing debate about the beneficial effects of HEMS, and may acknowledge HEMS as a valuable addition to the EMS systems in the treatment of the severely injured trauma patients.

For optimal estimation of the effects of HEMS on patient outcome, it is essential to know the efficiency in which HEMS is used. **Chapter 3** presents a systematic review of HEMS dispatch criteria for patients with traumatic injuries. This systematic review shows that there are few studies describing the validity of criteria defining appropriate HEMS dispatch, and that the results of these studies lack general applicability. The HEMS dispatch criterion, 'loss of consciousness', seems promising, but further assessment of its use is required using more rigorous methodology. The criterion 'mechanism of injury' lacks accuracy, and will inevitably lead to a significant over-triage. Efforts analogous to **chapter 2** should be made to achieve results that are more universally applicable and that allow for comparison between studies. It has been recommended that local and regional authorities prospectively discuss triage (criteria), and strive to adjust guidelines based upon utilization review. Therefore, a nationwide complete population-based trauma registry should be achieved. This should be a shared responsibility and obligation of all participants in (pre-) hospital trauma care.

In addition to the effectiveness and the accuracy of HEMS dispatch criteria, the protocol adherence of people working with the HEMS dispatch criteria also contributes to the efficacy of HEMS. **Chapter 4** provides insight into the actual dispatch rates and protocol adherence regarding helicopter dispatch criteria, by both emergency dispatchers (primary dispatch) and ambulance personnel (secondary dispatch). This study shows that the use of the HEMS in the south-western part of the Netherlands is far from optimal. On the other hand, complete protocol adherence would lead to an increase of primary dispatches by a factor 7. This would inevitably mean a significant over-triage rate. To achieve optimal use of HEMS, it is vital to increase knowledge-exchange, training and the use of standardized digital systems in which decisions need to be justified and are documented. In 14% of all A1 ambulance runs outside of uniform daylight period, an indication for HEMS dispatch existed. This stipulates once more the need for round-the-clock implementation of HEMS. Further research into the reasons for the suboptimal protocol adherence is warranted.

Besides optimal dispatch rates in terms of quantity, it is also important to gain insight into the influence of HEMS assistance on on-scene times (OST) and, consequently, on outcome. In **Chapter 5,** it has been demonstrated that combined EMS/HEMS assistance at the scene of the accident is associated with an increase in OST. The most likely explanation was that additional pre-hospital therapeutic interventions were performed on the scene. A 10-minute increase in OST was associated with an unadjusted higher chance of mortality. However, no influence of longer OST on mortality could be demonstrated after correction for injury severity and other patient characteristics (adjusted OR, 1.0; $p = 0.89$). No influence of longer OST, as a consequence of HEMS assistance at the accident scene, on mortality could be demonstrated.

Chapter 6 provides insight into the time management and interventions of the initial (pre) hospital trauma care. HEMS assistance on average consumes 83% of the first hour after an accident. As expected, the number of interventions that need to be performed predominantly determines the time necessary for prehospital treatment. HEMS involvement was associated with more pre-hospital interventions when compared with assessment by EMS only. However, although the number of interventions performed in-hospital may be lower, interventions performed prehospitally did not seem to result in any in-hospital time gain. Meaning that interventions performed prehospitally by HEMS do not results in an in-hospital time gain. This information regarding timeframes of initial trauma care may serve as a basis for further research into the consequences of interventions and time management on patient outcome.

As part of the debate about the need for HEMS in the Netherlands, the additional value of therapeutic options provided by HEMS at accident sites has been the subject of discussion for several years. Therefore, further analysis was undertaken into the procedure, results and complications of the chest tube thoracostomy, which is one of the HEMS major treatment interventions. The study, as described in **Chapter 7**, demonstrated that the prehospital chest tube thoracostomy procedure is a safe and lifesaving intervention that provides an added value to pre-hospital trauma care, if performed by a qualified physician. The infection rate for prehospital chest tube thoracostomy does not differ from emergency department performed chest tube thoracostomies and is, therefore, safe and effective.

Financial restrictions and Dutch legislation limited the HEMS dispatch to the Uniform Daylight Period (UDP), maximized to the time between 7.00h and 19.00h. The pilot study described in **Chapter 8** demonstrated that there is a need for specialized medical care in addition to the care provided for by ambulance teams also during nighttime. This need is the most apparent between 19.00h and midnight. The qualitative need for care during these hours is comparable with that during the day. Based upon this pilot study, in combination with the national daytime data, a nationwide requirement for 502 HEMS assistances between 19.00h and 7.00h was calculated. Therein, cancellations were not taken into account.

Possible beneficial effects of HEMS on the survival of severely injured (ISS>15) trauma patients have been evaluated in **Chapter 9.** Patients assisted by both EMS and HEMS sustained more severe injuries and had diminished vital parameters. Despite these differences in patient characteristics, this study revealed a positive association between the presence of HEMS and survival chances; the unadjusted mortality rate was 24.3% for the EMS group, versus 34.6% in the HEMS group. After correcting for possible confounding factors, a reversal of the crude odds ratio was observed. The adjusted odds ratio for survival was estimated at 2.2 times in favor of those aided by the HEMS; within the blunt-trauma-only subgroup, the OR for survival was 2.8.

The effectiveness of HEMS comprises more than just survival (chances) as a single outcome measure. Therefore, the effects of HEMS on quality of life were studied. In **Chapter 10** it was demonstrated that functional outcome and quality of life of patients surviving severe trauma had not returned to normal at one year after trauma. The prevalence of specific limitations in this population is very high (40-70%) and does not differ between HEMS and EMS assisted patients. Moreover, one year after trauma, the health-related quality of life of severely injured patients was found to be more related to personal factors, such as comorbidity and female gender, than to the level of prehospital care received (HEMS versus EMS).

In **Chapter 11** the costs, survival and quality of life were combined in a cost-effectiveness analysis**.** This analysis demonstrated that HEMS assistance is effective in saving lives of severely and moderately injured trauma patients. During the study period, patients receiving HEMS assistance were more severely injured than those receiving EMS assistance only. The costs for the use of HEMS instead of EMS are €28,537 per Quality Adjusted Life Year (QALY). The incremental costs for intramural care were €4,700 for HEMS treated patients compared with patients treated by EMS only. These figures were mainly determined by the costs of the intensive care stay and the used diagnostics. The costs per QALY for HEMS in the Netherlands remain below the acceptance threshold. Therefore, HEMS ought to be considered as cost-effective for treatment of moderately to severely injured trauma patients.

Preferences of the general public can play a role in the decision-making for the expansion of HEMS availability to nightly hours. The general public should value the positive effects of HEMS (in terms of lives saved) as well their negative consequences (in terms of noise disturbances and costs). **Chapter 12** describes the outcome of a willingness to pay study. The results of this study show positive preferences of the general public towards expansion of HEMS. Though possibly slightly overestimated, the willingness to pay derived from this study exceeds the 1-1.5 Million euro necessary per HEMS location per year for expanding the availability of HEMS in the Netherlands from daytime only to 24 hours a day. Respondents were willing to pay for lives saved by HEMS in spite of increases in flights and concurrent noise disturbances. Using these results in the decision-making process for the extension of HEMS for nighttime service would provide an additional positive argument for the extension of HEMS into a 24-hour nationwide service.

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Samenvatting

In 1995 werd het eerste Helikopter Mobiel Medische Team (Traumahelikopter) in Nederland geïntroduceerd. Sindsdien is de ontwikkeling van het landelijke traumasysteem, met onder andere traumacentra, Helikopter Mobiel Medische Teams (HMMT), traumaregio's en traumagerelateerde opleidingen van chirurgen en spoedeisende hulp artsen, snel gegaan. Sinds de landelijke invoering van HMMTs in 1999 heeft er geen evaluatie meer plaatsgevonden naar de effecten van HMMTs op de traumazorg in Nederland. Het ontbreken van een evaluatie en het ontbreken van gerandomiseerde studies resulteert in het voortduren van de discussie over de waarde van assistentie door het HMMT. Deze discussie wordt zowel in Nederland als in de rest van de wereld gevoerd..Het ontbreken van gegevens over de kosten, effecten en over de waarde van het HMMT was aanleiding voor het onderzoek dat beschreven is in dit proefschrift.

De invloed van HMMTs op het beloop, in het bijzonder op de overleving, van traumapatienten, wordt vaak ter discussie gesteld. In **Hoofdstuk 2** wordt een overzicht gegeven van de literatuur over de overlevingswinst als gevolg van HMMT assistentie. Zestien studies, variërend in methodologie, beschrijven de effecten van HMMT op overleving. De effecten worden uitgedrukt in aantal gewonnen levens per 100 HMMT inzetten. Een evaluatie van de vier methodologisch correcte studies laat een mortaliteitsreductie zien van 2.7 extra levens per 100 HMMT inzetten voor ernstig gewonde patiënten, ten opzichte van alleen ambulance assistentie. In het algemeen laten eerder gepubliceerde data een duidelijk positief effect zien van HMMT assistentie op overleving. Om nog sterker wetenschappelijk bewijs voor dit effect te verkrijgen, zullen volgende studies gebruik moeten maken van uniforme statistiek en vergelijkbare uitkomstmaten. Dit zal een belangrijke bijdrage leveren voor de discussie over de effecten van HMMT assistentie.

Voor een optimale en betrouwbare berekening van de effecten van HEMS assistentie, is het efficiënt inzetten van het HMMT belangrijk. In **Hoofdstuk 3** wordt een systematisch overzicht gegeven van de HMMT inzetcriteria voor ernstig gewonde patiënten. Dit overzicht laat zien dat er slechts een beperkt aantal studies gedaan zijn naar de validiteit van de inzetcriteria. Bovendien zijn de resultaten van deze studies moeilijk algemeen toe te passen. Het HMMT inzetcriterium ' bewustzijnsverlies' is het meest veelbelovend criterium in de zin van accuratesse. Er is echter meer, goed methodologisch opgezet onderzoek nodig op dit gebied. De criteria gebaseerd op 'traumamechanisme' ontberen bijvoorbeeld de benodigde accuratesse, daarom zullen deze criteria onvermijdelijk leiden tot overtriage. Vergelijkbare inspanningen als beschreven in hoofdstuk 2 zullen verricht moeten worden om meer algemeen toepasbare resultaten te krijgen. De lokale en regionale autoriteiten zouden de HMMT inzetcriteria in een prospectief onderzoek moeten toetsen, en ernaar streven om de richtlijnen voor de inzet van het MMT op basis van deze resultaten aan te passen. Om dit te bereiken moet er gestreefd worden naar een volledige en betrouwbare nationale traumaregistratie. Dit moet gedeelde verantwoordelijkheid en verplichting worden van alle betrokken ketenpartners in (pre-)hospitale traumazorg.

Naast de effectiviteit en accuratesse van de HMMT inzetcriteria draagt ook de protocoladherentie van degenen die met de criteria werken bij aan de effectiviteit van het HMMT. **Hoofdstuk 4** verschaft inzicht in de daadwerkelijke inzetcijfers, en de protocoladherentie met betrekking tot de HMMT inzetcriteria door centralisten (primaire inzet) en ambulance-personeel (secundaire inzet) in de Rotterdamse regio. Deze studie laat zien dat het gebruikt van het HMMT in de regio Zuidwest Nederland ten tijde van het onderzoek nog verre van optimaal was. Aan de andere kant zou een volledige protocoladherentie leiden tot een sterke overtriage met daarbij een verzevenvoudiging van het aantal primaire HMMT inzetten. Om een optimaal gebruik van het HMMT te bereiken is het noodzakelijk om ook met centralisten en ambulance personeel kennis uit te wisselen, trainingen voor hen te verzorgen, en gebruik te maken van gestandaardiseerde digitale documentatie systemen, waarin de motivatie van beslissingen dient te worden opgenomen. Verder onderzoek naar de oorzaken voor de niet optimale protocoladherentie is nodig. Buiten de uniforme daglicht periode was er in 14% van alle A1 ambulanceritten (hoge prioriteit) een indicatie voor het inzetten van een HMMT. Dit gegeven ondersteunt de noodzaak van de implementatie van een 24 uur per dag beschikbaar HMMT.

Naast een optimaal gebruik van de inzetcriteria is het ook belangrijk om inzicht te krijgen in de invloed van HMMT assistentie op de tijd die men ter plaatse (TTP) van het ongeval doorbrengt en op de uiteindelijke uitkomst van de assistentie. In **Hoofdstuk 5** wordt dit beschreven. HMMT assistentie resulteert in een geringe toename van de tijd die op de plaats van het ongeval gebruikt wordt. De meest voor de handliggende verklaring hiervoor is dat de HMMT-arts, op medische indicatie, extra therapeutische handelingen verricht op de plaats van het ongeval, die niet plaatsvinden wanneer door ambulancepersoneel alleen assistentie wordt gegeven. Een toename van de TTP met 10 minuten gaat gepaard met een hogere ongecorrigeerde kans op overlijden. Echter, na correctie voor letselernst en andere patiëntenkarakteristieken had de langere TTP geen invloed op mortaliteit (gecorrigeerde OR 1.0; $p = 0.9$).

Hoofdstuk 6 geeft inzicht in het (tijd) management en de interventies van de initiële (pre-)hospitale trauma zorg. HMMT assistentie verbruikt gemiddeld 83% van het eerste uur (het Golden hour) na een ongeval. Zoals verwacht, is met name het aantal interventies (medische handelingen) bepalend voor de tijd die prehospitaal verbruikt wordt. Bij HMMT assistentie, in vergelijking met enkel ambulancezorg, kwamen meer prehospitale interventies voor. Het aantal intrahospitale interventies in het HMMT patiëntengroep was lagers maar dit heeft niet geleid tot een intrahospitale tijdswinst. Dit betekent dat de door HMMT arts prehospitaal uitgevoerde medische handelingen niet geleid hebben tot een intrahospitale tijdswinst. Dit is een belangrijk gegeven met betrekking tot tijdsintervallen ter plaatse en kan gebruikt worden als een basis in onderzoek naar de consequenties van interventies en (tijd) management op overleving van ernstig gewonde patiënten.

In de discussie over de behoefte aan HMMT assistentie bij ernstige ongevallen in Nederland, staat de toegevoegde waarde van de therapeutische handelingen van het HMMT op de plaats van het ongeval al enige jaren ter discussie. Daarom werd in **Hoofdstuk 7** één van de behandelingsmogelijkheden van het HMMT, namelijk thoraxdrainage nader onderzocht en de resultaten geanalyseerd. Er werd aangetoond dat prehospitale thoraxdrainage uitgevoerd door de HMMT-arts een veilige levensreddende procedure is met toegevoegde waarde in de prehospitale traumazorg voor patiënten met een letsel van de thorax. Het percentage thoracale infecties dat optrad na prehospitaal uitgevoerde thoraxdrainages, verschilt niet van het aantal infecties bij thoraxdrainage uitgevoerd op de spoedeisende hulp.

Door financiële restricties en Nederlandse wetgeving werd de inzetperiode van het HMMT, tot zeer recent beperkt tot de Uniforme Daglicht Periode, maximaal van 7.00 uur tot 19.00 uur. De pilotstudie in **Hoofdstuk 8** toont aan dat er ook gedurende nachtelijke uren behoefte is aan gespecialiseerde medische zorg als aanvulling op de ambulance hulpverlening. De grootste behoefte aan deze zorg bestaat tussen 19.00 en middernacht. De kwalitatieve behoefte is vergelijkbaar met de behoefte aan zorg overdag. Voor wat betreft de kwantitatieve behoefte werd op basis van deze pilotstudie en in combinatie met landelijke gegevens van zorgbehoefte overdag, een landelijke nachtelijke HMMT behoefteraming gemaakt. Op grond van deze gegevens bestaat er jaarlijks in Nederland een landelijke vraag naar tenminste 502 HMMT assistenties per jaar, tussen 19.00 uur tot 7.00 uur. In deze berekening zijn geannuleerde inzetten buiten beschouwing gelaten.

In **Hoofdstuk 9** werden de effecten van HMMT assistentie op de overleving van ernstig gewonde patiënten (ISS>15) geëvalueerd. Patiënten waarbij ook HMMT assistentie verleend werd waren ernstiger gewond en hadden meer verstoorde vitale parameters dan de controle groep patiënten met alleen de gebruikelijke ambulance hulpverlening. Ondanks de verschillen in patiëntenkarakteristieken wordt in deze studie aangetoond dat er een verband bestaat tussen de behandeling door een HMMT en overleving van ongevalslachtoffers. De ongecorrigeerde mortaliteit in de ambulancegroep was 24.3% versus 34.0% in de HMMT-groep. Na correctie voor verstorende factoren (confounding factors) is er sprake van een omkering van de odds ratio (OR) voor overleving, in het voordeel van de HMMT-groep. Er werd een gecorrigeerde OR berekend voor overleving van 2.2 in het voordeel van de slachtoffers die aanvullende HMMT assistentie hadden gehad. Deze OR voor overleving liep op tot 2.8 in de subgroep van patiënten met uitsluitend stomp trauma.

De effectiviteit van het HMMT houdt meer in dan alleen het verbeteren van overlevingskansen als uitkomstmaat. Daarom werden ook de effecten van HMMT op de kwaliteit van leven bestudeerd. In het onderzoek beschreven in **Hoofdstuk 10** werd aangetoond dat de kwaliteit van leven van ernstige gewonde patiënten één jaar na het trauma nog niet genormaliseerd is. De prevalentie van specifieke beperkingen in deze populatie is zeer hoog (40-70%) en verschilt niet tussen de HMMT en ambulance populatie. Eén jaar na het trauma bleek de gezondheidsgerelateerde kwaliteit van leven meer verband te houden met persoonlijke factoren, zoals comorbiditeit en het vrouwelijke geslacht, dan met het type (HMMT versus ambulance) van ontvangen prehospitale zorg, ook wanneer gecorrigeerd werd voor letselernst en verstorende factoren.

In **Hoofdstuk 11** is een kosteneffectiviteitanalyse beschreven. De kosten die gepaard gaan met HMMT inzetten, overleving en kwaliteit van leven werden gecombineerd in een kosteneffectiviteitanalyse. HMMT assistentie is kosteneffectief bij het redden van levens van de matig tot ernstig gewonde patiënten. De patiënten die HMMT assistentie kregen waren gemiddeld ernstiger gewond dan patiënten enkel ambulance assistentie ontvingen. De kosten voor HMMT assistentie werden berekend op €28.537 per Quality Adjusted Life Year (QALY). De incrementele kosten voor intramurale zorg waren €4.700 hoger in de HMMT populatie vergeleken met de ambulance populatie. Deze hogere kosten werden voornamelijk veroorzaakt door de kosten voor een opname op intensive care afdelingen en de kosten van diagnostiek. De kosten voor het HMMT per QALY in Nederland overschreden de acceptatiegrens niet. Op grond van deze gegevens kan gesteld worden dat de HMMT-zorg kosteneffectief is.

Maatschappelijke voorkeuren kunnen een belangrijke rol spelen in de besluitvorming omtrent de uitbreiding naar nachtelijk beschikbaar HMMT. Daarom moeten in dergelijke besluitvorming de mening van het grote publiek met betrekking tot zowel de positieve effecten (geredde levens) als de negatieve consequenties (geluidsoverlast en kosten) van de uitbreiding van HMT beschikbaarheid HMMT worden meegenomen. In **Hoofdstuk 12** wordt een "Willingness to Pay" studie beschreven. De resultaten van deze studie toonden aan dat het maatschappelijk draagvlak voor de uitbreiding van HMMT beschikbaarheid groot is. Dit ondanks de toename van vluchten en de daarmee samenhangende geluidsoverlast. De Willingness to Pay berekent uit de resultaten van deze studie overtreft ruim het bedrag van de €1.5 miljoen per jaar dat nodig is per HMMT locatie voor de uitbreiding naar een landelijk 24 uur per dag paraat HMMT. Ondervraagden in een representatieve steekproefpopulatie waren bereid te betalen voor extra geredde levens door het HMMT ondanks een toename van het aantal vluchten en daarmee samenhangende toename van geluidsoverlast. Deze resultaten kunnen gebruikt worden in het besluitvormingsproces voor een uitbreiding naar een landelijk, 24 uur per dag beschikbaar HMMT. Inmiddels heeft het ministerie van Volksgezondheid, Welzijn en Sport de uitbreiding naar een landelijk 24 uur per dag beschikbaar Helikopter Mobiel Medisch Team toegekend.

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12. Varin D, Ringburg AN, van Lieshout EMM, Patka P, Schipper IB. Accuracy of Conventional Imaging of Penetrating Torso Injuries in the Trauma Resuscitation Room. Eur J Emerg Med, In Press, 2009.

PHD PORTFOLIO SUMMARY

Summary of PhD training and teaching activities

Name PhD student: A.N. Ringburg — PhD period: 2004-2009

Erasmus MC Department: Trauma Surgery — Promotor: Prof.dr. P. Patka, Prof.dr. I.B. Schipper

PhD training	Year	Workload (Hours/ECTS)
Research skills		
Statistics	2004	1 ECTS
In-depth courses (e.g. Research school, Medical Training)		
Medical training	2004	2 ECTS
Medical training	2008	1 ECTS
Presentations		
International conferences	2004	2 ECTS
National conferences	2004	0.6 ECTS
International conferences	2005	2 ECTS
National conferences	2005	0.6 ECTS
National conferences	2006	1.2 ECTS
International conferences	2007	2.0 ECTS
International conferences	2008	2.0 ECTS
National conferences	2008	1.2 ECTS
Conferences		
International conferences	2004	1 ECTS
National conferences	2004	1 ECTS
International conferences	2005	1 ECTS
National conferences	2005	0.6 ECTS
National conferences	2006	1 ECTS
International conferences	2007	1 ECTS
National conferences	2007	0.6 ECTS
International conferences	2008	1 ECTS
National conferences	2008	0.6 ECTS
Didactic skills		
Supervision student graduation projects	2005	1 ECTS
Supervision student graduation projects	2006	3 ECTS
Supervision student graduation projects	2007	2 ECTS
Supervision student graduation projects	2008	1 ECTS

DANKWOORD

Het promoveren is een apart instituut. Zo schreef Madeleine Albright in haar memoires: "Niemand vindt het echt leuk om een dissertatie te schrijven. Zelfs hoogleraren die andere boeken geschreven hebben kijken met afschuw op die ervaring terug. Het weerhoudt hen er echter niet van om hun studenten aan dezelfde verschrikkingen te onderwerpen. Je werk is het hoogtepunt van jaren strijd, waar je je hele ego in legt; je wordt beoordeeld door mensen die ook weer beoordeeld worden door hun collega's over hoe streng ze voor hun studenten zijn." Het is wel duidelijk dat Madeleine Albright niet gepromoveerd is op een chirurgische afdeling. Hoewel het hierboven beschreven wel enigszins herkenbaar is vergeet zij de mooie kanten van onderzoek doen te vermelden, namelijk vrijheid, vrijheid en vrijheid.

Promoveren kan je niet alleen. Zonder de steun van de mensen om me heen hadden mijn inspanningen nooit kunnen resulteren in het voor u liggende proefschrift. Daarom wil ik een ieder die bijgedragen heeft aan dit proefschrift bedanken en sommige mensen in het bijzonder.

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