Survival Benefit of Physician-staffed Helicopter Emergency Medical Services (HEMS) Assistance for Severely Injured Patients

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ETHICS APPROVAL

The study was exempted by the local Medical Research Ethics Committee Erasmus MC (No. MEC-2005-073).

ABSTRACT

Background: Physician-staffed Helicopter Emergency Medical Services (HEMS) provide specialist medical care to the accident scene and aim to improve survival of severely injured patients. Previous studies were often underpowered and showed heterogeneous results, leaving the subject at debate. The aim of this retrospective, adequately powered, observational study was to determine the effect of physician-staffed HEMS assistance on survival of severely injured patients.

Methods: All consecutive severely injured trauma patients (ISS >15) between October 1, 2000 and February 28, 2013 were included. Assistance of physician-staffed HEMS was compared to assistance from the ambulance paramedic crew (*i.e.*, EMS group) only. A regression model was constructed for calculating the expected survival and survival benefit.

Results: A total of 3,543 polytraumatized patients with an ISS >15 were treated at the Emergency Department, of whom 2,176 patients remained for analysis; 1,495 (69%) were treated by EMS only and 681 (31%) patients received additional pre-hospital care of HEMS. The model with the best fit and diagnostic properties (H-L coefficient 2.959, p=0.937; AUC 0.888; PPV 71.4%; NPV 88.0%) calculated that 36 additional patients survived because of HEMS assistance. This resulted in an average of 5.33 additional lives saved per 100 HEMS dispatches for severely injured patients.

Conclusion: The present study indicates an additional 5.33 lives saved per 100 dispatches of the physician-staffed HEMS. Given the excellent statistical power of this study (>90%), physician-staffed HEMS is confirmed to be an evidence-based valuable addition to the EMS systems in saving lives of severely injured patients.

INTRODUCTION

Trauma remains among the top leading causes of death before the age of 40 worldwide [1]. In the Netherlands, it is the leading cause of death between the age twenty and forty years [2]. Gaining insight into the efficacy of pre-hospital trauma care during the "golden hour" is a crucial step before optimizing the prognosis of polytraumatized patients. During the last twenty-five years several studies have been performed aiming to assess the effects of the implementation of Helicopter Emergency Medical Services (HEMS) [3-15]. The majority of these studies showed a possible beneficial effect of HEMS on survival for specific groups of injured patients [3, 5, 7, 8, 10, 11, 13-15]. Other studies, on the other hand, did not find a beneficial effect [4, 6]. Differences in HEMS team composition, HEMS dispatch protocols, methodology, and outcome measures hamper a comparison between the published studies. It is crucial in the discussion of HEMS efficacy to differentiate between HEMS as a transport modality (with added crew expertise) versus bringing a physician to the accident scene by HEMS as is done in The Netherlands. Data regarding the effect of physician assistance at the scene of an accident, is limited [16].

In 1996, Oppe *et al.* [17] performed a study in order to assess the effects of a physician-staffed HEMS on survival and quality of life for severely injured patients in the Netherlands. Their results showed a beneficial effect of physician-staffed HEMS on survival, and resulted in the nationwide implementation of HEMS in the Netherlands in 1997.

In the Netherlands, the HEMS team consists of a board-certified trauma surgeon or anesthesiologist, a specialized nurse, and a helicopter pilot. If the accident scene is not accessible by helicopter, the HEMS team travels by a specially designed ground vehicle as a so-called ground mobile medical team. The aim of the helicopter service is to transport the advanced care team to the accident scene in order to provide additional specialized medical care on scene. HEMS act in close collaboration with Emergency Medical Services (EMS), but do not replace EMS. The EMS units are staffed with paramedics, all of which are trained in prehospital trauma life support (PHTLS). EMS paramedics are not allowed to perform all Advanced Trauma Life Support (ATLS) procedures; for instance, they are not allowed to use general anesthesia for intubation or to insert a chest tube. With the introduction of physician-staffed HEMS the scope of pre-hospital treatment modalities is extended, since the physicians are trained to perform life-saving ATLS procedures ranging from advanced airway management including the surgical airway and chest tube insertion, up to amputation of an entrapped limb and even emergency thoracotomy for resuscitation purposes. Most patients are transported from the accident scene to the hospital by ambulance, accompanied by the HEMS physician. Only in restricted cases, patients are transported by helicopter.

The HEMS team can be dispatched based upon the information given during the distress call (primary dispatch). It can also be requested by the ambulance team upon assessment of the patient at the accident scene, as a secondary dispatch. Table 1 shows the primary and secondary dispatch criteria for HEMS in the Netherlands.

In 2004, Frankema *et al*. [3] studied the effect of a physician staffed HEMS on survival of trauma patients in a regional setting. This study, which involved a consecutive cohort of 346 severely injured patients, revealed that HEMS assistance resulted in an increased probability of survival for severely injured patients, especially for those suffering from blunt trauma (OR 2.8; 95% CI 1.07 to 7.52). However, due to an inadequate post-hoc power of 51% the issue remained in doubt.

In order to draw more reliable conclusions, the present study was performed as a continuation of the study conducted by Frankema *et al.* [3], with a longer inclusion period and subsequently a larger cohort size. The aim of the present study was to determine the effect of physician-staffed HEMS assistance (in combination with EMS assistance) versus paramedic-staffed EMS assistance alone on survival of severely injured patients.

PATIENTS AND METHODS

The study was performed at a level 1 Trauma Center serving a region with 4.9 million inhabitants. All consecutive severely injured trauma patients (Injury Severity Score (ISS) >15) presenting at the Emergency Department between October 1, 2000 and February 28, 2013 were included. Data for the current study supplemented the database of Frankema *et al*. [3]. Injuries were coded according to the Abbreviated Injury Score (AIS-98) [18]. Injury-related mortality was defined as death within 30 days after admission. Patients aged younger than 15 years at the time of admission, patients transferred from other hospitals, and patients who presented to the Emergency Department on their own initiative were excluded. Patients not suffering from either blunt or penetrating injuries, such as victims of drowning accidents, strangulation, electrocution, and inhalation injury were also excluded.

Based upon the type of pre-hospital trauma care the patients had received, the study population was divided into two groups: patients who had received assistance from the ambulance paramedic crew only (EMS group) and those who had received additional care from the physician-staffed Helicopter Emergency Medical Services at the accident scene or during transport to the hospital (HEMS group). Patients who had received additional care from a ground mobile medical team were also included in the HEMS group since they had received the same type and level of expert treatment.

Data regarding age, gender, mechanism of injury, means of transportation, Revised Trauma Score (RTS) [19], Glasgow Coma Score (GCS), ISS, vital signs, and mortality data were obtained from the National Trauma Registry.

The most commonly applied method for calculating the probability of survival of trauma patients is the Trauma Injury Severity Score (TRISS) methodology [19]. In this methodology, the coefficients of the regression model were calculated from Major Trauma Outcome Study (MTOS) population, a large North-American trauma population [20].

The TRISS methodology is only valid if the distribution of injury severity of the population under study equals that of the MTOS population. An estimate of this match between two populations is expressed by the M-statistic, which should be 0.88 or higher [21]. For calculation of the M-statistic, the revised coefficients of the National Trauma Data Bank for the TRISS methodology were used [22]. The M-statistic in the current study population was 0.542; therefore the TRISS methodology was not used to compensate for cofounders. Instead, a custom-fitted binary logistic regression model was constructed in order to reliably calculate the probability of survival in the current study population based on the most accurate coefficients.

For this regression model the correlation with survival was calculated for all available variables that could be related to survival, such as age, gender, trauma mechanism, ISS, the individual components of the RTS, and the study group (EMS group versus HEMS group). The RTS was determined from the GCS (RTS1), systolic blood pressure (RTS2), and the respiratory rate (RTS3) of which individual scores are grouped onto a five point scale, using data as documented upon arrival at the Emergency Department. For intubated patients, the GCS was 3. In addition the weighted RTS was calculated (wRTS=0.9368*RTS1 + 0.7326*RTS2 + 0.2908*RTS3). For correlation of non-parametric continuous variables and ordinal variable with survival, the Spearman Rank Correlation coefficient was calculated. For all dichotomous variables the phi-coefficient was determined from 2x2 tables in order to detect differences between the two groups. All variables with a p-value less than 0.05 were included in the model. The variable "study group (*i.e.*, HEMS or EMS)" was introduced into the model in order to differentiate between EMS group and HEMS group. This allows for a quantification of the effect of HEMS on survival.

Combinations of variables were systematically entered into a multivariable binary logistic regression model in order to identify the model with the best fit and discriminative ability. The goodness of fit of the models was determined using the Hosmer-Lemeshow statistic. The discriminative ability of the models was determined using the Area Under the Receiver Operating Characteristic (ROC) curve (AUC). From the observed and expected deaths, the diagnostic characteristics positive and negative predictive value (PPV and NPV, respectively) were calculated. Models were only considered adequate if the sensitivity and specificity were above 50% and the PPV and NPV were above 70%.

The model with the best fit and discriminative ability was used for calculating the probability of survival. Subsequently, the model was used for calculating the expected survival if all patients were to have received EMS assistance only, without additional HEMS crew assistance. The difference between the observed survival and the expected survival without HEMS assistance was calculated as a measure of the survival benefit for HEMS, and is expressed as number of lives saved per 100 HEMS dispatches.

A sample size calculation was performed prior to the study. Assuming a mortality rate of 24.3% in the EMS group and 34.6% in the HEMS group and assuming that 31% of patients would be in the HEMS group as reported by Frankema *et al.* [3] a total sample size of 770 patients would be enough for reaching a power of 90%.

Statistical analyses were performed using the Statistical Package for the Social Sciences, version 21.0 (SPSS, SPSS Inc, Chicago, Ill, USA).

RESULTS

During the study period 3,543 polytraumatized patients with an ISS >15 were treated at the Emergency Department. Of these, 1,367 were excluded (358 referrals, 42 arrived at own initiative, 260 were <15 years old, 30 were drowning victims, and 677 had incomplete pre-hospital data). A total of 2,176 patients remained for analysis; 1,495 (69%) were treated by ambulance personnel alone (*i.e.*, EMS group) and 681 (31%) patients received additional pre-hospital care from the physician-staffed HEMS or a ground mobile medical team (*i.e.*, HEMS group.

The excluded group consisted of 677 patients, of which 424 received EMS assistance, and 267 received additional HEMS assistance. Gender and trauma mechanism were not statistically significantly different when comparing the 2,176 included patients with the 677 patients who were excluded based on incomplete data (data not shown). The median ISS was 25 in both groups (p=0.168). The excluded group, however, had a median age at trauma of 48 years (P_{25}-P_{75} 29-66) versus 44 years (P_{25}-P_{75} 27-61) in the included group (p<0.001).

Baseline characteristics and vital parameters of the HEMS and EMS groups are shown in Table 2. The majority of the patients were male (74%). The median age was 44 years and did not differ statistically significantly between the HEMS and the EMS group. The fraction of patients who had sustained blunt force trauma was higher in the HEMS group than in the EMS group (93% versus 90%; p=0.008). Patients in the HEMS group were more severely injured (ISS 26 versus 22; p<0.001) and had more disturbed vital parameters (lower GCS and RTS; p<0.001).

Univariate analysis showed a higher crude mortality rate in the HEMS group compared with the EMS group (27% versus 21%, p=0.001). In line with expectations and dispatch criteria, patients in the HEMS group were more severely injured and had higher mortality. In order to correct for this inherent bias on mortality and isolate the effect of HEMS on mortality, a multivariable logistic regression model was developed. Table 3 shows the correlation coefficients of the variables with mortality. The basic set of variables included: ISS, age, mechanism of injury and the type of pre-hospital assistance (*i.e.*, HEMS or EMS). Different combinations of variables were added to this basic set in order to identify the model with the best fit and discriminative power. From this set of different models the best one was selected based on the Hosmer-Lemeshow statistic and its p-value, the Area Under the ROC curve (AUC) and the positive and negative predictive values, as shown in Table 4.

Table 4 shows the top-5 models with the best fit. The model with the best fit (H-L coefficient2.959, p=0.937; AUC 0.888; PPV 71.4%, NPV 88.0%) contained the basic set supplemented with the GCS and RTS for systolic blood pressure (RTS_2). The GCS sum score resulted in a better predictive model than the individual components of the GCS, the RTS score, or the weighted RTS score.

The observed, unadjusted odds ratio was 0.698 (95% CI 0.566 to 0.861) for survival when HEMS assistance is provided. Using the model to compensate for confounders, the adjusted odds ratio for survival was 1.501 (95% CI 1.127 to 1.999). In the HEMS cohort 497 patients survived, while 461 patients were predicted to survive if HEMS had been absent according to the model. The additional survivals resulting from HEMS assistance were therefore 36 (497 minus 461). This results in an average of 5.33 additional lives saved per 100 HEMS dispatches for severely injured patients.

DISCUSSION

Although beneficial effects of HEMS dispatch on survival have previously been described [3, 5, 7, 8, 10, 11, 13-15], HEMS related survival still remains a topic of debate. By applying an adequate and custom-fitted regression model with a good discriminative power, the current study indicates that HEMS assistance resulted in a mortality reduction of 36 lives for this population of severely injured patients over the study period. Expressed as lives saved per 100 dispatches, HEMS assistance results in an average of 5.33 lives saved per 100 HEMS dispatches for severely injured patients.

In the literature, the number of lives saved per 100 HEMS dispatches has been reported to range from 1.1 to 19 [5, 13, 15, 23]. Because of the great variety in study design, geographical settings (rural versus urban), organization of the trauma systems, type of pre-hospital trauma care (physician, nurse, EMS, HEMS), study population (blunt versus penetrating trauma), and definition of mortality (*i.e*, in-hospital mortality or mortality in a specific time frame), it is difficult to compare our results with previously published international studies. The 5.33 additional lives saved as found in the current study is within the range of 3.3 to 5.4 lives saved per 100 HEMS dispatches as previously reported, in which physician-staffed HEMS was compared with nurse-staffed EMS dispatched for blunt and penetrating trauma in adults, excluding interhospital transport [3, 7, 11, 15].

De Jongh *et al.* [24] compared EMS with HEMS and compared findings by discriminating on the presence of severe traumatic brain injury (TBI). By creating a control group matched on ISS, age, and TBI the authors compared EMS versus additional HEMS assistance, but odds ratios indicating survival benefits for patients with TBI when HEMS were present were none significant. The absence of significant odds ratios may indicate difference in results, however an inadequate a priori power calculation may also be the case. Their study remains interesting, as it is one of the few studies conducted in the Netherlands.

Another Dutch study focusing on polytraumatized patients treated at a level 1 trauma center in the North-Western trauma region was able to report 5.4 lives saved per 100 HEMS dispatches [11]. Although the M-statistic was below the cut-off value, the TRISS methodology was applied. Survival benefits from HEMS assistance increased as the RTS measured on the scene fell from nine. Especially patients with RTS scores below three for respiratory rate and two for systolic blood pressure had higher survival chances if HEMS were present.

A previous study in the Netherlands by Frankema *et al.* [3] suggested beneficial effects of HEMS on chances of survival. This study, however, had inadequate statistical power and therefore likely introduced a type two error. The post-hoc power calculations for the current study, which was aimed at expanding the inclusion period used by Frankema *et al.*, showed an adequate power of 93%, which supports our conclusion that HEMS assistance results in a survival benefit of 5.33 lives per 100 dispatches for severely injured patients.

A similar study investigating the beneficial effects of physician staffed HEMS was performed by Andruszkow *et al.* [10]. In Germany, HEMS is also staffed with an experienced physician, which makes the study particularly comparable. The study included patients treated at level 1 and level 2 trauma centers and also included patients at the lower end of the Injury Severity Scale (ISS 9 or higher), therefore also considering non-polytraumatized patients. The subgroup analysis including solely patients admitted to the level 1 trauma center revealed a significantly lower observed mortality in the HEMS group than in the Ground Emergency Medical Services (GEMS), which is similar to the Dutch EMS. The authors reported no M-statistic; they applied the TRISS method and were able to report a significantly standardized lower mortality rate in the HEMS group (HEMS: 0.772 versus GEMS 0.864; p=0.045) [10].

The retrospective design of the current study may be considered as a limitation. Moreover, although we have attempted to control for the differences between groups with a regression analysis there is an obvious selection process in those patients that receive HEMS assistance. Despite the statistical methods used it is not possible to exclude the conclusion being due to the selection process rather than the treatment received. One could argue that the mathematical assumptions underlying regression analysis might introduce a bias, causing limited under- or overestimation of the effects of HEMS assistance on survival. Although such a bias cannot be ruled out completely, the final model in the present study had an excellent goodness of fit (*i.e.*, Hosmer and Lemeshow coefficients of 2.959 with a P-value of 0.937) as well as a good Area Under the Receiver Operating Curve (AUC 0.888) as well as adequate diagnostic properties (*i.e.*, PPV 71.4% and NPV 88.0%).

Directions for future research point towards the necessity of a nationwide HEMS registry in which data from all four Dutch HEMS teams are pooled and combined with the national trauma registry. Detailed and complete information regarding on-scene time, as well as specific pre-hospital treatments and vital parameters are crucial. This will benefit the attribution of survival benefit to the different aspects of physician-staffed HEMS, *i.e.*, specific treatments and skills employed by the physician, and differences in on-scene time and transportation time.

CONCLUSIONS

The present study indicates an additional 5.33 lives saved per 100 dispatches of the physician-staffed HEMS in The Netherlands. This result is in line with results from a previous research. Given the excellent statistical power of the current study (>90%), physician-staffed HEMS is confirmed to be an evidence-based valuable addition to the EMS systems in saving lives of severely injured patients.

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Table 1. HEMS Dispatch criteria in the Netherlands

<u>Primary dispatch criteria, based on mechanism of injury</u>

1. High-energy trauma, motorcycle, scooter with an estimated speed of >30 km/h or a car with an estimated speed of >50 km/h
2. Collision of a pedestrian >30 km/h or thrown over a distance
3. Frontal collision on hardened roads outside urban area
4. Accident with a train, plane
5. Fall from height >6 meter
6. Lengthy extrication and significant injury
7. Patient's head of chest covered with debris
8. Electricity or lightning accident
9. (Near) Drowning/severe hypothermia <32ºC
10. Multiple casualty (>4) incidents
11. Multiple casualty incidents, with 1 fatality
12. Patient ejected from vehicle
13. Explosion
14. Exposure to hazardous materials
15. Fire in confined space
16. Burns covering 15% of TBSA or covering 10% of TBSA in combination with other injuries
17. Near drowning or diving accidents

<u>Secondary dispatch criteria, based on patient's vital signs</u>

18. Low (<10/min) or high (>30/min) respiratory rate or other signs of respiratory distress
19. Injury to the chest with a saturation <96%, despite O2
20. Shock: Systolic Blood pressure < 95 mmHg or pulse >120/minute
21. Revised Trauma Score <11
22. Estimated blood loss >1 liter
23. Comatose, Glasgow Coma Score < 9
24. Signs of paralysis or paresthesia

<u>Primary and secondary dispatch criteria, based on specific injuries</u>

25. Penetrating injury to head, neck, or trunk
26. (High-energy trauma with) spinal, pelvic or femur fracture
27. Open fractures to extremities/amputations

HEMS, Helicopter Emergency Medical Services; TBSA, Total Body Surface Area

Table 2. Characteristics and vital parameters of the study population divided by HEMS and EMS assistance

	Overall (N=2,176)	HEMS (N=681)	EMS (N=1,495)	P-value
Male[1]	1,610 (74)	528 (78)	1,082 (72)	0.011[a]
Age (years)[2]	44 (27-61)	43 (27-59)	44 (27-62)	0.231[b]
Age > 55 years[1]	715 (33)	217 (32)	498 (33)	0.523[a]
Blunt trauma[1]	1,972 (91)	634 (93)	1338 (90)	0.007[a]
ISS[2]	25 (18-30)	26 (22-35)	22 (17-29)	<0.001[b]
ISS Group[1]				
16-24	1034 (48)	238 (35)	796 (53)	<0.001[a]
25-49	1027 (47)	383 (56)	644 (43)	
50-74	100 (5)	52 (8)	48 (3)	
≥ 75	15 (1)	8 (1)	7 (1)	
Mortality[1]	491 (23)	184 (27)	307 (21)	0.001[a]
GCS[2]	13 (3-15)	8 (3-15)	14 (7-15)	<0.001[b]
Eye[2]	3 (1-4)	1 (1-4)	4 (1-4)	<0.001[b]
Motor[2]	6 (1-6)	4 (1-6)	6 (4-6)	<0.001[b]
Verbal[2]	4 (1-5)	1 (1-5)	4 (1-5)	<0.001[b]
SBP (mmHg)[2]	135 (116-159)	131 (112-155)	137 (119-160)	0.002[b]
RR (breaths/min)[2]	18 (14-21)	16 (14-20)	18 (15-22)	<0.001[b]
RTS[2]	11 (8-12)	10 (8-12)	12 (9-12)	<0.001[b]
RTS_1 (GCS)[2]	4 (0-4)	2 (0-4)	4 (2-4)	<0.001[b]
RTS_2 (SBP)[2]	4 (4-4)	4 (4-4)	4 (4-4)	0.026[b]
RTS_3 (RR)[2]	4 (4-4)	4 (4-4)	4 (4-4)	0.313[b]

Data are shown as [1]number of patients with percentages, or as [2]median with P_{25}-P_{75}.
Statistical significance of difference between the HEMS and EMS group was tested using [a]Chi squared analysis of [b]Mann Whitney U-test.
ISS, Injury Severity Scale; SBP, Systolic Blood Pressure; RR, respiratory rate; GCS, Glasgow Coma Score; Eye/Motor/Verbal, individual components of GCS; RTS, Revised Trauma Score; RTS_1, code for Glasgow Coma Score; RTS_2, code for blood pressure; RTS_3, code for respiratory rate.

Table 3. Correlation of variables with mortality

	Correlation Coefficient	P-value
Male[1]	0.006	0.789[a]
Age (years)[2]	0.158	<0.001[b]
Age > 55 (years)[1]	0.177	<0.001[a]
Blunt trauma[1]	0.011	0.601[a]
ISS[2]	0.302	<0.001[b]
ISS Group[2]	0.369	<0.001[b]
GCS[2]	-0.474	<0.001[b]
Eye[2]	-0.449	<0.001[b]
Motor[2]	-0.483	<0.001[b]
Verbal[2]	-0.460	<0.001[b]
SBP (mmHg)[2]	-0.092	<0.001[b]
RR (breaths/min)[2]	-0.202	<0.001[b]
RTS[2]	-0.484	<0.001[b]
RTS_1 (GCS)[2]	-0.483	<0.001[b]
RTS_2 (SBP)[2]	-0.287	<0.001[b]
RTS_3 (RR)[2]	-0.140	<0.001[b]

Data are shown as correlation with mortality. Correlation with [1]nominal variables is calculated with the [a]Phi-Coefficient (Pearson correlation). Correlation with [2]ordinal variables is calculated with the [b]Spearman rank correlation.

ISS, Injury Severity Scale; SBP, Systolic Blood Pressure; RR, respiratory rate; GCS, Glasgow Coma Score; Eye/Motor/Verbal, individual components of GCS; RTS, Revised Trauma Score; RTS_1, code for Glasgow Coma Score; RTS_2, code for blood pressure; RTS_3, code for respiratory rate.

Table 4. Goodness-of-fit and discriminative ability of the different combinations of variables entered into a custom-fitted binary logistic regression model

Variables included in the model	N	H-L coefficient	H-L p-value	AUC	PPV	NPV
Basic + GCS + RTS_2	**2,176**	**2.959**	**0.937**	**0.888**	**71.4**	**88.0**
Basic + GCS + RTS_3	2,176	2.522	0.961	0.883	68.8	88.1
Basic + GCS + RTS_2 + RTS_3	2,176	3.070	0.930	0.890	70.8	87.9
Basic + E + M + V + RTS_2	2,176	3.249	0.918	0.888	71.6	88.0
Basic + E + M + V + RTS_3	2,176	2.773	0.948	0.884	68.5	88.0

The basic set of variables contained ISS (as category), age (numeric), mechanism of injury (*i.e.*, blunt or penetrating), type of pre-hospital care (*i.e.*, EMS or HEMS). The goodness of fit was determined using the Hosmer-Lemeshow statistic (H-L), and the discriminative ability was determined by the Area Under the receiver operating Curve (AUC). The positive predictive value (PPV) and negative predictive value (NPV) were calculated. The model with the best fit indicated in bold contained the basic set of variables with the GCS score and the RTS_2 score.

Figure 1. Study population by treatment