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Original Research

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

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A B S T R A C T

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

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

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

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

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

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

The Netherlands has a population of over 17 million people and covers an area of 41,543 km^2. Prehospital medical care is primarily

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

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

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

Patients and Methods

Setting and Population

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

Data Collection

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

Statistical Analysis

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

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

The TRISS methodology is only valid if the distribution of injury severity of the population under study equals that of the Major Trauma Outcome Study population. This is the case if the M statistic is 0.88 or higher.[17] For calculation of the M statistic, the revised coefficients of the National Trauma Data Bank for the TRISS methodology were used.[18] The M statistic in the current study population was 0.678, which shows that the TRISS methodology does not adequately compensate for confounders in the current population. Therefore, a custom-fitted binary logistic regression model was constructed in order to reliably calculate the probability of survival in the current study population based on the most accurate coefficients. A detailed procedure has been published previously.[6] First, correlation with survival was calculated for each variable. A Spearman rank correlation coefficient was calculated for nonnormal continuous variables and ordinal variables; a phi coefficient was determined for dichotomous variables. Variables with a *P* value <.05 were tested in the multivariable model.

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

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

Results

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

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

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

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

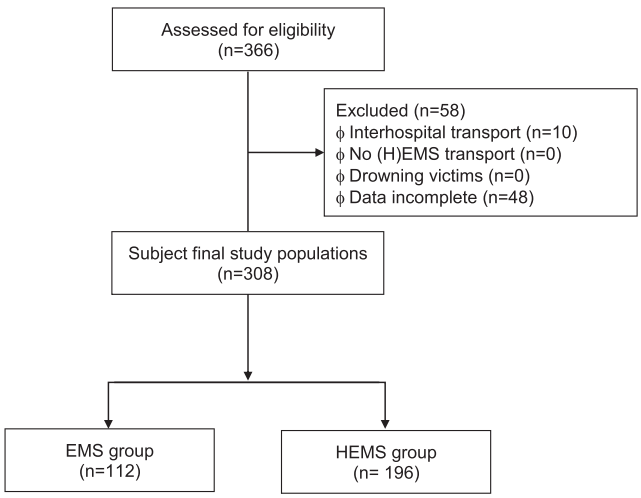

Figure 1. Study population by treatment.

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

Discussion

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

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

To the best of our knowledge, in the pediatric population, only 5 studies on HEMS and pediatric trauma exist. Three studies focus on mode of transport only.[7,8,11] In these studies, pediatric trauma patients transported by HEMS directly to a level 1 trauma center for children might save 1 life for every additional 41 to 47 children undergoing HEMS transport instead of ground EMS transport (2.1-2.4 lives saved per 100 HEMS dispatches in pediatric trauma). It is difficult to identify if HEMS has added (medical) value[10] in the pediatric trauma population or improves survival. By applying an adequate and custom-fitted regression model with a good discriminative power, the current study suggests that physician-based HEMS assistance resulted in a mortality reduction up to 2.5 lives per 100 physician-based HEMS dispatches for severely injured pediatric patients. This is just lower than the published data in adults showing 2.8 to 19 lives saved per 100 patients treated.[3-6] In a previous study,[6] it was shown that dispatch of the same physician-based HEMS, as investigated in the current study, resulted in an additional 5.3 lives saved per 100 dispatches for adult trauma patients. However, a reduction in mortality of 2.5 lives per 100 physician-based HEMS dispatches is at the upper range of the published data for pediatric trauma (2.1-2.4 lives per 100 physician-based HEMS dispatches[7,8]).

Only 4% of all patients in EMS are pediatric patients,[19] whereas in physician-based HEMS, 21% of all patients are pediatric patients. Despite the fact that pediatric patients treated by physician-based HEMS are more critically ill or more severely injured than the EMS population, the survival rate is higher. Others found a similar beneficial effect and

Table 1
Characteristics and Vital Parameters of the Study Population Divided by Helicopter Emergency Medical Services (HEMS) and Emergency Medical Services (EMS) Assistance

	Overall (N = 308)	HEMS (N = 196)	EMS (N = 112)	*P* Value
Male, n (%)	207 (67.2)	125 (63.8)	82 (73.2)	.102[a]
Age (years)	13 (7-16)	12 (7-16)	13 (8-16)	.218[c]
Blunt trauma, n (%)	285 (92.5)	184 (93.9)	101 (90.2)	.263[a]
ISS	24 (17-29)	25 (18-34)	19 (17-26)	<.001[c]
ISS group, n (%)				
16-24	162 (52.6)	85 (43.4)	77 (68.8)	<.001[b]
25-49	128 (41.6)	96 (49.0)	32 (28.6)	
50-74	15 (4.9)	12 (6.1)	3 (2.7)	
≥ 75	3 (1.0)	3 (1.5)	0 (0.0)	
GCS	8 (3-14)	4 (3-12)	12 (8-15)	<.001[c]
Eye, n (%)				
No eye opening	157 (51.0)	127 (64.8)	30 (26.8)	<.001[b]
Eye opening to pain	20 (6.5)	9 (4.6)	11 (9.8)	
Eye opening to verbal command	49 (15.9)	23 (11.7)	26 (23.2)	
Eyes open spontaneously	82 (26.6)	37 (18.9)	45 (40.2)	
Motor, n (%)				
No motor response	107 (34.7)	94(48.0)	13 (11.6)	<.001[b]
Extension to pain	9 (2.9)	7 (3.6)	2 (1.8)	
Flexion to pain	15 (4.9)	11 (4.6)	4 (3.6)	
Withdrawal from pain	14 (4.5)	4 (2.0)	10 (8.9)	
Localizing pain	53 (17.2)	27 (13.8)	26 (23.2)	
Obeys commands	110 (35.7)	53 (27.0)	57 (50.9)	
Verbal, n (%)				
No verbal response	149 (48.4)	125 (63.8)	24 (21.4)	<.001[b]
Incomprehensible sounds	33 (10.7)	17 (8.7)	16 (14.3)	
Inappropriate words	17 (5.5)	6 (3.1)	11 (9.8)	
Confused	24 (7.8)	8 (4.1)	16 (14.3)	
Orientated	85 (27.6)	40 (20.4)	45 (40.2)	
SBP (mm Hg)	125 (110-141)	123 (105-140)	130 (114-148)	.021[c]
RR (breaths/min)	18 (15-24)	18 (15-24)	20 (15-25)	.260[c]
RTS1 (GCS), n (%)				
GCS = 3	105 (34.1)	92 (46.9)	13 (11.6)	<.001[b]
GCS 4-5	16 (5.2)	12 (6.1)	4 (3.6)	
GCS 6-8	42 (13.6)	28 (14.3)	14 (12.5)	
GCS 9-12	43 (14.0)	18 (9.2)	25 (22.3)	
GCS 13-15	102 (33.1)	46 (23.5)	56 (50.0)	
RTS2 (SBP), n (%)				
SBP < 50 mm Hg	12 (3.9)	9 (4.6)	3 (2.7)	.055[b]
SPB 50-89 mm Hg	25 (8.1)	21 (10.7)	4 (3.6)	
SBP ≥ 90 mm Hg	271 (88.0)	166 (84.7)	105 (93.8)	
RTS3 (RR), n (%)				
RR 0-5 breaths/min	14 (4.5)	8 (4.1)	6 (5.4)	.844[b]
RR 6-9 breaths/min	4 (1.3)	2 (1.0)	2 (1.8)	
RR 10-29 breaths/min	253 (82.1)	161 (82.1)	92 (82.1)	
RR ≥ 30 breaths/min	37 (12.0)	25 (12.8)	12 (10.7)	
Heart rate (HR), n (%)				
HR 0 beats/min	10 (3.2)	6 (3.1)	4 (3.6)	.709[b]
HR 1-60 beats/min	10 (3.2)	8 (4.1)	2 (1.8)	
HR 61-100 beats/min	132 (42.9)	80 (40.8)	52 (46.4)	
HR 101-140 beats/min	130 (42.2)	88 (43.9)	44 (39.3)	
HR ≥ 141 beats/min	26 (8.4)	16 (8.2)	10 (8.9)	
Mortality	64 (20.8)	52 (26.5)	12 (10.7)	.001[a]

GCS = Glasgow Coma Scale; HR = heart rate; ISS = Injury Severity Scale; RR, Respiratory Rate; RTS1 = categoric variable for Glasgow Coma Scale; RTS2 = categoric variable for blood pressure; RTS3 = categoric variable for respiratory rate; SBP = systolic blood pressure.
Data are shown as the number of patients with percentages or as the median with the 25th percentile-75th percentile. Eye/motor/verbal are individual components of GCS.
The statistical significance of the difference between the HEMS and EMS group was tested using the [a]Fisher exact test, [b]chi-square analysis, or [c]the Mann-Whitney *U* test.

explained this because HEMS performs Advanced Trauma Life Support on a higher standard than EMS and have much more pediatric experience.[20] EMS should call the physician-based HEMS in an early stage (if not primarily dispatched) when treating (severely) injured pediatric patients. Research in EMS states that Advanced Trauma Life Support skills rapidly deteriorate after training, indicating that frequent training and experience are needed to maintain these skills, which is quite challenging given the limited resources and competing needs for training.[21] Successful Advanced Trauma Life Support procedures and skills require training, skills, and ongoing experience to consistently perform these procedures in an effective, timely, and safe manner.[22]

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

The retrospective design of the current study may be considered a limitation. Also, only pediatric patients who reached the hospital are

Table 2
Correlation of Variables With Mortality

	Correlation Coefficient	*P* Value
Male[a]	0.001	.997[c]
Age (years)[b]	0.007	.905[d]
Blunt trauma[a]	0.068	.235[c]
ISS[b]	0.349	<.001[d]
ISS group[b]	0.412	<.001[d]
GCS[b]	−0.486	<.001[d]
Eye[b]	−0.407	<.001[d]
Motor[b]	−0.485	<.001[d]
Verbal[b]	−0.452	<.001[d]
SBP (mm Hg)[b]	−0.299	<.001[d]
RR (breaths/min)[b]	−0.154	.007[d]
RTS1 (GCS)[b]	−0.456	<.001[d]
RTS2 (SBP)[b]	−0.428	<.001[d]
RTS3 (RR)[b]	−0.150	.008[d]
HR (beats/min)[b]	−0.055	.340[d]

GCS = Glasgow Coma Scale; HR = heart rate; ISS = Injury Severity Scale; RR = respiratory rate; RTS1 = categoric variable for Glasgow Coma Scale; RTS2 = categoric variable for blood pressure; RTS3 = categoric variable for respiratory rate; SBP = systolic blood pressure.
Data are shown as correlation with mortality. [a]Nominal variables are calculated. [b]Ordinal variables are calculated. [c]Phi-Coefficient (Pearson correlation). [d]Spearman rank correlation.

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

Table 3
Goodness of Fit and Discriminative Ability of 5 Best Binary Logistic regression models

Variables included in the model	N	H-L Coefficient	H-L *P* Value	AUC	PPV (%)	NPV (%)
Basic + E + M + V + RTS2 + RTS3	**308**	**8.692**	**.346**	**0.904**	**71.4**	**92.2**
Basic + E + M + V + RTS2 + RR	308	6.646	.575	0.905	71.4	92.2
Basic + E + M + V + RTS2	308	9.953	.268	0.904	71.4	92.2
Basic + RTS1 + RTS2 + RR	308	7.296	.505	0.901	71.2	91.2
Basic + RTS1 + RTS2 + RTS3	308	7.714	.462	0.898	70.7	90.8

AUC = area under the receiver operating curve; E = eye score of Glasgow Coma Scale; H-L = Hosmer-Lemeshow; M = motor score of Glasgow Coma Score; NPV = negative predictive value; PPV = positive predictive value; RR = respiratory rate; RTS1 = categoric variable for Glasgow Coma Scale; RTS2 = categoric variable for blood pressure; RTS3 = categoric variable for respiratory rate; V = verbal score of Glasgow Coma Scale.
The basic set of variables contained Injury Severity Score (as category) and the type of prehospital care (ie, emergency medical services or helicopter emergency medical services). The goodness of fit was determined using the H-L statistic (H-L coefficient with *P* value), and the discriminative ability was determined by the AUC. The PPV and NPV were calculated. The model with the best fit, indicated in bold, contained the basic set of variables with the RTS1 and RTS2 score.

Conclusions

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

Supplementary materials

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

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