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Effect of time intervals in critical care provided by helicopter emergency medical services on 30-day survival after trauma

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ABSTRACT

Background: Trauma is the leading cause of death especially in children and young adults. Prehospital care following trauma emphasizes swift transport to a hospital following initial care. Previous studies have shown conflicting results regarding the effect of time on the survival following major trauma. In our study we investigated the effect of prehospital time-intervals on 30-day mortality on trauma patients that received prehospital critical care.

Methods: We performed a retrospective study on all trauma patients encountered by helicopter emergency medical services in Finland from 2012 to 2018. Patients discharge diagnoses were classed into (1) trauma without traumatic brain injury, (2) isolated traumatic brain injury and (3) trauma with traumatic brain injury. Emergency medical services response time, helicopter emergency medical services response time, on-scene time and transport time were used as time-intervals and age, Glasgow coma scale, hypotension, need for prehospital airway intervention and ICD-10 based Injury Severity Score were used as variables in logistic regression analysis.

Results: Mortality data was available for 4,803 trauma cases. The combined 30-day mortality was 12.1% (582/4,803). Patients with trauma without a traumatic brain injury had the lowest mortality, at 4.3% (111/2,605), whereas isolated traumatic brain injury had the highest, at 22.9% (435/1,903). Patients with both trauma and a traumatic brain injury had a mortality of 12.2% (36/295). Following adjustments, no association was observed between time intervals and 30-day mortality.

Discussion: Our study revealed no significant association between different timespans and mortality following severe trauma in general. Trends in odds ratios can be interpreted to favor more expedited care, however, no statistical significance was observed. As trauma forms a heterogenous patient group, specific subgroups might require different approaches regarding the prehospital timeframes.

Study type: prognostic/therapeutic/diagnostic test.

Introduction

Trauma remains one of the leading causes of death and disability worldwide and is the leading cause of death in children and young adults [1,2]. Prehospital patients suffering from trauma have been given special scrutiny by being in the "first hour quintet," with the other four emergencies being cardiac arrest, acute coronary syndrome, respiratory failure, and stroke [3]. All these conditions require critical care in specialized facilities. However, current trends in European and Australasian politics dictate a centralization of these tertiary care facilities [4], and this centralization might prolong the transport times of trauma patients from the scene of injury to definitive care [5].

The dogma of the "golden-hour" of trauma patients was minted during the Vietnam war, when studies showed a 2% reduction in mortality with expedited helicopter transport versus a five-hour transport through the jungle. Swift transport was also advocated in the 1970s when helicopter emergency units were deployed in Maryland, USA [6,7]. Nevertheless, more recent studies reporting

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prehospital response times have shown conflicting results. For example, a Cochrane review by Galvagno et al. in 2015 and a systematic review by Harmsen et al. in 2015 concluded that prehospital response time is not necessarily a factor contributing to mortality, except in hemodynamically unstable penetrating torso injuries and in traumatic brain injury (TBI) [5,8]. However, the authors regretted the heterogeneity of the included studies.

Studies evaluating prehospital physician involvement have shown either increases or indifferent results regarding the length of the on-scene time [9–11]. In this context, time may be confounding, since patients who are more severely injured might be treated longer at the scene [12]. In this respect, TBI is of special interest. Following the initial injury to the brain, the man focus is the prevention of secondary injury and minimizing the penumbra [13,14]. Guidelines recommend that patients suffering from a TBI should be transported to specialized centers for optimal treatment [13,14]. Expedited neurosurgical operative care is limited to expanding bleeds, while other emergencies are not time-critical to the same extent.

The non-surgical treatment of neurotrauma consists of controlled ventilation – aiming for normal oxygenation and normocarbia to mild hypocarbia - frequently requiring prehospital airway management. Optimization of the hemodynamics, administration of hypertonic solutions, and elevation of the upper torso are also standard of care [13,14]. In the prehospital setting, a physician-led team might be a contributing factor in the management of the aforementioned factors. The intervention by physician-led prehospital teams has previously been shown to decrease mortality in patients suffering from major trauma [15–18].

In the present study, we investigated the effect of prehospital time intervals on 30-day mortality following trauma requiring physician-led prehospital critical care. Our hypothesis was that a longer response time and a delay in Helicopter Emergency Medical Services (HEMS) are associated with increased mortality, whereas the on-scene time (OST) and transport time are not. We hypothesized that this would be particularly true among patients suffering from a TBI.

Methods

We performed a retrospective study on patients encountered by Finnish HEMS during 2012 to 2018. We assessed the association between the different prehospital time intervals and 30-day mortality in trauma patients receiving HEMS critical care. Prehospital data were obtained from the national HEMS database (FinnHEMS database [FHDB]) and mortality data were acquired from the national Population Register Center on 11 November 2019. The national hospital discharge register (HILMO) provided the hospital discharge ICD-10 diagnoses on 31 December 2018. Diagnosis specific survival probabilities were calculated from hospital diagnoses using an international pool for ICD-10 based Injury Severity Score (ICISS) [19]. HILMO, run by the Finnish Institute for Health and Welfare, collects data on the population's use of health services and hospital services, as well as discharge diagnoses. The Population Register centre in Finland collects data on Finnish citizens or foreign citizens residing in Finland on a permanent or temporary basis. The recorded data include age, sex, marital status, place of residence, and dates of birth and death.

The primary endpoint in the present study was the effect of different time intervals following trauma on 30-day mortality following HEMS critical care. Patients were followed until 30 days after the HEMS mission, until death, until emigration, or until 31 March 2019, whichever came first.

Study permission was granted by all the participating hospital districts (Oulu University Hospital 200/2019 2.7.2019, Helsinki University Hospital HUS/280/2019 9.7.2019, Turku University Hospital J30/19 4.8.2019, the Hospital District of Lapland 32/2019 22.8.2019, Kuopio University Hospital RPL 102/2019 22.8.2019, and Tampere University Hospital RTL-R19580 2.9.2019). The ethical board of Helsinki University approved the study (HUS/3115/2019 §194). We were also granted the use of mortality data by the Population Register Center (VRK/5613/2019–3 1.11.2019) and hospital data from the national hospital discharge register (21.2.2020 Dnro THL/2231/5.05.00/2019). The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement was followed in reporting the study. [20]

Setting

HEMS is a part of the nationally organized and funded Emergency Medical Services (EMS) in Finland. The HEMS units are physician-staffed units, except for the advanced-level paramedic staffed unit in Lapland, and they respond primarily to major disturbances in vital functions, such as out-of-hospital cardiac arrest, major trauma, and unconsciousness for different reasons. The specific characteristics of HEMS operations in Finland have recently been described elsewhere [21]. No major changes in response criteria were done during the study period. All HEMS units use the FHDB to report their missions. FHDB follows the international consensus guidelines for reporting physician led HEMS operations [22]. Previous studies have validated the data in the FHDB [23].

Participants

We included all patients encountered by HEMS and transported to a University Hospital with a discharge diagnosis in the HILMO of trauma (the included ICD-10 codes are provided in **Error! Reference source not found.**). Based on the ICD-10 diagnoses, trauma was further divided into (1) trauma without TBI, (2) isolated TBI, and (3) trauma with TBI.

Variables

We analyzed the following time intervals: EMS response time, HEMS response time, OST, and transport time to hospital. Response times were defined as the time from the emergency alarm to patient contact, while OST was defined as the time from patient contact by the HEMS team to the time of initiation of patient transport toward the hospital and transport time was defined as time of initiation of patient transport to arrival at the hospital. The time intervals are presented as continuous variables and analyzed in 15-minute increments for the logistic regression analyses. Logistic regression analysis took the following factors into account: age, initial Glasgow Coma Scale (GCS), initial hypotension (defined as a systolic blood pressure of <90 mmHg), and the need for prehospital airway intervention as well as ICISS [13]. Accuracy of time stamps, time point definitions and time interval definitions are well described in the international consensus guidelines for physician-staffed HEMS services. [22]

Statistical methods

We presented quantitative data as medians with their respective interquartile ranges (Q_1–Q_3). Categorial data were presented as numbers and percentages. Comparisons were calculated with the Chi-square, the Mann-Whitney U test, and the two-sample *t*-test, where applicable. We used a p-value of <0.05 as indicating evidence against the null hypothesis. A multivariable logistic regression analysis was used to describe the effects on 30-day mortality. We used Box-Tidwell transformations to investigate nonlinearity of the delays. We set the p-value to 0.005 for these tests

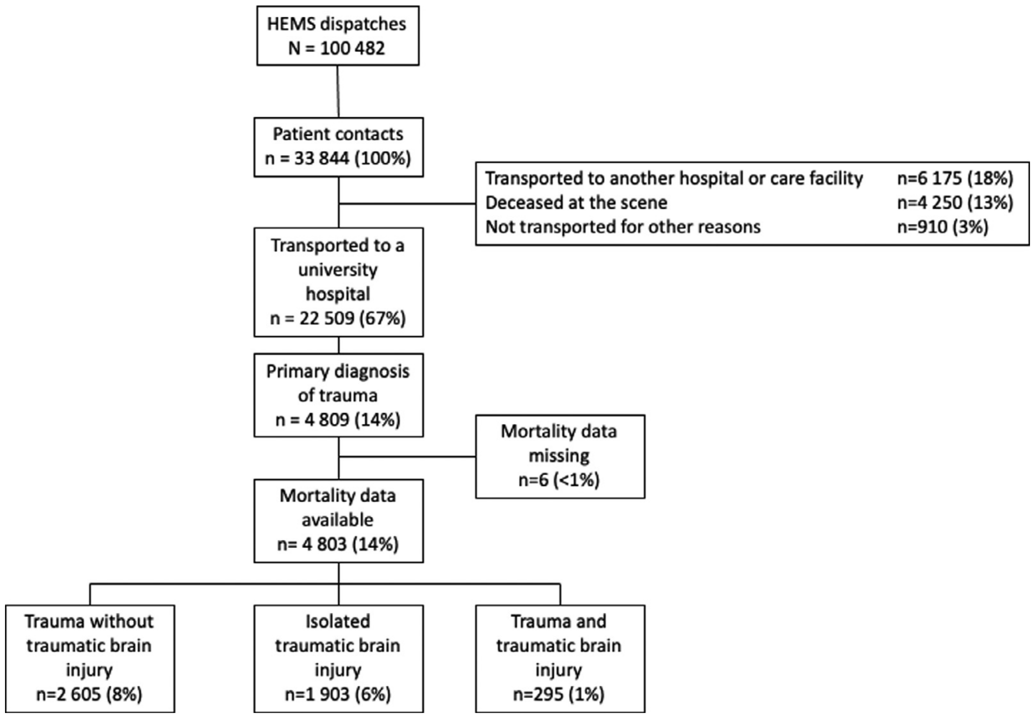

Fig. 1. Flow-chart showing patient selection. Of the patients transported to a university hospital and treated for trauma. Mortality data were missing for only 6 patients.

to avoid false positives as the tests were repeated for all the timeframes in all the subgroups. We further investigated the behavior of the different timeframes against the 30-day mortality by creating risk plots using the loess-method (locally estimated scatterplot smoothing).

The inclusion time represents the foundation of the FHDB to a latest practical point and, as such, no power calculations were performed. Data were processed with IBM SPSS Statistics 27 (IBM Corporation, Armonk, NY, USA). Figures were prepared using Prism 9 (GraphPad Prism 9, GraphPad Software, San Diego, CA, USA).

Results

During the study period, HEMS participated in the care of 33,844 patients. Trauma was the primary discharge diagnosis in 4809 patients (14.2%). A flowchart of patient selection is presented in Fig. 1.

The overall 30-day mortality was 12.1% (582/4803). Patients with trauma without a TBI had the lowest mortality, at 4.3% (111/2605), whereas isolated TBI had the highest, at 22.9% (435/1903). Patients with both trauma and a TBI had a mortality of 12.2% (36/295).

Patient characteristics and comparisons between survivors and non-survivors are presented in Table 1. Crude observations showed differences in hemodynamic patterns, but these were within normal physiological ranges. Non-survivors were generally older, more obtunded, and hypoxic and needed more frequently airway intervention. Non-survivors also were more severely injured when regarding the ICISS. Tests for linearity showed non-linearity in only OST for isolated TBI, presented in Appendix 2 and 3.

A description of the various timeframes between survivors and non-survivors in the subgroups is presented in Table 2. The EMS delay did not differ in the survivors and non-survivors, while non-survivors in patients with trauma without a TBI or an isolated TBI had a longer HEMS response time. On-scene time was also significantly longer in non-survivors in all groups.

Fig. 2 shows the univariate and adjusted odds ratios for 30-day mortality for the different time intervals. The small sample size for all patients with trauma and TBI and EMS delay in patients with trauma without TBI did not allow for a multivariable analysis. Adjustment for crude parameters describing the medical state of the patient revealed no association between time intervals and 30-day mortality.

Discussion

Our study of prehospital critical care patients suffering from trauma revealed no statistical association between longer timespans and an increase in 30-day mortality. Trends in different odds ratios can be viewed to favor a more expedited care; however, no statistically significant difference was observed.

The strengths of this study include its combination of well-established and robust databases. All the HEMS missions are centrally collected in the national FHDB, while the patient registry center and national hospital discharge registry are governed by law. However, as with all registry studies in the medical field, inter-operator variability exists, both in the prehospital field and the hospital diagnoses. We used the ICD-10-based Injury Severity Score (ICISS) to evaluate the mortality for the patient groups. ICISS has been evaluated as a robust tool for classification of the trauma severity [24].

The major limitation of our study was that no uniform national trauma registry exists.[28] Furthermore, we did not include patients deceased before HEMS contact and this can lead to survivor bias. Patients who with a prompt EMS could have survived but the EMS delay was prolonged might have deceased before EMS contact and this in turn would lead to the HEMS unit cancelling the call.

[25] Tests for linearity showed that only OST in isolated TBI was marginally non-linear. Further studies should address the possible

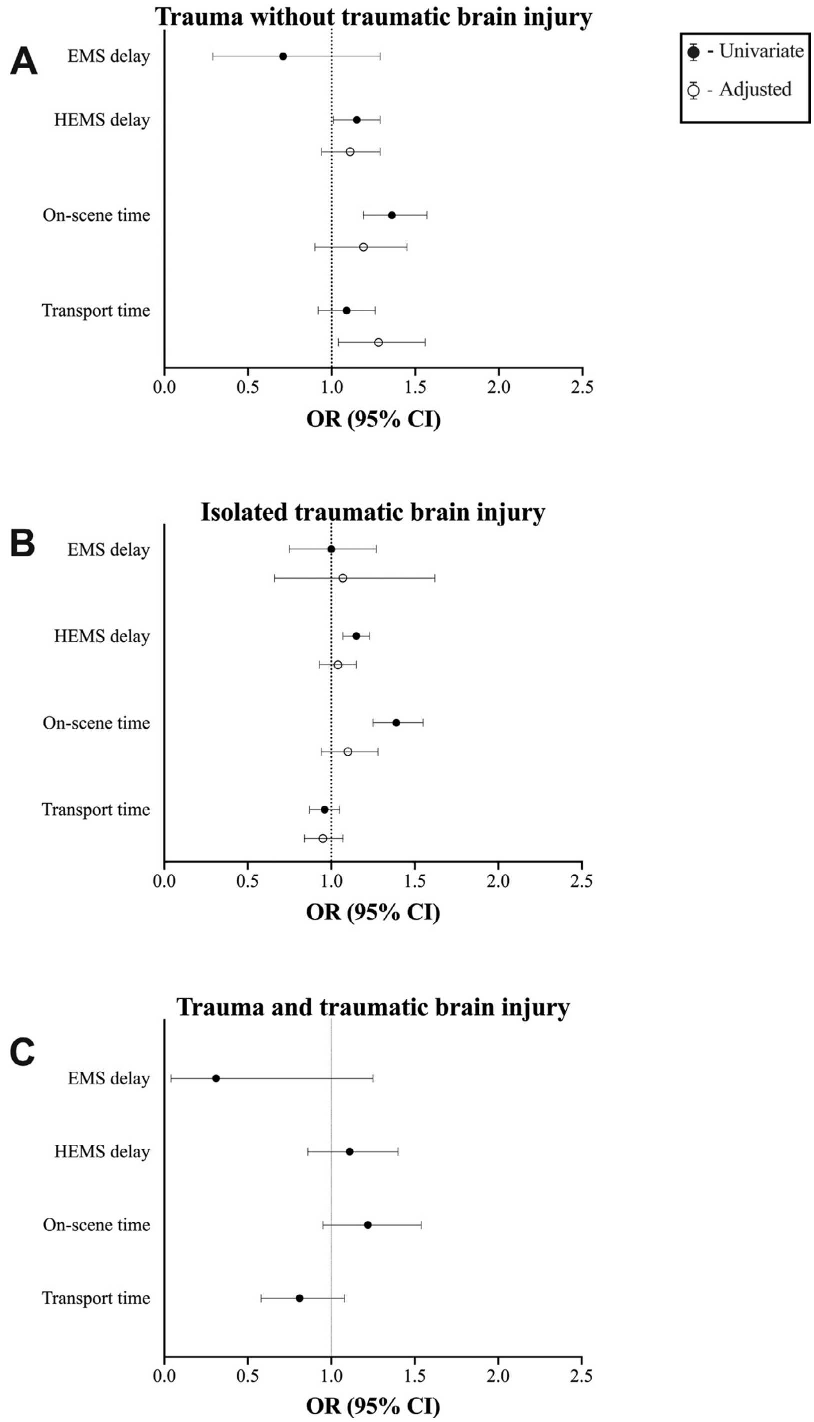

Fig. 2. Odds ratios for different time intervals presented in 15 min increments for 30-day mortality. Adjusted values—presented as hollow circles (A, B)—are adjusted for age, initial Glasgow coma scale, hypotension, need for prehospital airway intervention and Injury severity by ICISS. The small sample and missingness in trauma and traumatic brain injury (C) and EMS delay in patients with trauma without TBI (A) did not allow for adjustment. The trends seem to favor more expedited care, but no statistically significant observations were seen following adjustment.

derivative changes in linearity in respect to the injuries sustained. The marked missingness might partially skew the results in either direction. However, the missingness between groups is of the same magnitude, speaking for a systematic fault. Improvements in the FHDB are continuous and coming studies should provide even more robust data [21].

Instantaneous critical care might be beneficial for some time-critical patients, but this is impossible in practice. Hence, the effect of prehospital response time in this study on general survival of trauma patients should be interpreted with caution. Operational factors could affect the results, such as the HEMS unit being unable to attend the mission or the HEMS physician might evaluate that the EMS can transport the patient sufficiently swiftly to a nearby hospital for damage control, without HEMS contact. Subsequent interfacility transport is not a criterion for HEMS involvement in Finland.

Table 1
Patient characteristics in the different trauma groups. GCS=Glasgow Coma Scale ICISS=International classification of diseases-10 based injury severity score.

	Trauma without traumatic brain injury				Isolated traumatic brain injury				Trauma and traumatic brain injury			
	All n = 2605	Dead at 30 days n = 111 (4.3%)	Alive at 30 days n = 2494 (95.7%)	p	All n = 1903	Dead at 30 days n = 435 (22.9%)	Alive at 30 days n = 1486 (77.1%)	p	All n = 295	Dead at 30 days n = 36 (12.2%)	Alive at 30 days n = 259 (87.8%)	p
	n/median (%/IQR)	n/median (%/IQR)	n/median (%/IQR)		n/median (%/IQR)	n/median (%/IQR)		n/median (%/IQR)	n/median (%/IQR)	n/median (%/IQR)	n/median (%/IQR)	
Age, yrs	40 (23–58)	63 (38–76)	39 (23–57)	<0.001	49 (23–67)	69 (56–80)	41 (20–61)	<0.001	43 (21–59)	63 (44–77)	41 (20–57)	<0.001
Male gender	1937 (74%)	92 (83%)	1845 (74%)	0.047	1322 (70%)	290 (67%)	1032 (70%)	0.166	220 (75%)	27 (75%)	193 (77%)	1
GCS	15 (14–15)	6 (3–14)	15 (14–15)	<0.001	9(5–14)	4 (3–6)	12 (7–15)	<0.001	10 (6–14)	3 (3–4)	11 (7–14)	<0.001
Heart rate, min^{-1}	90 (80–103)	93 (77–116)	90 (80–102)	0.358	90 (76–104)	83 (69–100)	90 (78–104)	<0.001	90 (76–110)	91 (70–111)	90 (77–110)	0.913
Systolic blood pressure, mmHg	128 (110–144)	116 (95–141)	128 (110–144)	0.021	135 (120–159)	150 (120–180)	132 (119–151)	<0.001	126 (111–150)	125 (95–165)	127 (112–148)	0.634
SpO2,%	97 (94–99)	93 (88–97)	97 (95–99)	<0.001	97 (95–99)	96 (92–98)	98 (96–99)	<0.001	98 (94–99)	95 (92–98)	98 (95–99)	0.003
Need for airway intervention	294 (11%)	55 (50%)	239 (10%)	<0.001	824 (43%)	319 (73%)	505 (34%)	<0.001	142 (48%)	27 (75%)	115 (44%)	0.001
ICISS	0.95 (0.88–0.98)	0.85 (0.74–0.94)	0.95 (0.88–0.98)	<0.001	0.84 (0.70–0.98)	0.82 (0.65–0.84)	0.84 (0.73–0.99)	<0.001	0.76 (0.61–0.86)	0.67 (0.54–0.77)	0.77 (0.63–0.87)	0.001

Table 2
Comparison of the various timeframes for survivors and non-survivors at 30-days in the different trauma groups. Time is presented as minutes. All values are presented as continuous variables. EMS=Emergency Medical Services, HEMS=Helicopter Emergency Medical Services.

	Trauma without traumatic brain injury n = 2605				Isolated traumatic brain injury n = 1903				Trauma and traumatic brain injury n = 295			
	All n = 2605	Dead at 30 days n = 111 (4.3%)	Alive at 30 days n = 2494 (95.7%)	p	All n = 1903	Dead at 30 days n = 435 (22.9%)	Alive at 30 days n = 1486 (77.1%)	p	All n = 295	Dead at 30 days n = 36 (12.2%)	Alive at 30 days n = 259 (87.8%)	p
	n/median (%/IQR)	median (IQR)	median (IQR)		n/median (%/IQR)	median (IQR)	median (IQR)		n/median (%/IQR)	median (IQR)	median (IQR)	
EMS response time	12 (9–17)	11 (7–15)	12 (9–17)	0.115	10 (7–15)	10 (8–15)	11 (7–16)	0.616	11 (8–18)	8 (6–12)	11 (8 –18)	0.127
missing	1771 (68)	82 (74)	1685 (68)		1285 (68)	285 (66)	998 (67)		208 (71)	25 (69)	183 (71)	
HEMS response time	24 (16–35)	27 (19–43)	23 (16–35)	0.019	24 (17–40)	29 (19–46)	23 (16–39)	<0.001	26 (17–41)	26 (20–45)	26 (17–41)	0.362
missing	660 (25)	27 (24)	629 (25)		513 (27)	123 (28)	388 (26)		76 (26)	10 (28)	66 (26)	
On-Scene time	18 (10–27)	29 (16–40)	17 (10–26)	<0.001	21 (12–32)	26 (18–36)	20 (11–30)	<0.001	22 (14–34)	27 (20–39)	21 (13–33)	0.032
missing	533 (21)	13 (12)	516 (21)		351 (18)	37 (9)	312 (21)		42 (14)	4 (11)	38 (15)	
Transport time	28 (16–41)	30 (17–44)	28 (16–41)	0.318	29 (16–42)	29 (17–40)	28 (16–43)	0.872	32 (19–45)	25 (14–42)	33 (20–46)	0.152
missing	986 (38)	22 (20)	960 (39)		589 (31)	58 (13)	529 (36)		65 (22)	7 (19)	58 (22)	

In light of our results, time would not appear to be a major factor for the majority of prehospital patients suffering from major trauma. Initial care and advanced care provided by the EMS and HEMS personnel takes time, but this time does not seem to increase mortality. More specifically, the degree of injury severity and need for prehospital interventions seems to prolong the prehospital on-scene time but does not affect mortality to the same extent. Less severely injured patients – as defined by the ICISS – were, logically, more likely to survive following trauma.

A special subgroup that requires treatment that cannot be given in the prehospital field is the group of patients with penetrating exsanguinating torso trauma or an increasing neurological process requiring prompt surgical care. These time-critical patients can be few and far between; however, the HEMS physician needs to identify this patient group and focus on expedited transport to a definitive care facility [25,26].

These observations are in line with previous studies in the area. Harmsen et al. published a systematic review in 2015 regarding the influence of prehospital time on patient outcome [5]. They concluded that on-scene time and total prehospital time do not increase the odds for mortality in undifferentiated hemodynamically stable patients. By contrast, patients with neurotrauma and hemodynamically unstable patients with penetrating thoracic trauma warrant swift transport. A Cochrane review by Galvagno et al. in 2015 concluded that time might not be the main factor for HEMS in management of trauma; rather, crew expertise and an organized trauma system are more important [8]. However, both studies regretted the heterogeneity of the quality in prehospital studies. In their revisit to the “golden hour,” Newgard et al. found that among patients suffering from traumatic shock or TBI, only patients requiring early critical interventions had a higher mortality if they arrived in hospital at over 60 min after trauma [26]. These studies strengthen our findings that patients suffering from trauma require urgent initial prehospital care, but that subsequent care is not similarly time dependent to the same extent [15]. On the other hand, a large study of patients suffering from trauma in France treated by prehospital physicians showed a linear increase in mortality, when regarding the prehospital time [25].

The heterogeneity of trauma makes time-frames difficult to study. Some patients might benefit from prompt care where some do not require specialist care at all – the only thing they have in common is that bodily harm has taken place.

[27,28] The results of our study can readily be used to govern HEMS dispatch criteria and EMS care. The results can be generalized to patients suffering from trauma in a high-income country with well-established EMS and HEMS level care and tertiary care systems. However, the results cannot be generalized for systems with HEMS responding primarily via secondary dispatch or interfacility transport.

To conclude, thorough prehospital care seems beneficial except for the select few patients who benefit from prompt transport. Driving with “lights and sirens” to the scene of accident seems rational and teleological, whereas the subsequent transport and care options must be carefully pondered. The “golden hour” cannot be verified by our study. Should the patient survive to the point of EMS and HEMS contact, then time does not seem to make a significant difference in terms of mortality, regarding the majority of patients suffering from trauma.

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Declaration of Competing Interest

The authors have no conflicts of interest to declare.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.injury.2022.01.025.

CRediT authorship contribution statement

Johannes Björkman: Conceptualization, Project administration, Formal analysis, Writing – original draft. **Piritta Setälä:** Conceptualization, Project administration, Writing – review & editing, Writing – original draft. **Ilkka Pulkkinen:** Conceptualization, Project administration, Writing – review & editing, Writing – original draft. **Lasse Raatiniemi:** Conceptualization, Project administration, Writing – review & editing, Writing – original draft. **Jouni Nurmi:** Conceptualization, Project administration, Writing – review & editing, Writing – original draft.

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