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Comparison of physician-staffed helicopter with ground-based emergency medical services for trauma patients

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ABSTRACT

Introduction: Few studies have discussed whether physician-staffed helicopter emergency medical services (HEMS) provide temporal and geographical benefits for patients in remote locations compared to ground emergency medical services (GEMS). Our study seeks to clarify the significance of HEMS for patients with severe trauma by comparing the mortality of patients transported directly from crash scenes by HEMS or GEMS, taking geographical factors into account.
Methods: Using medical records from a single center, collected from January 2014 to December 2018, we retrospectively identified 1674 trauma patients. Using propensity score analysis, we selected adult patients with an injury severity score ≥16, divided them into groups depending on their transport to the hospital by HEMS or GEMS, and compared their mortality within 24 h of hospitalization. For propensity score-matched groups, we analyzed distance and time.
Results: Of the 317 eligible patients, 202 were transported by HEMS. In the propensity score matching analysis, there was no significant difference in mortality between the HEMS and GEMS groups: 8.7% vs. 5.8%, odds ratio (OR), 1.547 (95% confidence interval [CI], 0.530–4.514). The inverse probability of treatment weighting (IPTW): 11% vs. 7.8%, OR, 1.080 (95% CI, 0.640–1.823); stabilized IPTW: 11% vs. 7.8%, OR, 1.080 (95% CI, 0.502–2.324); and truncated IPTW: 10% vs. 6.4%, OR, 1.143 (95% CI, 0.654–1.997). The distance from the crash scene to the hospital was farther in the HEMS group, and it took a longer period of time to arrive at the hospital ($P < 0.001$).
Conclusions: HEMS may provide equal treatment opportunities and minimize trauma deaths for patients transported from a greater distance to an emergency medical center compared to GEMS for patients transported from nearby regions.

1. Introduction

Most traumatic deaths occur shortly after injury and within hours of arrival at the hospital [1]. In recent years, the mortality rate in the acute phase has decreased due to better training for trauma caregivers and improvements in diagnostic imaging techniques. However, brain injury and bleeding remain the major causes of traumatic death, especially in patients with multiple traumas [2]. To avoid these acute-phase deaths, appropriate respiratory and circulatory management must be initiated, and patients must be quickly transported to the hospital that can provide the best treatments.

In Japan, paramedic treatments are restricted by the ordinance of the Ministry of Health, Labor, and Welfare. Paramedics can only perform venous cannulation and crystalloid infusion on a trauma patient with shock to avoid imminent cardiopulmonary arrest [3,4]. Therefore, physician-staffed helicopter emergency medical services (HEMS) are considered most effective for patients with severe trauma, as reported in several studies [4-6]. However, in comparison with conventional ground emergency medical services (GEMS) provided by paramedics, few studies have discussed the ability of HEMS to overcome challenges of a long geographical distance from a medical center.

Abbreviations: AIS, abbreviated injury scale; CI, confidence interval; HEMS, helicopter emergency medical services; GEMS, ground emergency medical services; IPTW, inverse probability of treatment weighting; ISS, injury severity score; OR, odds ratio; RTS, revised trauma score.

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The aim of this study was to determine the efficacy of patient transport with HEMS for patients with severe trauma through an appraisal of mortality weighted for geographical distances.

2. Methods

This study was approved by the institutional review board of Kurume University Hospital (Approval No. 20060). By ensuring the anonymity of the data, the requirement for informed consent was waived.

2.1. Study design

This study was a single-center, retrospective cohort study. We investigated the medical records of trauma patients who were transported to the Kurume University Hospital Advanced Emergency and Critical Care Center from January 2014 to December 2018. This facility is a core hospital of the region and equals level 1 trauma centers in Europe and the United States. In the present study, we enrolled 1674 trauma patients. We included patients who were transported directly from the crash scene by HEMS or GEMS and were ≥16 years of age, had an injury severity score (ISS) ≥16 points, and were transported within 24 h of injury. We excluded patients with cardiopulmonary arrest at the scene or in transit, an unknown time of injury, transported by physician-staffed ambulance, and penetrating trauma (because the frequency of penetrating trauma is less).

We collected the following data from the medical records: age, gender, vital signs during ambulance crew contact on the crash scene, direct distance from scene to the hospital, time from injury to the paramedic contact, time from injury to the physician contact, time from injury to arrival at the hospital, prehospital intervention (intubation, chest tube insertion and volume of intravenous fluid), laboratory tests at admission, diagnosis, and outcomes. The diagnosis of injury was performed using the abbreviated injury scale (AIS) 90, update 98, and multiple trauma was defined as patients having an injury of AIS 3 or higher at multiple sites [7]. Anatomical injury severity and physiological severity were assessed using the ISS and revised trauma score (RTS) [8,9].

2.2. HEMS in Japan

The HEMS crew consists of one or two physicians and a nurse (including a pilot and a mechanic), waiting at the base hospital. The dispatch request is made by the Fire Command Center based on the content of the report about when the crash occurred or the judgment of the paramedics who rushed to the scene. Once the helicopter lands at a safe location near the scene, the boarding physician contacts the rescued patient and initiates trauma care. Thus, the first contact with the patient is the paramedics.

2.3. Outcome measures

Patients were divided into two groups, HEMS and GEMS, according to the selected transportation system. The primary outcome of interest was mortality within 24 h of hospitalization, and the secondary outcome of interest was in-hospital mortality. We also compared direct distance, time intervals, prehospital interventions, and laboratory tests between the two groups. HEMS is likely to be selected for more severely injured patients when determining the means of transport, which can be a bias in treatment selection. To solve this, we performed propensity score analysis to eliminate selection bias.

2.4. Statistical analysis

We performed one-to-one matching, without replacement, between the HEMS and GEMS groups, based on estimated propensity scores for each patient. To estimate the propensity score, we used a logistic regression model with age, gender, prehospital RTS, ISS, presence of multiple trauma, and presence of head injury with AIS ≥3. The prehospital RTS was calculated from vital signs taken by the ambulance crew on the scene. The caliper width was 0.2 of the standard deviation of the logit of the propensity score. We used the standardized differences to evaluate covariate balance between the two groups before and after matching [10].

We also performed these statistical analyses based on propensity scores to assess the strength of the statistical analysis results: unadjusted analysis, inverse probability of treatment weighting (IPTW) [11,12], stabilized IPTW [13], and truncated IPTW [14]. The weight truncate was performed for weights <1% and ≥99% of the estimated propensity score.

To compare the rates of mortality within 24 h of hospitalization and the in-hospital mortality between the HEMS group and the GEMS group, we performed logistic regression analysis for each of the propensity scores and calculated the odds ratios (OR) and their 95% confidence intervals (CI). A Mann-Whitney *U* test was used to compare the distance from the scene to the hospital, the time from injury to physician contact, the time from injury to arrival at the hospital, and the laboratory tests at admission: hemoglobin, platelet count, prothrombin time-international normalized ratio, fibrinogen, lactate in the propensity score-matched groups.

Statistical analyses were conducted by an independent statistician (K.M.) with JMP 13.2 software and SAS 9.4 (SAS Institute, Inc., Cary, NC, US). Data were expressed as median (interquartile range) or number (%), and $P < 0.05$ was considered statistically significant.

3. Results

Among 317 eligible patients who underwent trauma during the study period, 202 patients were transported to the hospital by a physician-staffed helicopter (HEMS group) and 115 patients were transported by a paramedic-staffed ambulance (GEMS group) (Fig. 1).

Propensity score matching created 104 matched pairs. Table 1 shows the baseline characteristics of the patients in the unmatched and propensity score-matched groups. Age, ISS, and rate of multiple traumas were imbalanced between the unmatched groups. After propensity score matching, all the standardized differences were <10% in the matched patients, and the characteristics of the two groups were appropriately balanced.

In the logistic regression analysis, there were no significant differences in the 24-h mortality between HEMS and GEMS: unadjusted; OR, 1.513 (95% CI, 0.675–3.392); propensity score matching: OR, 1.547 (95% CI, 0.530–4.514), IPTW; OR 1.080 (95% CI, 0.640–1.823), Stabilized IPTW; OR 1.080 (95% CI, 0.502–2.324); truncated IPTW: OR, 1.143 (95% CI, 0.654–1.997) (Fig. 2). The number of subjects and mortality rates for each analysis are presented in Fig. 2.

Table 2 shows the in-hospital mortality rates and OR according to each analysis. The in-hospital mortality rates were not significantly different between the two groups.

Although the distances and periods of time between the crash scene and the hospital could be lengthy, the patients had a significantly narrower window for initial contact with the physician using HEMS compared to GEMS. There was no difference in the time from injury to the paramedic contact (Table 3).

Table 4 shows the comparison of prehospital interventions and laboratory tests at admission in the propensity score-matched groups. Paramedics in the GEMS group were not allowed to perform intubation for non-cardiopulmonary arrest patients, chest tube insertions, or even crystalloid infusion. In the HEMS group, tracheal intubation was performed in 28 of 104 patients (27%), and chest drainage was performed in eleven patients (11%). All patients in the HEMS group were administered acetated Ringer's solution and the average infusion volume was 300 mL. The platelet count and the value of the fibrinogen were significantly lower in the HEMS group.

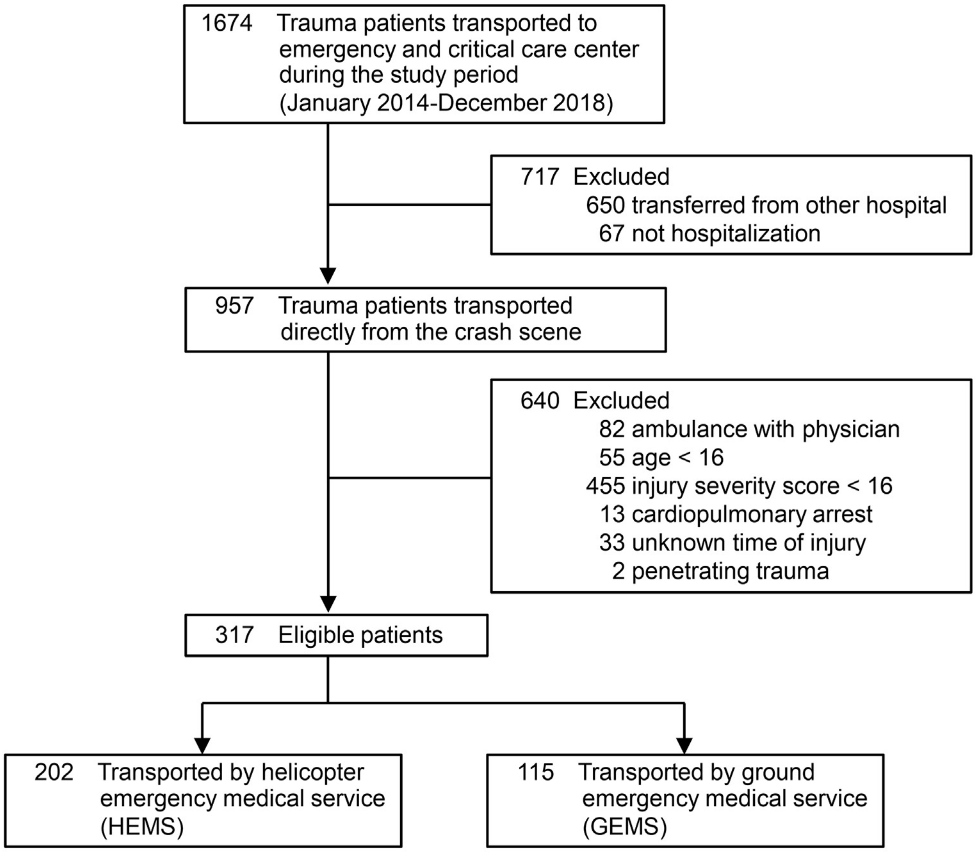

Fig. 1. Flow diagram of the study population.

4. Discussion

In this study, we showed the effect of HEMS for patients with severe trauma injured at a distance from an emergency center. The frequency of trauma death of patients transported from remote locations by HEMS did not differ from those of patients transported from closer regions by GEMS, despite a significant increase in transport time.

There are conflicting studies about the effectiveness of HEMS, with one recent retrospective study reporting that HEMS does not provide survival benefit to trauma patients when geographic considerations are used [15], while several reports show the superiority of HEMS [4-6]. However, another study reported that HEMS is useful for survival when HEMS flight distances are at least 14.3 miles (22.9 km) [16].

In Japan, the cost of prehospital care including HEMS is covered by the government. There are 53 physician-staffed helicopters deployed nationwide, and each helicopter covers a radius of approximately 50 km. Considering the actual dispatch range of HEMS, which is the subject of this study, there was no difference in mortality rates between the HEMS and GEMS groups. However, when compared to trauma patients transported by ambulance from nearby regions, this result is significant in the sense that HEMS can correct regional disparities and improve patient outcomes within a medical area. This is because previous study has reported the distance from the crash scene to the nearest trauma center is a strong geographic determinant of mortality [17].

One advantage of HEMS is that intervention by a physician starts at the scene of the crash [18]. Two interventions, tracheal intubation for shock

Table 1
Demographics and injury characteristics in unmatched and propensity score-matched groups

	Unmatched groups			Matched groups		
Characteristic	HEMS ($n = 202$)	GEMS ($n = 115$)	Standardized Difference, %	HEMS ($n = 104$)	GEMS ($n = 104$)	Standardized Difference, %
Age, years	68 (55–78)	63 (43–74)	30.9	66 (46–78)	66 (49–75)	4.5
Male, n (%)	149 (74)	85 (74)	0.3	77 (74)	80 (77)	6.7
Prehospital RTS[a]	7.55 (5.97–7.84)	7.55 (5.97–7.84)	2.5	7.55 (5.97–7.84)	7.55 (6.27–7.84)	1.4
ISS, n (%)			28.3			4
16 to 24	88 (44)	61 (53)		59 (57)	57 (55)	
25 to 34	62 (31)	37 (32)		31 (30)	32 (31)	
>34	52 (25)	17 (15)		14 (13)	15 (14)	
Multiple trauma, n (%)	101 (50)	35 (30)	40.7	36 (35)	34 (33)	4.1
Head injury, n (%)[b]	100 (50)	61 (53)	7.1	52 (50)	54 (52)	3.8

Data are presented as median (interquartile range) or n (%).
HEMS: helicopter emergency medical services, GEMS: ground emergency medical services, RTS: Revised Trauma Score, ISS: Injury Severity Score.
[a] RTS was calculated from vital signs at the time of ambulance crew contact on scene.
[b] Head injury was defined as having an intracranial injury of AIS 3 or higher.

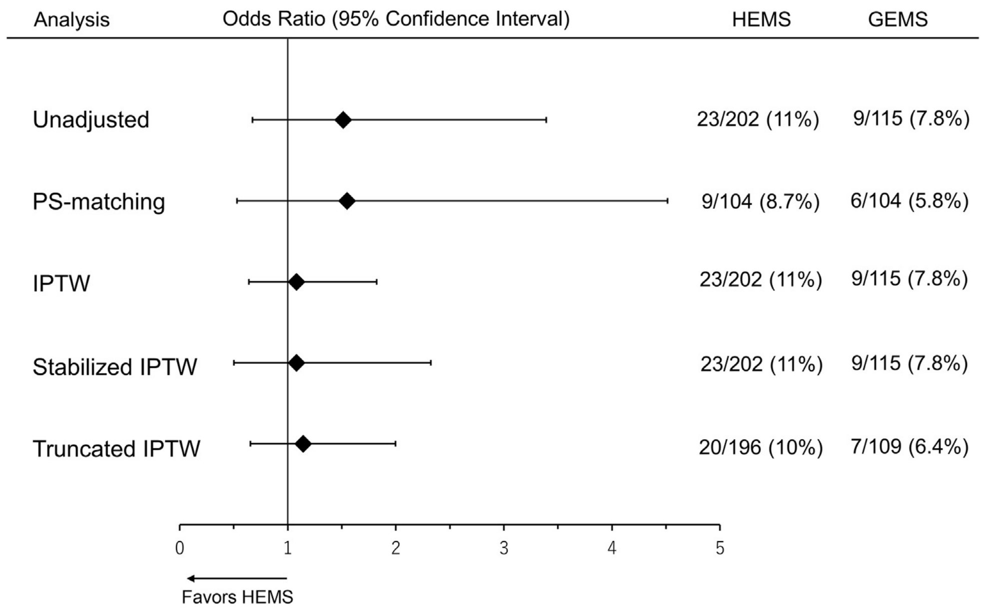

Fig. 2. Odds ratio of the 24-h mortality rates between HEMS and GEMS. HEMS, helicopter emergency medical services; GEMS, ground emergency medical services; PS, propensity score; IPTW, inverse probability of treatment weighting.

Table 2
The in-hospital mortality rates between HEMS and GEMS

	HEMS	GEMS	Odds ratio (95% CI)	*P*-value
Unadjusted analysis	37/202 (18)	19/115 (17)	1.133 (0.617–2.080)	0.687
Matching analysis	15/104 (14)	15/104 (14)	1.000 (0.465–2.152)	1.000
IPTW analysis	37/202 (18)	19/115 (17)	0.834 (0.554–1.254)	0.382
Stabilized IPTW analysis	37/202 (18)	19/115 (17)	0.834 (0.455–1.528)	0.555
Truncated IPTW analysis	33/196 (17)	16/109 (15)	0.928 (0.603–1.427)	0.733

Data are presented as n (%) or odds ratio (95% confidence interval).
HEMS: helicopter emergency medical services, GEMS: ground emergency medical services, CI: confidence interval, IPTW: inverse probability of treatment weighting.

Table 3
Distance and time intervals in the propensity score-matched groups

	HEMS	GEMS	*P*-value
Direct distance from scene to the hospital, kilometers	20.1 (16.0–27.3)	5.55 (3.35–10.6)	<0.0001
Time from injury to the paramedic contact, minutes	13 (10−21)	13 (9–18)	0.7890
Time from injury to the physician contact, minutes	31.5 (26–47)	38.5 (30–53)	0.0041
Time from injury to arrival at the hospital, minutes	65.5 (58–83)	38.5 (30–53)	0.0002

Data are presented as median (interquartile range).
HEMS: helicopter emergency medical services, GEMS: ground emergency medical services.

Table 4
Prehospital intervention and laboratory tests at admission in the propensity score-matched groups

	HEMS	GEMS	*P*-value
Prehospital interventions			
Intubation, n (%)	28 (27)	none	
Chest tube insertion, n (%)	11 (11)	none	
Intravenous fluid, ml	300 (200–500)	none	
Laboratory tests			
Hemoglobin, g/l	129 (114–141)	131 (113–143)	0.6812
Platelet count, 10^9/l	182 (144–211)	197 (162–237)	0.0034
PT-INR	1.07 (0.99–1.18)	1.04 (0.97–1.10)	0.0020
Fibrinogen, g/l	2.33 (1.88–2.80)	2.48 (2.11–3.08)	0.0076
Lactate, mmol/l	1.8 (1.2–2.5)	2.0 (1.3–2.8)	0.4933

Data are presented as n (%) or median (interquartile range).
HEMS: helicopter emergency medical services, GEMS: ground emergency medical services, PT-INR: prothrombin time-international normalized ratio.

or disturbance of consciousness and chest drainage, are especially linked with respiratory and hemodynamic stabilization, and result in prevention of secondary brain injury. Prehospital airway management performed by a physician for a severe traumatic brain injury improves prognosis [6]. But aggressive prehospital interventions may contribute to a delay in-hospital arrival time [19], and, combined with prehospital fluid administration (fluid resuscitation), can cause impaired clotting [20,21]. This study had similar results with respect to time elapse, i.e., from the time of injury to the time of arrival to the hospital, with significantly lower platelet counts and fibrinogen at admission in the HEMS groups; however, an average of 300 mL of intravenous fluid administered prehospital is considered as restrictive. These differences in platelet count and fibrinogen are statistically significant but may not be clinically important because the value itself did not mean coagulopathy.

The present study has several limitations. First, it was a single-center, retrospective cohort study. The study population was small, so we did not use the types of crash leading to injury or the site of injuries as covariates in the logistic regression model to estimate the propensity score. Although a propensity score analysis was performed to eliminate selection bias, there may be residual confounding due to differences in unmeasured factors. Second, the results of propensity score matching in this study are generalized only among those propensity scores in the paired analysis. Therefore, we performed IPTW analysis to include cases that had different propensity scores.

5. Conclusion

We performed propensity score analysis to compare outcomes of trauma patients transported from remote distances by HEMS to patients transported from nearby regions by GEMS, using anatomical and physiological severities. Our analysis suggests that HEMS may provide equal treatment opportunities for trauma patients in regions farther away from medical centers.

Author contributions

All of the authors reviewed and discussed the manuscript. All authors read and approved the final manuscript.

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Declaration of Competing Interest

There are no conflicts of interest for all authors in this study.

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