Original Contribution

Efficacy of the presence of an emergency physician in prehospital major trauma care: A nationwide cohort study in Japan

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ABSTRACT

Purpose: The beneficial effect of the presence of an emergency physician in prehospital major trauma care is controversial. The aim in this study is to assess whether an emergency physician on scene can improve survival outcome of critical trauma patients.
Methods: This retrospective cohort study was conducted by using nationwide trauma registry data between 2004 and 2013 in Japan. Severe trauma patients (injury severity score (ISS) ≥ 16) who were transported directly to the hospital from the injury site were included in our analysis. Patients who were predicted to be untreatable (abbreviated injury score (AIS) = 6 and/or cardiopulmonary arrest at least one time before hospital arrival) were excluded. Participants were divided into either a physician or paramedics group based on the prehospital practitioner. The primary outcome was survival rate at discharge. Multivariable logistic regression analysis was performed to compare the outcome with adjustment for age, gender, ISS, cause of injury, and pre-hospital vital signs.
Results: A total of 30,283 patients were eligible for the selection criteria (physician: 1222, paramedics: 29,061). Overall, 172 patients (14.1%) died in the physician group compared to 3508 patients (12.1%) in the paramedics group. Patients in the physician group had higher ISSs than those in the paramedics group. In multivariable logistic regression, the physician group had an odds ratio (OR) of 1.16 (95% confidence interval (CI) = 0.97 to 1.40, p = 0.11) for in-hospital survival.
Conclusions: Our results failed to show a difference in survival at discharge between non-physician-staffed ambulances and physician-staffed ambulances.

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1. Introduction

Major trauma comprising serious and multiple injuries is often life threatening. As some deaths after trauma were commonly considered preventable only if injuries were detected and treated rapidly and accurately [1], the concept that a physician deployment to the scene of trauma for the prehospital rapid advanced intervention might improve the outcome of major trauma patients has been raised. In fact, studies have demonstrated that prompt initiation of advanced techniques such as intubation and chest decompression before hospital arrival reduce mortality in patients with severe trauma [2,3]. Nevertheless, the efficacy of the presence of an emergency physician in the pre-hospital setting is still controversial and debated. The main argument against the involvement of an emergency physician in prehospital trauma care is that it could delay transfer time due to unnecessary prehospital interventions [4]. Several reports have highlighted the importance of rapid patient transfer to the trauma center and of definitive trauma care, including surgery, which strongly influence outcome [5-7]. Moreover, involvement of an emergency physician requires considerable financial and human resources. Therefore, it is important to demonstrate the benefits of direct physician involvement in the field, such as improved survival outcome.

Emergency medical services (EMS) and laws vary around the globe. In Japan, EMS generally adopt the Anglo-American model in which paramedics are the only prehospital scene responders. For prehospital trauma patients alive, Japanese paramedics are permitted to perform limited prehospital interventions such as intravenous administration (since 2014), a supraglottic airway device use (since 1991) and intubation (since 2014) if they finished special training program. Thus, Japanese paramedics have performed medical procedures on the scene less actively than paramedics in the United State (U.S.) and Europe historically [8]. On the other hand, some districts have their own physician-staffed EMS system in Japan. They can perform several

advanced procedures including ultrasound examination, intravenous administration, intubation, thoracotomy, resuscitative endovascular balloon occlusion of the aorta (REBOA) when the equipment was available. Based on these regional differences, trauma patients in Japan represent an interesting population to compare the outcome of prehospital care provided by a physician versus paramedics. In this study, we aimed to investigate whether the presence of an emergency physician on scene in the pre-hospital setting improves outcome among patients with major trauma.

2. Methods

2.1. Study design and data collection

This retrospective cohort study investigated the effectiveness of the involvement of an emergency physician versus paramedics in prehospital trauma care. The data were obtained from the Japan Trauma Data Bank (JTDB), which was established in 2003 by the Japanese Association for the Surgery of Trauma (Trauma Registry Committee) and the Japanese Association for Acute Medicine (Committee for Clinical Care Evaluation) to assure the quality of trauma care in Japan. During the study period, a total of 244 hospitals including over 90% of tertiary emergency medical centers in Japan participated in the JTDB [9]. The tertiary emergency medical centers are major hospitals that usually have a full complement of services including major operations, consultations with sub-specialists. There are no specific trauma centers in Japan, but tertiary emergency medical centers are considered to be equivalent to level I or II trauma centers in the U.S. Japan Prehospital Trauma Evaluation and Care (JPTEC) recommends that major trauma patients such as high-energy trauma patients should be transferred rapidly to the nearest tertiary emergency medical center. In most cases, the physicians who attended the AIS coding course registered the data. During the study period, AIS90 Update 98 version was used for AIS coding. The JTDB variables include patient characteristics, injury type, cause of injury, transportation type (ambulance with or without a physician, helicopter with physician), prehospital vital signs and treatments (oxygenation, cervical collars, backboard, ventilation, intubation, nasal airway tube, and intravenous fluid), abbreviated injury scale (AIS) score, injury severity score (ISS), survival at discharge and in the emergency department (ED), disposition at ED, and information regarding
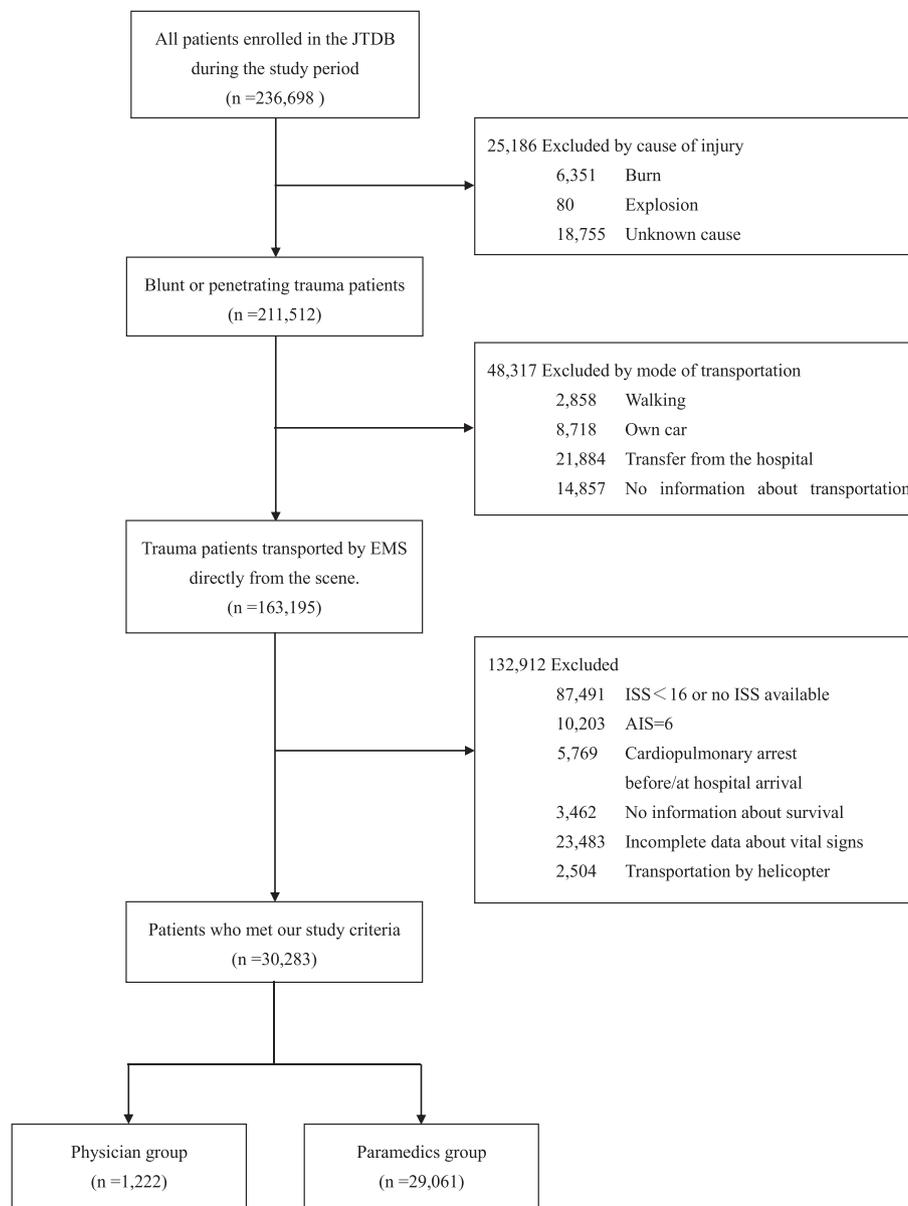
Fig. 1. Flow diagram of participants selection procedure. JTDB: Japan trauma data bank, EMS: emergency medical service, ISS: injury severity score, AIS: abbreviated injury scale.

the timing of events such as pre-hospital contact, hospital arrival, CT scans, blood transfusion, and surgery. The shock index, the Revised Trauma Score (RTS), and the probability of survival based on the Trauma and Injury Severity Score (TRISS) were calculated using these data.

2.2. Ethical approval and consent to participate

The ethics committee at our institution approved JTDB data analysis (29-061). The requirement for patient consent was waived as this was an observational study using anonymous data. Permission for the use of the data was granted by the JTDB.

2.3. Selection of participants

A total of 236,698 patients were enrolled in the JTDB between 2004 and 2015. We identified 163,195 patients with blunt or penetrating trauma who were transported by the emergency medical services directly from the injury site. Of these, patients with ISS ≥ 16 were selected for this study because of the requirement for specialized trauma care [10]. Patients with cardiopulmonary arrest before/at hospital arrival or with an AIS score of 6 were excluded from this study because their conditions were considered non-survivable. Cases with incomplete data regarding survival, pre-hospital and in-hospital vital signs [systolic blood pressure (SBP), diastolic blood pressure (DBP), respiratory rate (RR), and heart rate (HR)] were also excluded. Finally, we excluded patients who were transported by helicopter to reduce the influence of vehicle type of emergency services. Thus, a total of 30,283 patients with trauma met our study criteria (Fig. 1).

2.4. Outcome measures

The primary outcome of this study was survival to hospital discharge. The secondary outcomes were survival to ED discharge and time from arrival of EMS to the following events: hospital arrival, CT scan, blood transfusion, and surgery.

2.5. Statistical analysis

To display the patient data, the mean ± standard deviation (SD) or median with interquartile range (IQR) were used for numerical variables, according to data distribution and previous reporting style. Categorical variables were displayed as raw values followed by percentages in parentheses. The t-test was used to compare the means of the two samples. The Mann-Whitney U test was used to compare the medians of the two samples. The chi-square test was used to compare frequencies. Time from EMS site arrival to hospital arrival, CT scan, blood transfusion, and surgery were compared by drawing the cumulative event rate curve and log rank tests. For this analysis, we extracted only data for events achieved so that the cumulative event rate eventually reached 100% in both groups. To assess the independent effect of the presence of a physician during pre-hospital trauma care on study endpoints, multivariable logistic regression for survival and cox proportional-hazards regression analysis for time to events were performed. Following previous reports [11,12], covariates were carefully selected based on the assumption that none were affected directly by the intervention. These variables included age, sex, cause of injury, ISS, and pre-hospital vital signs (SBP, DBP, RR, HR, and level of consciousness measured by the Japan Coma Scale (JCS)). The two-sided significance level for all tests was set at 5% ($p < 0.05$). All analyses were performed using EZR software, version 3.3.2 (Easy R, Saitama Medical Center, Jichi Medical University; Saitama, Japan) [13].

Table 1
Baseline characteristics of the study population

Characteristics	Physician (n = 1222)	Paramedics (n = 29,061)	p value
Age (years)	52.6 ± 22.1	54.9 ± 22.7	<0.001
Gender (male)	873/1222 (71.4%)	20,482/29,051 (70.5%)	0.646
Injury type (blunt vs penetrating)	1190/1222 (97.4%)	28,706/29,061 (98.8%)	<0.001
Cause of injury			
Motor vehicle crash	804/1222 (65.8%)	15,267/29,061 (52.5%)	<0.001
Falls	322/1222 (26.4%)	12,917/29,061 (44.4%)	<0.001
Other reasons	96/1222 (7.9%)	877/29,061 (3.0%)	<0.001
Prehospital vital signs			
SBP (mm Hg)	130 (110–151)	133 (112–157)	<0.001
DBP (mm Hg)	78 (63–92)	78 (64–90)	0.576
MAP (mm Hg)	94.0 (79.3–110.6)	96.7 (81.7–112.0)	0.052
HR (beats/min)	86 (72–102)	84 (72–99)	0.002
Shock index (HR/SBP)	0.67 (0.53–0.86)	0.63 (0.51–0.79)	<0.001
RR (breaths/min)	24 (20–28)	22 (18–24)	<0.001
JCS			
Grade 0	270/1199 (22.5%)	8459/28,973 (29.2%)	<0.001
Grade 1	413/1199 (34.4%)	11,178/28,973 (38.6%)	0.004
Grade 2	183/1199 (15.3%)	3570/28,973 (12.3%)	0.003
Grade 3	333/1199 (27.8%)	5766/28,973 (19.9%)	<0.001
AIS (≥3)			
Head	698/1222 (57.1%)	16,951/29,061 (58.3%)	0.407
Face	34/1222 (2.8%)	351/29,061 (1.2%)	<0.001
Neck	8/1222 (0.7%)	91/29,061 (0.3%)	0.064
Thorax	647/1222 (52.9%)	11,597/29,061 (39.9%)	<0.001
Abdomen and pelvis	157/1222 (12.8%)	2402/29,061 (8.3%)	<0.001
Spine	179/1222 (14.6%)	4918/29,061 (16.9%)	0.039
Upper extremity	70/1222 (5.7%)	1157/29,061 (4.0%)	0.004
Lower extremity	328/1222 (26.8%)	5089/29,061 (17.5%)	<0.001
ISS	25 (19–34)	21 (17–26)	<0.001
RTS	7.55 (5.97–7.84)	7.84 (6.90–7.84)	<0.001
TRISS (probability of survival)	0.91 (0.71–0.97)	0.93 (0.84–0.97)	<0.001

All categorical variables are shown as n (%). Continuous variables are shown as mean ± standard deviation or median (interquartile range). Missing data are age (n = 36), gender (n = 10), JCS (n = 111), RTS (n = 1051), TRISS (n = 439).
SBP: systolic blood pressure, DBP: diastolic blood pressure, MAP: mean arterial pressure, HR: heart rate, RR: respiratory rate, JCS: Japan coma scale (Grade 0: alert, Grade 1: possible eye-opening, not lucid, Grade 2: possible eye-opening upon stimulation, Grade 3: no eye-opening and coma), AIS: abbreviated injury score, ISS: injury severity score, RTS: revised trauma score, TRISS: trauma and injury severity score.

3. Results

3.1. Characteristics of study subjects

Among a total of 30,283 patients with trauma who met our study criteria, 1222 patients were transported to hospital accompanied by a physician (physician group) and 29,061 patients were accompanied by paramedics (paramedics group). The main characteristics of the patients are shown in Table 1. The mean age was 52.6 ± 22.1 years in the physician group and 54.9 ± 22.7 years in the paramedics group ($p < 0.001$). Blunt trauma was the most frequently occurring injury type in both groups (97.4% vs 98.8%, $p < 0.001$). Although there were statistically significant differences in prehospital vital signs such as SBP, RR, and HR between two groups, almost all of these differences are not clinically significant. Severe disturbance of consciousness (JCS Grade 3) was observed more frequently in the physician group than in the

Table 2
Comparison of prehospital intervention.

	Physician (n = 1222)	Paramedics (n = 29,061)	p value
Prehospital intervention			
Oxygenation	906/1222 (74.1%)	9174/29,061 (68.4%)	<0.001
Cervical collars	804/1222 (65.8%)	18,620/29,061 (64.1%)	0.23
Backboards	853/1222 (69.8%)	17,714/29,061 (61.0%)	<0.001
Ventilation	35/1222 (2.9%)	259/29,061 (0.9%)	<0.001
Intubation	87/1222 (7.1%)	823/29,061 (2.8%)	<0.001
Nasal airway tube	7/1222 (0.6%)	70/29,061 (0.2%)	0.05
Intravenous fluid	387/1222 (31.7%)	171/29,061 (0.6%)	<0.001

All categorical variables are shown as n (%).

paramedics group (27.8% vs 19.9%, $p < 0.001$). Patients in the physician group had more severe trauma scores with higher ISS (median [IQR]: 25 [19–34] vs 21 [17–26], $p < 0.001$) and lower RTS (7.55 [5.97–7.84] vs 7.84 [6.90–7.84], $p < 0.001$) than those in the paramedics group. The probability of survival was also lower in the physician group compared with that in the paramedics group (0.91 [0.71–0.97] vs 0.93 [0.84–0.97], $p < 0.001$).

3.2. Main results

Table 2 presents the comparison of pre-hospital treatment. There were significant differences in prehospital treatment including oxygenation, backboard stabilization, respiratory ventilation, and airway intubation between the physician and paramedics groups; specifically,

there was a significant difference in the frequency of prehospital intravenous fluid administrated (31.7% vs 0.6%, $p < 0.001$).

The physician and paramedics groups were compared for time from EMS site arrival to hospital arrival, CT scan, blood transfusion, and surgery by determining the cumulative event rate curve and log rank tests (Fig. 2A–D). Compared with the paramedics group, time to hospital arrival and time to CT scan were significantly longer in the physician group (hospital arrival: 37 [25–52] vs 28 [22–37], $p < 0.001$. CT scan: 81 [60–102] vs 66 [52–89], $p < 0.001$). Conversely, time to blood transfusion was significantly shorter in the physician group than in the paramedics group (137 [95–200] vs 172 [111–265], $p < 0.001$). There was a difference in time to surgery between the two groups, although it was not statistically significant (174 [119–276] vs 195 [130–294], $p = 0.056$).

Table 3 compares survival outcomes (survival to ED discharge and survival to hospital discharge) between the two cohorts. Fewer patients in the physician group survived to ED or to hospital discharge than in the paramedics group, although absolute difference was quite low (survival to ED discharge: 97.4% vs 98.8%, $p < 0.001$; survival to discharge: 85.9% vs 87.9%, $p = 0.04$).

The results of multivariable logistic regression for survival outcomes are shown in Table 4. The presence of a physician did not improve survival to hospital discharge (odds ratio (OR) = 1.16. confidence interval (CI) = 0.97 to 1.40, $p = 0.109$) or survival to ED discharge (OR: 0.69. CI = 0.47 to 1.01, $p = 0.058$). Cox proportional-hazard regression analysis revealed that time to hospital arrival and time to CT scan, adjusting for age, sex, cause of injury, ISS, and pre-hospital vital signs (SBP, DBP, RR, HR, and JCS), were longer in the physician group (hospital arrival: hazard ratio (HR) = 0.59. CI = 0.55 to 0.62, $p < 0.001$. CT scan: HR = 0.74. CI
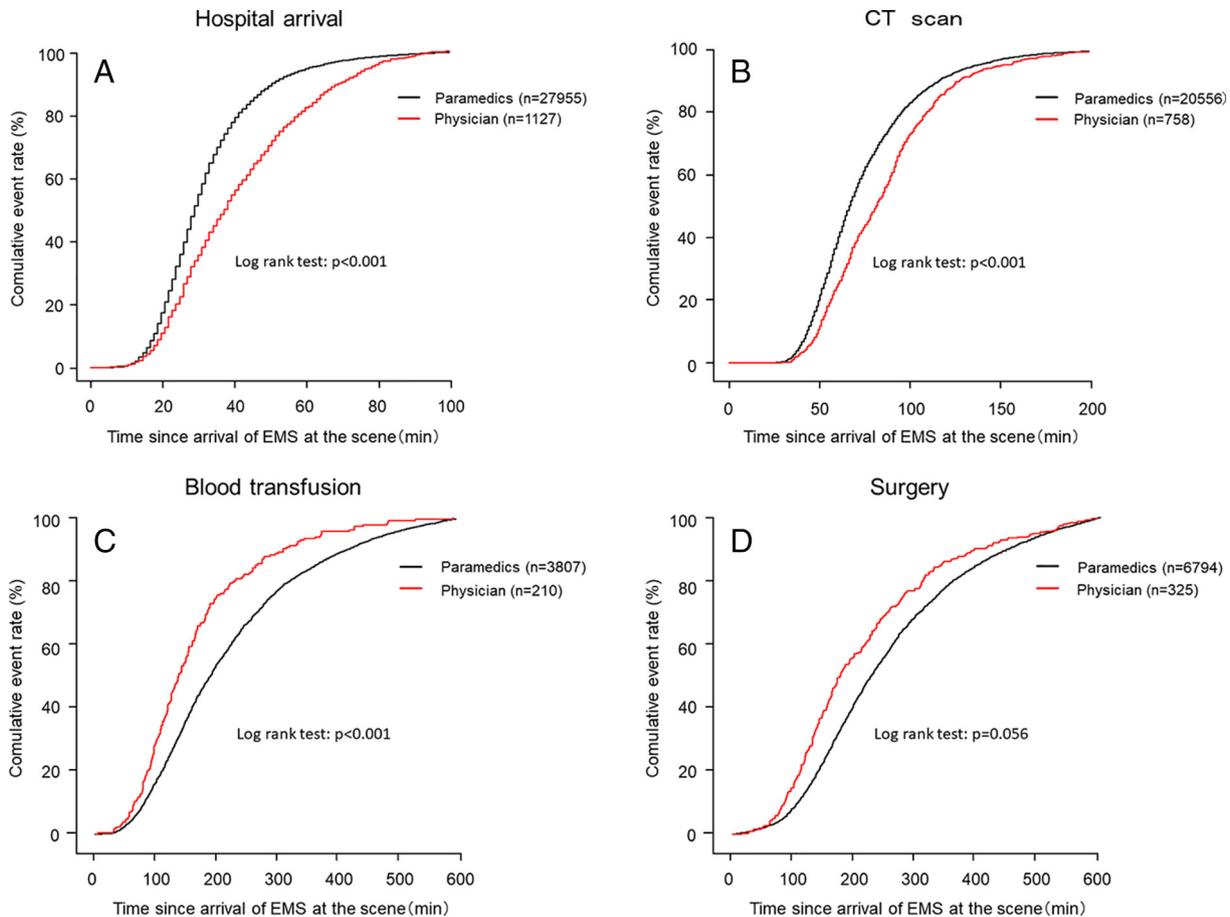
Fig. 2. Comparison of cumulative event rate curve of (A) hospital arrival, (B) CT scan, (C) blood transfusion, and (D) surgery. (A) 883 of data were missing of required information. 318 of data were detected as outlier and removed from analysis. (B) 362 of data were detected as outlier and removed from analysis. (C) 453 data were detected as outlier and removed from analysis. (D) 2400 data were detected as outlier and removed from analysis. EMS: emergency medical service.

Table 3
Comparison of disposition at ED and hospital discharge.

	Physician (n = 1222)	Paramedics (n = 29,061)	p value
Disposition at ED			
Survived	1190/1222 (97.4%)	28,679/29,018 (98.8%)	<0.001
(ICU admission)	1083/1222 (88.6%)	23,059/29,018 (79.5%)	<0.001
(Ward admission)	107/1222 (8.8%)	5620/29,018 (19.4%)	<0.001
Died	32/1222 (2.6%)	339/29,018 (1.2%)	<0.001
Disposition at hospital discharge			
Survived	1050/1222 (85.9%)	25,553/29,061 (87.9%)	0.04
(Home)	384/1222 (31.4%)	12,210/29,061 (42.0%)	<0.001
(Transferred)	666/1222 (54.5%)	13,343/29,061 (45.9%)	<0.001
Died	172/1222 (14.1%)	3508/29,061 (12.1%)	0.04

All categorical variables are shown as n (%). 43 of data for disposition at ED is missing.
ED: emergency department, ICU: intensive care unit, CI: confidence interval.

= 0.70 to 0.79, $p < 0.001$). Conversely, time to blood transfusion was shorter in the physician group than in the paramedics group (HR = 1.26. CI = 1.10 to 1.45, $p = 0.001$). There was no difference in the time to surgery between the two groups (HR = 1.06. CI = 0.95 to 1.19, $p = 0.29$).

4. Discussion

To the best of our knowledge, the current study is one of the largest cohort studies investigating the effectiveness of advanced trauma care delivered by the emergency physician in the prehospital setting. In summary, trauma patients transported with an emergency physician were injured more severely than those accompanied with only paramedics in Japan. However, we were not able to demonstrate an improvement in survival in physician-staffed ambulance when adjusting for severity of clinical status.

The improvement on outcome by a physician-staffed ambulance has still been controversial. Yequiayan JM et al. demonstrated that prehospital management by an emergency physician was associated with a significant reduction in 30-day mortality in their multicenter cohort study on patients with severe blunt trauma requiring admission to university hospital intensive care units within the first 72 h [14]. However, this study might have major institutional bias because they investigated only patients transferred to the university hospital (equivalent to level I trauma center in the U.S.) and 62% of patients treated by non-physician were first admitted to general hospitals. On the other hand, the results of a recent matched pair analysis of the trauma registry of the German Trauma Society showed no difference in mortality during hospitalization and within the first 24 h between prehospital physician and non-physician management [12]. Similarly, the present study did not find a survival benefit with the involvement of a physician in the prehospital trauma care despite the fact that we included only patients

Table 4
Primary and secondary outcome comparisons.

Logistic regression analysis	Survival OR	95% CI	p value
Survival to hospital discharge	1.160	0.967 to 1.400	0.109
Survival to ED	0.689	0.468 to 1.010	0.058
Cox proportional hazard regression analysis	HR	95% CI	p value
Time to events from the site arrival of EMS			
Hospital arrival	0.588	0.554 to 0.623	<0.001
CT scan	0.741	0.695 to 0.791	<0.001
Blood transfusion	1.261	1.097 to 1.449	0.001
Surgery	1.062	0.950 to 1.188	0.290

Multivariable logistic regression analysis for survival outcomes and Cox proportional-hazard regression analysis for other secondary outcomes were performed with adjustment for age, gender, Injury Severity Score, cause of injury, and pre-hospital vital signs (systolic blood pressure, diastolic blood pressure, respiratory rate, heart rate, and Japan Coma Scale).
OR: odds ratio, CI: confidence interval, ED: emergency department, HR: hazard ratio, EMS: emergency medical service.

with severe trauma (ISS ≥ 16). Actually, a considerable number of less severe patients receive prehospital care by a hospital physician in the real world. Therefore, we could reduce financial costs and human resources because we showed no major clinical benefit with physician involvement in prehospital trauma care.

The current study demonstrated that compared to paramedic management, prehospital advanced interventions, particularly delivery of intravenous fluid and airway management, were more frequently performed by a physician in Japanese EMS. However, the issue is that prompt prehospital treatment does not guarantee clinical benefit. For example, recent studies indicate that prehospital administration of fluid to patients with trauma could be deleterious because of impaired clotting [15,16]. Most importantly, advanced prehospital intervention is time consuming, potentially prolonging on-scene time or transportation time, which considerably affects outcome [5-7]. The current study found that prehospital time was significantly prolonged in the physician group compared to the non-physician group. This finding is controversial, possibly due to differences in study design, emergency medical systems, number of hospitals, and the country size between previous studies [4,12,17], nevertheless delayed hospital arrival was one of the reasons for the failure of the presence of a prehospital physician to improve outcome.

We evaluated not only prehospital time but also time to CT scan for diagnosis and time to blood transfusion and surgery for treatment. Diagnosis by whole-body CT scan in early trauma care significantly increases the probability of survival for patients with polytrauma [18,19]. Our study demonstrated that time to CT scan was significantly longer among patients treated by a prehospital physician than that among patients treated by paramedics. In contrast, blood transfusion was achieved significantly more rapidly in patients treated by a physician. Prehospital blood transfusion is unusual in Japan. Therefore, this difference was attributed to the prompt order for blood transfusion in the hospital. Accurate prehospital information about trauma patients provided by a physician on scene may result in rapid preparation and infusion of blood. Although variations in hospital capability could remain, early blood transfusion could be beneficial aspect by a physician-staffed ambulance. Finally, time to surgery was not significantly different between the physician and paramedics group, indicating that unaltered speed of definitive control of bleeding by operation could be one of the reasons why prehospital early advanced intervention by a physician could not show the improvement of the survival rate for trauma care.

Our study has several limitations. First, there may have been institutional bias. We did not control for the capability of each hospital for trauma care and this affects outcome. However, over 90% of the hospitals participating in the JTDB are tertiary emergency medical centers approved by the Japanese Ministry of Health, Labor and Welfare as being competent in delivering trauma care. Second, there is minimal data on exactly which procedures were performed by physicians or paramedics on scene. Our data did not contain information on some prehospital advanced procedures by a physician such as ultrasound, REBOA, and chest drainage, which might independently affect the outcome. Third, there were cases of missing data which could affect the results. Multiple

imputation (MI) was considered as a method to handle missing data [20]. However, MI may also generate bias. We chose to exclude patients with missing data because of a large study population. Fourth, there was a striking difference in prehospital intravenous fluid administrated between two cohorts. We assume that this is mainly due to the Japanese EMS system which did not allow paramedics to perform fluid administration in prehospital trauma care till it was permitted in 2014. As there are some evidence that prehospital administration of fluid to patients with trauma could be deleterious [15,16], huge difference of this single prehospital intervention could have influence on outcome. Fifth, the current study includes only participants without prehospital cardiopulmonary arrest transferred by ambulance so that the results do not fit in all trauma cases. In fact, Abe et al. demonstrated that transport by helicopter with a physician could be associated with improved survival at discharge compared to ground services using the same JTDB database [11]. In addition, efficacy of advanced life support by a prehospital physician for trauma patients with cardiopulmonary arrest compared to basic life support by paramedics could be beneficial and still debated [21,22]. Finally, we did not evaluate quality of life of surviving trauma patients because we could not obtain detailed information regarding patient status at/after discharge. However, the quality of post-trauma life is an important clinical goal in the assessment of major trauma care.

5. Conclusion

In conclusion, this nationwide retrospective cohort study failed to show a difference in mortality between non-physician staffed ambulances and physician-staffed ambulances. The presence of a physician on scene might lead to rapid resuscitation but delay definitive care.

Abbreviations

EMS   emergency medical services
REBOA   resuscitative endovascular balloon occlusion of the aorta
JTDB   Japan trauma data bank
JPTEC   Japan prehospital trauma evaluation and care
AIS   abbreviated injury scale
ISS   injury severity score
ED   emergency department
RTS   revised trauma score
TRISS   trauma and injury severity score
SBP   systolic blood pressure
DBP   diastolic blood pressure
RR   respiratory rate
HR   heart rate
SD   standard deviation
IQR   interquartile range
JCS   Japan coma scale
OR   odds ratio
CI   confidence interval
HR   hazard ratio

Conflict of interest

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

Author contributions

All of the authors jointly conceived of and designated this study. YH and TA conducted data cleaning and analyzed the data. All of the authors interpreted the data. YH drafted the manuscript. All of the authors reviewed and discussed the manuscript. All authors read and approved the final manuscript.

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