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Clinical paper

Evaluation of outcomes after EMS-witnessed traumatic out-of-hospital cardiac arrest caused by traffic collisions

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Abstract

Aim: The survival rate of patients with traumatic cardiac arrest is 3% or lower. Cardiac arrest witnessed by emergency medical services (EMS) accounts for approximately 16% of prehospital traumatic cardiac arrests, but the prognosis is unknown. We aimed to compare the 1-month survival rate of cardiac arrest witnessed by EMS with that of cardiac arrest witnessed by bystanders and unwitnessed cardiac arrest in trac trauma victims; further, the time from injury to cardiac arrest was assessed.

Methods: This analysis used the Utstein Registry in Japan and included data of 3883 patients with traumatic cardiac arrest caused by trac collisions registered between 2014 and 2019 in Japan.

Results: The 1-month survival rate was 10.9% in the EMS-witnessed cardiac arrest group; this was significantly higher than that in the bystander-witnessed (7.2%) and unwitnessed (5.6%) cardiac arrest groups ($P < 0.01$). The median time from injury to cardiac arrest was 18 min (25% quartile: 12, 75% quartile: 26).

Conclusion: The 1-month survival rate was significantly higher in the EMS-witnessed cardiac arrest group than in the bystander-witnessed and unwitnessed cardiac arrest groups. It is important to prevent progression to cardiac arrest in trauma patients with intact respiratory function and pulse rate at the time of contact with EMS. A system for early recognition of severe trauma is needed, and a doctor's car or helicopter can be requested as needed. We believe that early recognition and prompt intervention will improve the prognosis of prehospital traumatic cardiac arrest.

Keywords: Cardiac arrest, Trauma, Emergency Medical Service

Introduction

Traffic collisions are responsible for approximately 3000 deaths per year in Japan.[1] Injury due to traffic collisions is a typical injury mechanism of blunt trauma. The majority of patients with traumatic cardiac arrest (TCA) are young (mean age 39–40 years), male (79%), and injured by blunt mechanisms (67–68%).[2] Prognosis of traumatic out-of-hospital cardiac arrest (OHCA) is poor, with reported survival below 3%.[3,4] Various factors affect prognosis; these include the presence or absence of witnesses during the cardiac arrest, rapid emergency medical services (EMS) response, time from onset to cardiopulmonary resuscitation (CPR) or defibrillation, hospital care, and patient demographics, such as age, sex, and comorbidities.[5] Previous studies have shown that the prognosis of witnessed TCA is good[6]; however, detailed information regarding the bystander type is lacking.

In general, if not a trauma patient, patients with cardiac arrest witnessed by EMS exhibit signs and symptoms, such as chest pain, dyspnoea, and changes in vital signs.[7] Previous studies excluding non-cardiac causes such as trauma and acute drug overdoses have

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found that patients whose cardiac arrest was witnessed by paramedics had a higher survival rate from cardiac arrest than those whose cardiac arrest occurred before paramedics arrived.[5] Owing to the lack of similar studies in trauma, the prognosis of EMS-witnessed cardiac arrest is unknown. Moreover, previous studies did not compare prognosis based on bystander type.

This study aimed to compare the survival rate of patients with TCA due to traffic collisions who arrested after EMS arrival with that of patients who had witnessed and unwitnessed arrests before EMS arrival. Further, the time from injury to cardiac arrest was assessed.

Methods

Study design and setting

This analysis used the Utstein Registry in Japan—a retrospective, nationwide, population-based OHCA registry system and included all patients with TCA caused by traffic collisions between 1 January 2014 and 31 December 2019, who were treated by EMS. Thus, patients with TCA caused by traffic collisions were included in this study. The database was compiled by the Fire and Disaster Management Agency (FDMA) in Japan, and contained all OHCA cases that were transferred to hospitals by EMS personnel. The data set included age, sex, whether the collapse was witnessed, whether bystander CPR was performed, cause of cardiac arrest (cardiac or non-cardiac origin), first documented cardiac rhythm, whether the patient was defibrillated, whether epinephrine was administered, and whether advanced airway devices were used by the EMS.[8] These data were logically checked by the computer system and were confirmed by the implementation working group. If a data form was incomplete, the FDMA would return it to the respective fire station for completion and follow up on missing data.[9] This study was approved by the ethical review board of Nippon Sport Science University (approval No. 021-H102).

Participants

The patient flowchart is shown in Fig. 1. Records were excluded in the following cases: if the patient had missing data on the type of bystander, patient age was under 18 years, not a case of TCA, doctor's car was dispatched, no response was provided to the 1-month survival question, or an illogical value related to time, such as the arrival time being recorded earlier than the 119 call. EMS-witnessed cardiac arrest was defined as a cardiac arrest that occurred after the fire department or EMS arrived at the scene. A bystander-witnessed cardiac arrest was defined as a cardiac arrest that was witnessed by a family member, friend, colleague, or passer-by.

Data collection

The following data were extracted from the Utstein Registry in Japan: patient age, sex, type of bystander witness status, first recorded cardiac rhythm, procedures performed by EMS personnel (i.e., use of advanced airway management device, insertion of an intravenous line, adrenaline [epinephrine] administration), time of cardiac arrest, time intervals such as from 119 calls to arrival at the scene, from arrival at the scene to departure from the scene, and from departure from the scene to arrival at the hospital, prehospital return of spontaneous circulation (ROSC), 1-month survival, and Cooperative Patent Classification (CPC).

Trauma care by EMS

In Japan, the Japan Prehospital Trauma Evaluation and Care (JPTEC), which was developed with reference to the Basic Trauma Life Support of the United States, is used as a guideline for prehospital trauma care.[10] The clinical practice guidelines contained in the JPTEC aid to determine the degree of urgency and severity of injury based on the mechanism of injury, physiological and anatomical assessment, and decide on procedures and hospital destination. In

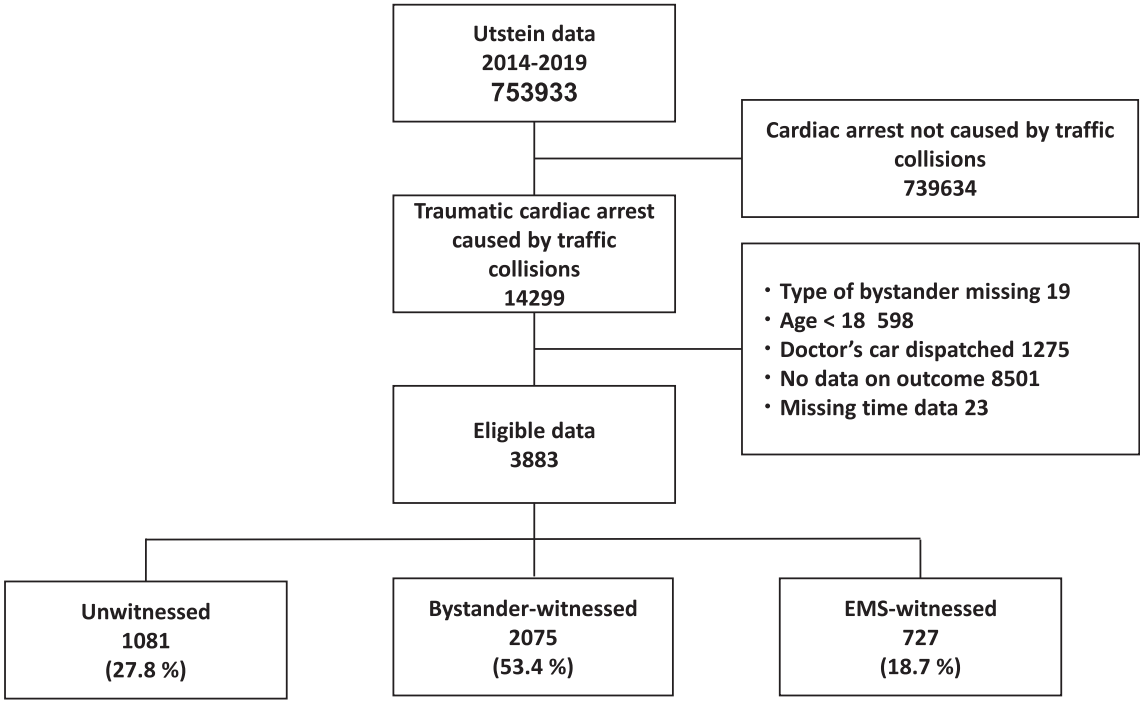

Fig. 1 – Patient flow.

patients with shock, intravenous access was performed and fluids were administered. Endotracheal intubation can be performed in the case of cardiac arrest. If the patient is not in cardiac arrest, laryngeal tube should be used or oropharyngeal airway should be secured. The field activities for traumatic cardiopulmonary arrest include Basic Life Support (BLS) followed by instrumentation to secure the airway and adrenaline administration. If the shockable rhythms is present, defibrillation should be performed.[11]

EMS unit and training

In Japan, EMS units are categorized into Emergency Medical Technician (EMT) and Emergency Life-Saving Technician (ELST). ELST are trained to perform advanced airway management and can also administer adrenaline under online medical control. There are two options to becoming certified as an ELST in Japan. The first is through the educational system within the fire department itself. To become an EMT, all fire department personnel must have received fundamental medical education in emergency care for 250 h through a training academy. After being actively engaged in the pre-hospital setting as an EMT for more than five years or 2000 h, EMTs must pass the national examination of ELST after having received at least one additional year of medical education and training at the fire academy. The second way is through the education system in an accredited EMT school or college. To become an ELST, candidates must pass the national examination of ELST after receiving medical education and training in emergency care at the certified EMT school or college for at least two years.[12]

Outcomes

The primary outcome was 1-month survival. The secondary outcomes were prehospital ROSC and a good neurological outcome (CPC 1–2); urther, the time from injury to cardiac arrest was determined.

Statistical analysis

Patients with TCA were divided into three groups: EMS-witnessed, bystander-witnessed, and unwitnessed. Comparisons of categorical variables between the groups were performed using the chi-squared test. Numerical variables were analysed using the Kruskal–Wallis test. Further, the median time from injury to cardiac arrest was calculated. Data regarding intravenous line and adrenaline administration were missing for 13.2% and 15% of TCA patients treated by EMS, respectively. Missing values were not excluded because they were not used in the statistical analysis of the outcomes; they are listed in Table 1. The logistic regression model was used to calculate the adjusted odds ratio (OR) with 95% confidence interval (CI) for better prognosis of 1-month survival. The multivariate logistic regression model was performed by adjusting for potential con-

Table 1 – Patient characteristics.

	Unwitnessed	Bystander-witnessed	EMS-witnessed	*P* value
	n = 1081	*n* = 2075	*n* = 727	
Age	61 (25% quartile: 41, 75% quartile: 75)	65 (25% quartile: 41, 75% quartile: 77)	65 (25% quartile: 41, 75% quartile: 77)	*P** < 0.05
Sex				
Male	786 (72.7%)	1,391 (67.0%)	510 (70.2%)	*P* < 0.05
Female	295 (27.3%)	684 (33.0%)	217 (30.8%)	
Bystander CPR				
Yes	169 (15.6%)	673 (32.4%)	-	-
No	912 (84.4%)	1,402 (67.6%)	-	
First monitored rhythm				
Shockable	19 (1.8%)	54 (2.6%)	17 (2.3%)	*P* = 0.326
Non-shockable	1062 (98.2%)	2021 (97.4%)	710 (97.7%)	
Intravenous line missing data 514 (13.2%)				
Yes	298 (32.2%)	572 (31.3%)	190 (30.7%)	*P* = 0.80
No	627 (67.8%)	1253 (68.7%)	429 (69.3%)	
Adrenaline missing data 585 (15.0%)				
Yes	176 (19.4%)	371 (20.8%)	125 (20.4%)	*P* = 0.71
No	729 (80.6%)	1413 (79.2%)	488 (79.6%)	
Airway management				
Yes	826 (76.5%)	1682 (81.1%)	577 (79.4%)	*P* < 0.001
No	255 (23.6%)	393 (18.9%)	150 (20.6%)	
Time				
Response time	9 min (25% quartile: 7, 75% quartile: 12)	8 min (25% quartile: 6, 75% quartile: 10)	8 min (25% quartile: 6, 75% quartile: 10)	*P** < 0.001
Scene time	24 min (25% quartile: 17, 75% quartile: 34)	22 min (25% quartile: 16, 75% quartile: 30)	24 min (25% quartile: 17, 75% quartile: 33)	*P** < 0.001

P = Pearson's chi-squared test.

*P** = Kruskal-Wallis test.

CPR, cardiopulmonary resuscitation; EMS, emergency medical services.

founders among the features listed in Table 1. Factors such as age, sex, bystander CPR, shockable rhythm, intravenous line, adrenaline, airway management, response time, scene time, EMS-witnessed, and bystander-witnessed were included. Statistical significance was defined as a two-sided $P < 0.05$ in all statistical analyses. Data were analysed using SPSS Statistics Version 28 (IBM Japan, Ltd.).

Results

Participants

Data of 753 933 OHCA patients were recorded between 1 January 2014 and 31 December 2019, of which 14 299 patients had cardiac arrest presumed to be of traumatic origin caused by traffic collisions. A total of 3883 patients with TCA were included in the analysis (Fig. 1).

Of these, 1081 patients had unwitnessed cardiac arrest (unwitnessed group), 2075 patients had cardiac arrest witnessed by a bystander (bystander-witnessed group), and 727 patients had cardiac arrest witnessed by EMS (EMS-witnessed group). Patient characteristics are shown in Table 1. Dispatch time was defined as the time from EMS call to arrival at the scene, and scene time was defined as the time from arrival at the trauma scene to arrival at the hospital.

Main results

Table 2 and Fig. 2 show the comparison of outcomes between the unwitnessed, bystander- and EMS-witnessed groups. Among the three groups, a significant difference was observed in 1-month survival (5.6% vs. 7.2% vs. 10.9%, $P < 0.01$) and prehospital ROSC (7.9% vs. 10.2% vs. 14.4%, $P < 0.01$). There was no significant difference in good neurological outcome (CPC 1–2) between the groups (1.8% vs. 2.6% vs. 3.4%, $P = 0.78$). Table 3 contains the adjusted OR of 1-month survival with TCA for each variable listed in Table 1. Subjects with EMS-witnessed groups or bystander-witnessed group were associated with better prognosis of 1-month survival, with an adjusted OR of 2.4 in EMS-witnessed group (95% CI: 1.59–3.65, $P < 0.01$) and 1.39 in bystander-witnessed group (95% CI: 0.963–2.01, $P = 0.07$).

Other analysis

We evaluated the time from injury to cardiac arrest. The time of injury was defined as the time the caller made the 119 call (dispatch time). The unwitnessed arrest and bystander-witnessed groups were excluded from the other analysis because the time of arrest could not be estimated. The median time from injury to cardiac arrest was 18 min (25% quartile: 12, 75% quartile: 26) (Fig. 3).

Discussion

The EMS-witnessed group had a significantly better prognosis than the unwitnessed and bystander-witnessed groups in terms of 1-month survival and prehospital ROSC rates. However, there was no significant difference in good neurological outcome between the three groups. Therefore, we found that witnessing of cardiac arrest by EMS personnel improved the ROSC rate and 1-month survival prognosis but did not affect good neurological outcomes. The median time from injury to cardiac arrest was 18 min.

The prognosis of TCA is poor, and the factors that affect it have been investigated. The most important predictors of survival are the presence of cardiac motion on ultrasound or a shockable initial cardiac rhythm, based on pooled unadjusted analyses.[6] Further, the presence or absence of witnesses during a cardiac arrest is an important prognostic factor. Witnessed cardiac arrest has a better prognosis than unwitnessed cardiac arrest.[2,13–17] The survival rate of EMS-witnessed TCA was reported to be 15% and 5.7%, but the statistical significance is unknown.[15,16]. In this study, the prognosis of 1-month survival in patients with EMS-witnessed TCA was found to be significantly higher than that in patients with unwitnessed and bystander-witnessed TCA. However, there was no significant difference in proportions of good neurological outcomes. Further, in this study, the 1-month survival rate in the EMS-witnessed TCA group was 10.9%, this is about halfway between the values reported in previous studies.[15,16]

In this study, approximately 80% of patients had cardiac arrest before EMS arrival and approximately 20% of patients after EMS arrival. The pathology of trauma may be different in cardiac arrest before and after EMS arrival; in the former case, airway problems

Table 2 – Primary and secondary outcomes.

	Unwitnessed		Bystander-witnessed		EMS-witnessed		*P* value
	n = 1081		*n* = 2075		*n* = 727		
Primary Outcome							
1-month survival		Adjusted residual		Adjusted residual		Adjusted residual	
Yes	60 (5.6%)	−2.8	149 (7.2%)	−0.6	79 (10.9%)	3.9	$P < 0.01$
No	1021 (94.4%)		1926 (92.8%)		648 (89.1%)		
Secondary Outcome							
ROSC		Adjusted residual		Adjusted residual		Adjusted residual	
Yes	85 (7.9%)	−3.2	212 (10.2%)	−0.3	105 (14.4%)	4.0	$P < 0.01$
No	996 (92.1%)		1863 (89.8%)		622 (85.6%)		
Good outcome							
1–2	19 (1.8%)	−1.9	54 (2.6%)	0.3	25 (3.4%)	1.7	$P = 0.78$
3–5	1062 (98.2%)		2021 (97.4%)		702 (96.6%)		

P value = Pearson's Chi-squared test.
ROSC, return of spontaneous circulation; EMS, emergency medical services.

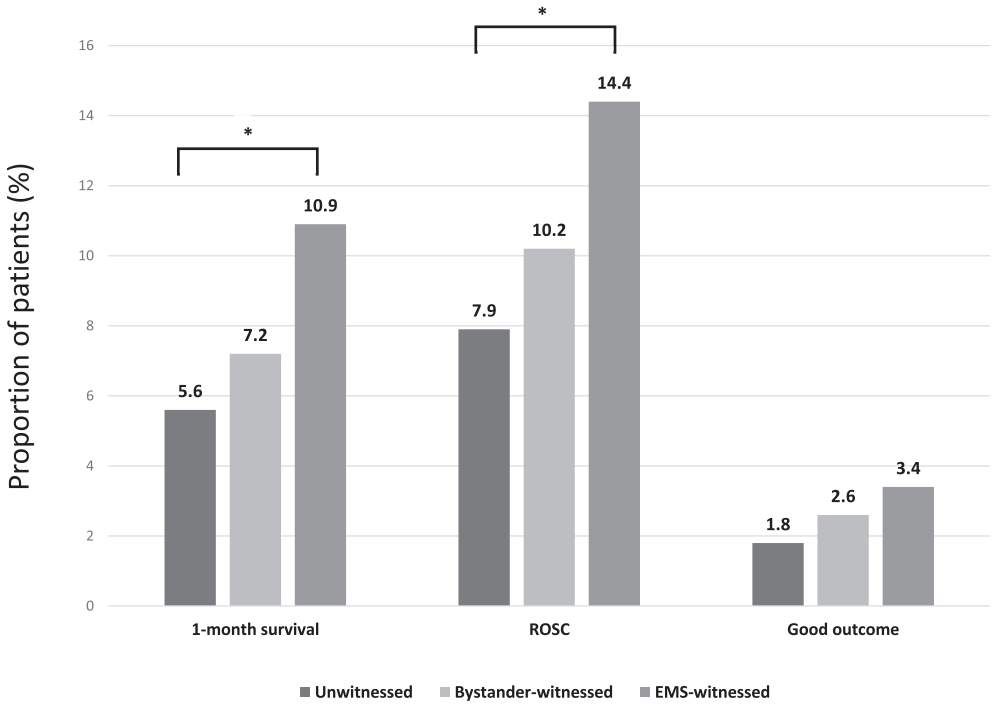

Fig. 2 – Primary and secondary outcomes.

Table 3 – Multivariate logistic regression model of characteristics.

Characteristics	OR	95% CI	*P* value
Age	1.00	0.99–1.00	0.40
Male	1.26	0.92–1.72	0.15
Bystandar CPR	0.67	0.48–0.93	<0.05
Shockable rhythm	1.31	0.59–2.92	0.51
Intravenous line	1.61	1.10–2.37	<0.05
Adrenaline	0.43	0.26–0.71	<0.01
Airway management	0.82	0.59–1.16	0.26
Response time	1.00	1.00–1.00	<0.01
Scene time	1.00	1.00–1.00	0.60
EMS-witnessed	2.42	1.60–3.66	<0.01
Bystander-witnessed	1.40	0.97–2.03	0.07

Hosmer-Lemeshow test ($P = 0.51$).

CPR, cardiopulmonary resuscitation; EMS, emergency medical services.

OR, Odds Ratio; CI, Confidence Interval.

or spinal cord injuries and injuries of the thoracic and abdominal aorta are likely causes, while in the latter case, haemorrhagic shock or obstructive shock and severe head trauma may be the cause.

In some cases, first aid by bystanders, and in some cases by doctors, increases the likelihood of preventing a cardiac arrest. Most trauma-related deaths occur at the scene of injury, especially in rural areas, where deaths often occur before EMS personnel arrive.[18,19] Bystanders who encounter an accident are able to provide first aid, such as securing an airway and stopping bleeding, even before the arrival of EMS.

The median time from injury to cardiac arrest was 18 min; this time is important for early assessment of the severity of the injury. It is too late to call for additional support after the EMS arrives at the scene. In Japan, there is a system called D-Call Net® that automatically requests the dispatch of doctors via a car or helicopter in case of serious car accidents, thus allowing for the early detection of accidents and arrival of medical staff at the scene. This system has reduced the time taken for the Helicopter Emergency Medical Services (HEMS) to arrive at the scene by 17 min, compared to before the system's introduction.[20] Regarding emergency services, previous studies have shown that shortening the EMS response times increases the survival rates of OHCA patients. The survival rate at 1 month was 20% for an EMS response time of 6 min or less, and 8% for an EMS response time of 15 min or more.[21] In some EMS systems, doctors and nurses arrive at the scene by cars or helicopters to start medical treatment in the prehospital setting; one of the most famous is Service d'Aide Medicale d'Urgence (SAMU) in France for cars and HEMS in the United Kingdom for helicopters.

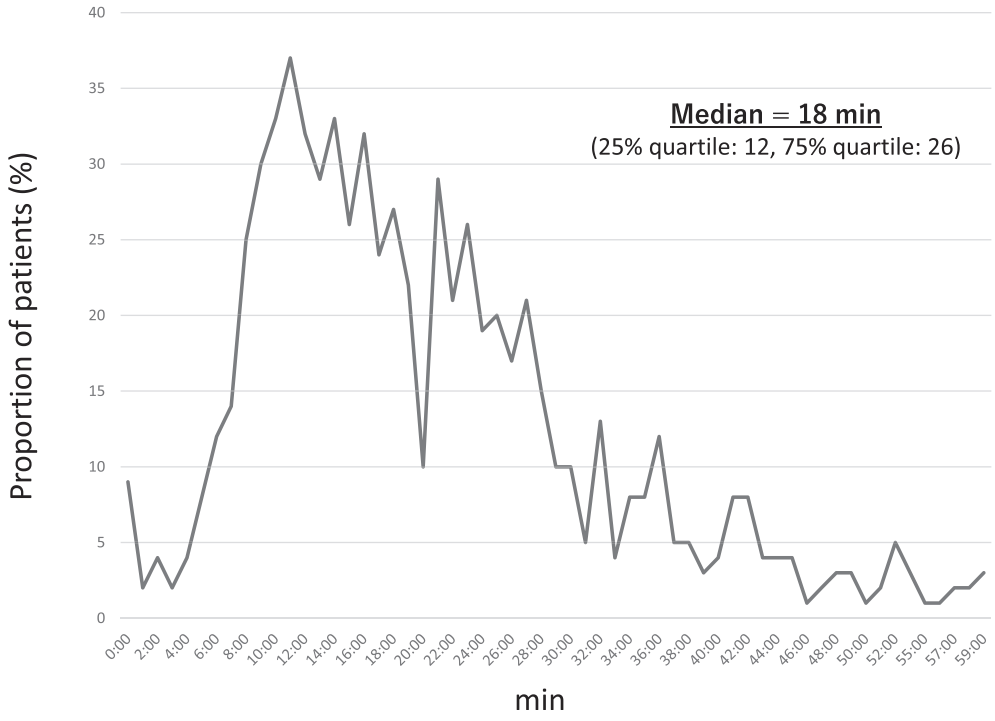

Fig. 3 – Time from injury to cardiac arrest.

Japan also has these prehospital medical systems. There are several advantages to early treatment by a physician—airway, respiratory, and circulatory management will help avoid secondary brain injury. Previous studies have reported that airway management in cases of severe head trauma improves patient outcomes.[22]

If the injury is urgent, severe, and high-risk mechanism of injury,[11] EMS will transport the patient to the nearest tertiary emergency facilities, called "Life-Saving Emergency Centers". And provide total care for critically ill and severely traumatised patients.[23] In some areas, the destination may be determined based on trauma bypass.[24] In Japan, tertiary emergency facilities are located all over the country where advanced medical care can be provided. One of the criteria for tertiary emergency facilities is to be able to respond to traumatic patients 24 hours a day.[25] There are two benefits of EMS-witnessed arrest. First, it increases the likelihood of saving the patient's life; thus, turning on the life-saving chain of survival from prehospital to in-hospital. Second, due to abnormal airway and breathing, circulation and consciousness, it affects the decision to "trauma bypass". I believe that various decisions can be made on a case-by-case basis, such as rapid intervention in the field and early transport decisions.

Overall, it is important to avoid cardiac arrest in patients with severe trauma.

Limitation

This study had several limitations. First, this study was a retrospective, non-random electronic review of patient care data that were not originally collected for this purpose. Second, many data were missing. Of the 14 299 patients, 8501 (59%) did not respond to prognosis questions. Third, the diagnoses were unknown in the Utstein database used in this study. In addition, trauma severity classifications such as the Abbreviated Injury Scale (AIS) and Injury Severity Score (ISS) were unknown. Fourth, the status of the patient before cardiac arrest, including the injury mechanism and vital signs at the injury site, was unknown.

Conclusion

To summarise, significantly higher 1-month survival and ROSC rates were observed in patients with EMS-witnessed TCA than in those with unwitnessed and bystander-witnessed TCA. However, there was no significant difference in good neurological outcomes. We found that witnessing of cardiac arrest by EMS increased the ROSC rate and 1-month survival prognosis but did not affect good neurological outcomes. Further, as the median time from injury to cardiac arrest was 18 min, it is desirable to request a doctor car or helicopter for early medical intervention before 18 min have passed from the time of injury.

Conflict of interest

None.

CRediT authorship contribution statement

Shinnosuke Kitano: Conceptualization, Methodology, Writing – original draft. **Kenji Fujimoto:** . **Kensuke Suzuki:** Methodology, Supervision. **Satoshi Harada:** . **Kenji Narikawa:** . **Marina Yamada:** Formal analysis, Writing – review & editing. **Mayumi Nakazawa:** . **Satoo Ogawa:** . **Hiroyuki Yokota:** Supervision.

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