Original Article

Prehospital advanced airway management of emergency medical service-witnessed traumatic out-of-hospital cardiac arrest patients: analysis of nationwide trauma registry

Takeshi Nishimura,[1,2] Masafumi Suga,[1,2] Atsunori Nakao,[1] Satoshi Ishihara,[2] and Hiromichi Naito[1]

[1]Department of Emergency and Critical Care Medicine, Okayama University Graduate School of Medicine, Dentistry, and Pharmaceutical Sciences, Okayama, Japan, and [2]Department of Emergency and Critical Care Medicine, Hyogo Emergency Medical Center, Nishinomiya, Japan

Aim: Survival of traumatic out-of-hospital cardiac arrest (OHCA) is poor. Early use of advanced airway management (AAM) techniques, including endotracheal intubation and supraglottic devices, are expected to contribute to the improved survival of these patients. The aim of this study was to determine whether prehospital use of AAM improves the outcomes for emergency medical service (EMS)-witnessed traumatic OHCA.

Methods: A nationwide retrospective study was carried out. Trauma patients with EMS-witnessed cardiac arrest who received cardiopulmonary resuscitation during transport were included. Patients younger than 16 years and those with missing data were excluded. We compared two groups using propensity score matching. The primary outcome was survival to discharge. The secondary outcome was return of spontaneous circulation (ROSC) on hospital arrival. A logistic regression model was used to calculate odds ratios (OR) and confidence intervals (CI).

Results: After propensity score matching, 1,346 patients were enrolled (AAM 673 versus non-AAM 673). Forty-four AAM cases (6.5%) and 39 non-AAM cases (5.8%) survived. Logistic regression analysis did not show a contribution of AAM for survival to discharge (AAM 44/673 (6.5%), non-AAM 39/673 (5.8%); OR 1.12; 95% CI, 0.70–1.76; P = 0.64). However, AAM improved ROSC on admission (AAM 141/673 (21.0%), non-AAM 77/673 (11.4%); OR 2.05; 95% CI, 1.51–2.78; P < 0.001). This tendency was consistent throughout our subgroup analysis categorized by body region of the severe injury (head trauma, torso trauma, and extremity/spine trauma).

Conclusions: Prehospital AAM among EMS-witnessed traumatic OHCA patients was not associated with survival to discharge; however, ROSC on hospital admission improved for the AAM patients.

Key words: AAM, Endotracheal intubation, JTDB, supraglottic airway, traumatic cardiac arrest

INTRODUCTION

TRAUMA IS ONE of the most common causes of death worldwide.[1] Regardless of progress in traumatology and improvements in prehospital medical systems and intensive care medicine, salvaging traumatic out-of-hospital cardiac arrest (OHCA) patients is still one of the most difficult challenges.[2] Therefore, resuscitation efforts for traumatic OHCA have been occasionally considered futile in the prehospital setting and debate continues regarding the benefit of prehospital cardiopulmonary resuscitation (CPR) in trauma.[2,3] However, some subgroups of traumatic OHCA patients are indicated as potentially salvageable.[4]

The pathophysiology of traumatic OHCA differs from that of nontraumatic (medical) OHCA.[5] As optimal oxygenation and ventilation by securing a definitive airway could be beneficial in the resuscitation process, we investigated whether secured airway management improved the outcomes of traumatic OHCA patients.

Advanced airway management (AAM), including endotracheal intubation (ETI) and the use of supraglottic airway (SGA) devices, is currently one of the most crucial methods used to secure airways for OHCA patients in the prehospital

Corresponding: Hiromichi Naito, MD, PhD, Department of Emergency, Critical Care, and Disaster Medicine, Okayama University Graduate School of Medicine, Dentistry, and Pharmaceutical Sciences, 2-5-1 Shikata, Okayama 700-8558, Japan. E-mail: naito-hiromich@s.okayama-u.ac.jp.
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setting. The European Resuscitation Council Guidelines for Resuscitation recommend to secure airway and maximize oxygenation for patients with traumatic cardiac arrest.[6] Advanced Trauma Life Support guidelines recommend performing ETI for patients with a Glasgow Coma Scale (GCS) score less than or equal to 8 and for those with a GCS score more than or equal to 2 deterioration among traumatic patients without cardiac arrest.[7] However, there is still limited evidence regarding the use of AAM for traumatic OHCA patients, especially its early use and with consideration of the injured body region. Therefore, the current study aimed to determine whether early use of prehospital AAM improves the outcomes of traumatic OHCA patients using the Japan Trauma Data Bank (JTDB), a large-scale, nationwide, multicenter trauma patient database. As various mechanisms are involved in traumatic OHCA, more robust designs are necessary to delineate whether AAM provides a survival advantage. To enhance the quality of the study and stratify the patients who might benefit the most from AAM use, this study was limited to emergency medical service (EMS)-witnessed traumatic OHCA patients.

METHODS

Emergency medical system and providers

IN JAPAN, THE fire defense headquarters of each local government manages their own EMS. Japan implemented the Anglo-American EMS system, where patients are brought to physicians by prehospital medical providers. All certified emergency medical technicians (emergency life-saving technicians, ELSTs) are allowed to use SGA devices for cardiac arrest patients if the patient's airway is unsecured. Only specially trained ELSTs, who undergo additional training compared to basic emergency medical technicians, are allowed to perform ETI under instruction from physicians, who provide navigation over the telephone when patients are in cardiac arrest. They are also allowed to give fluid resuscitation to patients in shock or with crush syndrome.[8] When an ambulance staffed with physicians is dispatched, the physicians typically perform ETI if needed.

Study design and data collection

The Okayama University Ethics Committee approved the study (K2007-002) and waived the requirement for written informed consent.

We reviewed the JTDB (2004–2017), a nationwide trauma registry. All trauma patients registered in the Data Bank were screened. The JTDB data are collected through a Web-based form and registered by emergency physicians in cooperation with medical assistants. We included patients aged 16 years old or older with traumatic OHCA occurring after leaving the scene (EMS-witnessed traumatic OHCA) who received CPR during transport. Mortality among traumatic OHCA patients is extremely low, which could give rise to selection bias. To minimize this bias and eliminate dead or nearly dead patient, we excluded patients with OHCA at the trauma scene, which was defined as patients having neither a blood pressure nor a heart rate. Also, for the same reason, patients with Abbreviated Injury Scale (AIS) scores of 6 (lethal trauma) or 9 for any body region (unknown or missing AIS), missing data on return of spontaneous circulation (ROSC) on hospital admission (ROSC defined as heart rate >0 and systolic blood pressure >0), and patients with burns and unknown prehospital AAM use were omitted.

The JTDB includes the following characteristics of patients who sustained injuries: vital signs on admission, heart rate, systolic blood pressure, respiratory rate, type and mechanism of trauma, GCS score, means of transportation (ambulance, ambulance staffed with physicians or other types of medical personnel), Injury Severity Score (ISS), AIS, Revised Trauma Score, emergent surgical intervention for hemorrhage (craniotomy, craterization, thoracotomy, celiotomy, bone fixation, arterial embolization, and operation for hemorrhage), need for transfusion within 24 h, ROSC on admission, and survival to discharge.

We compared two traumatic OHCA groups: the AAM group, defined as patients receiving AAM including prehospital ETI or use of SGA device, and the non-AAM group, defined as patients not receiving AAM. Use of the AAM was identified from the JTDB registry on hospital arrival settings. The primary outcome was survival to discharge. The secondary outcome was ROSC on admission.

Data analysis

To minimize various confounders, we carried out propensity score (PS) matching. The PS was calculated using multivariable regression to predict the likelihood of AAM versus non-AAM use based on patient characteristics that could influence the treatment assignment.[9] The PS model included patient characteristics (sex, age), mechanism of trauma (blunt or nonblunt), prehospital physician involvement (ambulance staffed with physicians or not), and head trauma, which could affect patients' prognosis for different physiological changes. A nearest neighbor matching algorithm without replacement was used. With evolving trauma care including permissive hypotension, restricted prehospital fluid resuscitation, and transfusion balance, improved survival rate was expected. Therefore, to achieve a good balance of patients' distribution, PS matching was binned with the year the patient was admitted to the hospital (2004–2008, 2009–2013, 2014–2017). Success of the PS matching process was evaluated using standardized differences for each PS variable, with an absolute standardized difference of <0.2 considered to represent good balance between the matched pairs.[10,11]

After PS matching, we undertook a univariable comparison of the AAM and non-AAM groups using conditional logistic regression to evaluate the effect of prehospital AAM on ROSC and survival to discharge.[12] The results of logistic regression are described using odds ratios (OR) and 95% confidence intervals (CI).

Furthermore, we undertook a subgroup analysis using conditional logistic regression analysis based on body regions where the severe injury occurred, as physiological impact could differ depending on the injury site (severe head injury, severe torso (chest or abdominal) injury, severe extremity/spine injury).[13] Severe injury was defined as AIS ≥ 3. The same analyses were applied for each respective subgroup.

Statistical analyses were carried out using STATA/IC 15 (StataCorp, Lakeway, TX, USA).

RESULTS

Patient flowchart and baseline characteristics

AMONG 294,274 AVAILABLE patients in the JTDB, 8,843 patients with EMS-witnessed traumatic OHCA receiving CPR during transport were eligible. After excluding patients, a total of 5,144 patients were enrolled in the study. Of those patients, 740 had AAM performed in prehospital settings and 4,404 patients were transported without AAM (Fig. 1).

Table 1 shows patient characteristics. Patients in the AAM group were more frequently transported by ambulances staffed with physicians (non-AAM, 4.5%; AAM, 30.1%). The AAM group patients received intravenous access (non-AAM, 16.5%; AAM, 46.8%) and defibrillation (non-AAM, 2.4%; AAM, 4.3%) more frequently. The incidence of severe chest injury was similar in both groups (non-AAM, 68.7%; AAM, 68.8%), and consequently,

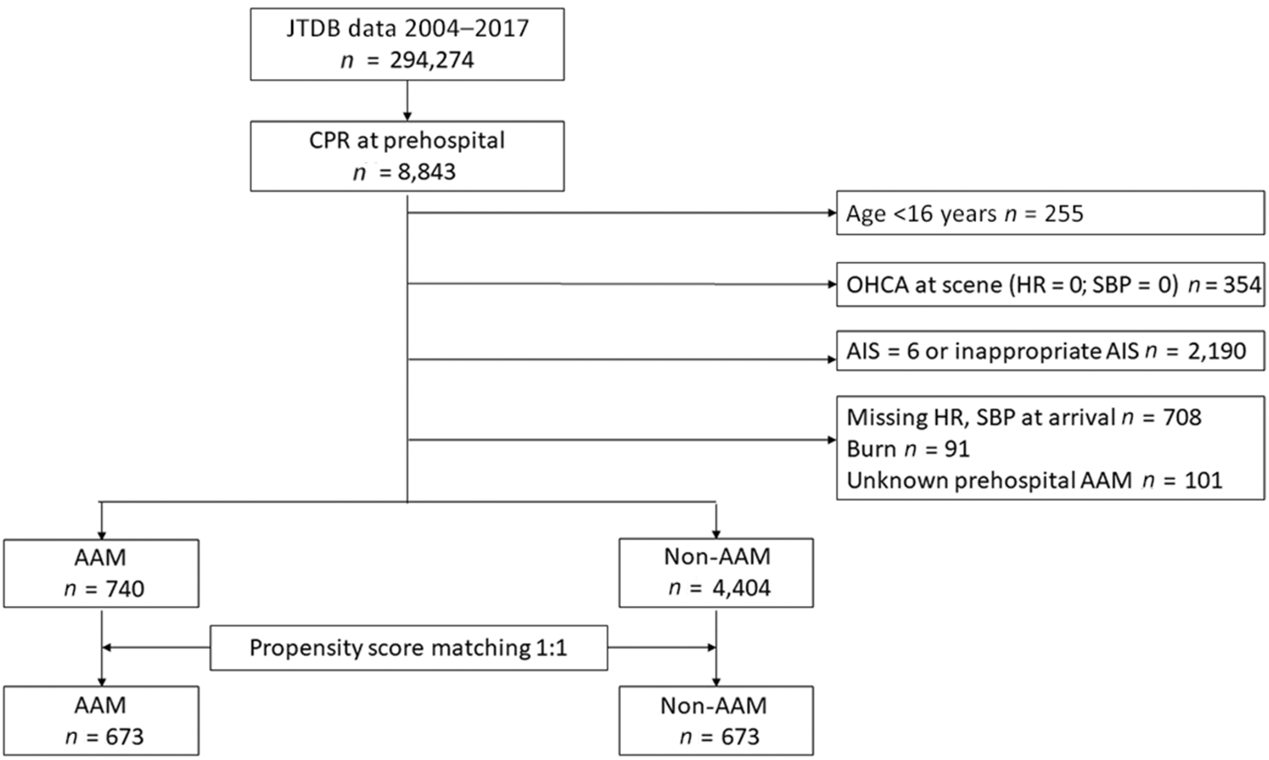

Fig. 1. Flowchart of patients analyzed in the study. AAM, advanced airway management; AIS, Abbreviated Injury Scale; CPR, cardiopulmonary resuscitation; HR, heart rate; JTDB, Japan Trauma Data Bank; OHCA, out-of-hospital cardiac arrest; SBP, systolic blood pressure.

Table 1. Characteristics and epidemiology of enrolled patients with emergency medical service-witnessed traumatic out-of-hospital cardiac arrest

	Non-AAM *n* = 4,404	AAM *n* = 740	*P*-value
Age, years; mean (SD)	52.9 (20.5)	54.1 (20.5)	0.140
Gender, *n* (%)			
Male	2,999 (68.1)	517 (69.9)	0.430
Time period			
2004–2008	851 (19.3)	131 (17.7)	0.061
2009–2013	2,265 (51.4)	361 (48.7)	
2014–2017	1,288 (29.2)	248 (33.5)	
Type of trauma			
Blunt	4,029 (91.5)	692 (93.5)	0.089
Penetrating	263 (6.0)	38 (5.1)	
Other	112	10	
Means of transportation			
Ambulance	4,051 (92.0)	381 (51.5)	<0.001
Car staffed with doctor	199 (4.5)	223 (30.1)	
Other	112	136	
EMS intervention			
IV access	725 (16.5)	346 (46.8)	<0.001
Defibrillation	107 (2.4)	32 (4.3)	0.003
ISS	29 (20–41)	29 (24–41)	0.100
AIS ≥ 3			
Head	2,146 (48.7)	355 (48.0)	0.700
Chest	3,027 (68.7)	509 (68.8)	0.980
Abdomen	321 (7.3)	76 (10.3)	0.005
Extremity/spine	2,008 (45.6)	329 (44.5)	0.570
Vitals on hospital admission, median (IQR)			
SBP	0 (0–0)	0 (0–0)	<0.001
HR	0 (0–0)	0 (0–0)	<0.001
RR	0 (0–0)	0 (0–0)	<0.001
GCS	3 (3–3)	3 (3–3)	0.140
Surgical intervention within 24 h			
Craniotomy	23 (0.52)	6 (0.81)	0.330
Craterization	30 (0.68)	12 (1.6)	0.009
Thoracotomy	622 (14.1)	135 (18.2)	0.003
Celiotomy	138 (3.1)	42 (5.7)	<0.001
Bone fixation	34 (0.77)	5 (0.68)	0.780
TAE	50 (1.1)	15 (2.0)	0.044
Arrest hemorrhage	57 (1.3)	25 (3.4)	<0.001
Blood transfusion within 24 h	694 (15.8)	163 (22.0)	<0.001
RTS, median (IQR)	0 (0–0)	0 (0–0)	<0.001

Data are shown *n* (%) unless otherwise indicated. AAM, advanced airway management; AIS, Abbreviated Injury Scale; EMS, emergency medical service; GCS, Glasgow Coma Scale; HR, heart rate; ISS, Injury Severity Score; IV, intravenous; RR, respiratory rate; RTS, Revised Trauma Score; SBP, systolic blood pressure; SD, standard deviation; TAE, transarterial embolization.

thoracotomy was performed for some cases in both groups (non-AAM, 14.1%; AAM, 18.2%). The AAM group was more likely to receive transfusion within 24 h compared to the non-AAM group (non-AAM, 15.8%; AAM, 22.0%).

Propensity-matched cohort analyses

Table 2 shows results of the PS matching. We matched 1,346 patients in a 1:1 ratio (non-AAM, 673 patients; AAM,

Table 2. Demographics of patients with emergency medical service-witnessed traumatic out-of-hospital cardiac arrest treated with advanced airway management (AAM group) and the non-AAM group for matched data

	Non-AAM n = 673	AAM n = 673	Absolute SMD
Age, years; mean (SD)	55.2 (20.9)	53.7 (20.5)	0.069
Gender			
Male	470 (69.8)	464 (68.9)	0.019
Time period			
2004–2008	101 (15.0)	101 (15.0)	–
2009–2013	342 (50.8)	342 (50.8)	–
2014–2017	230 (34.2)	230 (34.2)	–
Type of trauma			
Blunt	621 (92.3)	628 (93.3)	0.040
Prehospital physician involvement	180 (26.7)	180 (26.7)	0.000
ISS, median (IQR)	26 (21–41)	29 (24–41)	0.049
Head trauma	343 (51.0)	379 (56.3)	0.107

Data are shown n (%) unless otherwise indicated. IQR, interquartile range; ISS, Injury Severity Score; SD, standard deviation; SMD, standardized mean difference.

673 patients). The mean ages were 55.2 (standard deviation, 20.9) years in the non-AAM group and 53.7 (standard deviation, 20.5) years in the AAM group. The same number of patients (180) were transported by ambulances staffed with physicians in the AAM group and non-AAM group, respectively. The median ISS was 26 (IQR, 21–41) in the non-AAM group and 29 (IQR, 24–41) in the AAM group.

The results of primary and secondary outcomes are shown in Table 3. Thirty-nine cases (5.8%) in the non-AAM group and 44 cases (6.5%) in the AAM group survived. As a secondary outcome, 77 cases (11.4%) in the non-AAM and 141 cases (21.0%) in the AAM group had ROSC on hospital admission. Conditional logistic regression analysis revealed that prehospital AAM was associated with the increase in ROSC on hospital admission (OR 2.05; 95% CI, 1.51–2.78, P < 0.001); however, prehospital AAM was not associated with survival to discharge (OR 1.12; 95% CI, 0.70–1.76; P = 0.64) in this analysis.

Table 4 shows the results of the subgroup analysis. Return of spontaneous circulation improved significantly in all groups (severe head injury: OR 1.68; 95% CI, 1.05–2.68; P = 0.03; severe torso injury: OR 2.46; 95% CI, 1.56–3.88; P < 0.001; severe extremity/spine injury: OR 2.73; 95% CI, 1.37–5.44; P = 0.004). However, survival to discharge did not improve (severe head injury: OR 1.17; 95% CI, 0.54–2.52; P = 0.70; severe torso injury: OR 1.00; 95% CI, 0.48–2.10; P = 1.00; severe extremity/spine injury: OR 1.13; 95% CI, 0.43–2.92; P = 0.81), respectively.

DISCUSSION

OUR RESULTS SHOWED that the use of prehospital AAM did not improve survival to discharge for EMS-witnessed traumatic OHCA patients. However, prehospital AAM was positively associated with ROSC for patients with EMS-witnessed traumatic OHCA. Based on increasing evidence of exceedingly poor outcomes and low survival rates of traumatic OHCA even following CPR, these studies have defined criteria for prehospital withholding or termination of CPR for trauma patients.[14,15] Terminating resuscitation should be considered when there are no signs of life on the scene or no response to field resuscitation efforts with minimal interrupted CPR.[16]

However, several studies have indicated that nonnegligible traumatic OHCA patients who might not be resuscitated if the proposed guidelines of termination of resuscitation rules are strictly applied, could survive.[4,17] Practices could differ depending on geographic region or trauma transport system. Because it would be quite difficult to identify predictors for survival among traumatic OHCA patients following CPR, treatment decisions should not be made on the

Table 3. Primary and secondary outcomes in this study of patients with emergency medical service-witnessed traumatic out-of-hospital cardiac arrest

	Non-AAM	AAM	OR	95% CI	P-value
ROSC on admission	77/673 (11.4%)	141/673 (21.0%)	2.05	1.51–2.78	<0.001
Survival to discharge	39/673 (5.8%)	44/673 (6.5%)	1.12	0.70–1.76	0.64

Conditional logistic regression analysis revealed that return of spontaneous circulation (ROSC) on admission was associated with prehospital advanced airway management (AAM), but not associated with survival to discharge. CI, confidence interval; OR, odds ratio.

Table 4. Subgroup analysis for return of spontaneous circulation (ROSC) and survival to discharge among trauma patients grouped by injured body part

	Cases		OR	95% CI	*P*-value
Head AIS ≥ 3	649	ROSC on admission	1.68	1.05–2.68	0.030
		Survival to discharge	1.17	0.54–2.52	0.700
Torso (chest or abdominal) AIS ≥ 3	1,007	ROSC on admission	2.46	1.56–3.88	<0.001
		Survival to discharge	1.00	0.48–2.10	1.000
Extremity/spine AIS ≥ 3	628	ROSC on admission	2.73	1.37–5.44	0.004
		Survival to discharge	1.13	0.43–2.92	0.810

AIS, Abbreviated Injury Scale; CI, confidence interval; OR, odds ratio.

scene, but rather in the well-controlled atmosphere of the emergency department.

Our results suggest that AAM for selected trauma OHCA patients seems justifiable. We are aware of several studies showing that prehospital AAM is not beneficial for improving mortality in trauma patients.[2,13,18] Tsur *et al*.[19] showed prehospital definitive airway did not benefit the improvement of survival. However, the survival rates in their series were 77.6% for secured airway patients and 78.0% for failed definitive airway patients. Thus, the benefits of AAM for improved prognosis among OHCA patients have been controversial and could depend on the etiologies of traumatic OHCA.

Factors associated with favorable traumatic OHCA outcomes may include injury type (penetrating versus blunt trauma), presence of organized cardiac rhythm on first EMS arrival, short duration of CPR, and short prehospital time.[17] Several studies that undertook subgroup analyses of traumatic OHCA survivors found that traumatic OHCA with hypoxia is associated with relatively good outcomes.[20,21] Survivors with AAM in our study could be patients who suffered from hypoxic insult leading to traumatic OHCA.

Although injury severity and region might affect patient mortality, these factors have not been extensively analyzed in previous publications.[3,22] Prehospital AAM was reported to improve neurological functions among patients with severe traumatic brain injury,[23] which could indicate potential prehospital AAM benefits among traumatic OHCA in specific conditions. However, we failed to show the benefit of AAM in head trauma-associated OHCA, because the frequency of head trauma in our study was similar between the AAM (56.3%) and non-AAM (51.0%) groups.

Our study included levels of trauma severity as variables and eliminated unwitnessed OHCA. A previous study using the Japanese Utstein Registry data bank showed that advanced life support carried out by physicians was associated with a higher chance of 1-month survival compared to those carried out by EMS.[24] Although this report recorded elapsed time, the information on trauma such as ISS or location of injury were limited. In addition, patients with unwitnessed OHCA were enrolled, which might cause a misunderstanding of the results. Our analysis including traumatic severity as a variable guarantees quality in the study of prehospital AAM use.

Prehospital activity of physicians could affect the prognosis of traumatic OHCA patients. The study addressing prehospital activity reported that ambulances staffed with physicians may improve the survival rate among severe trauma patients.[25] Furthermore, compared to patients transported by EMTs only, those transported by ambulances staffed with physicians are likely to receive not only airway protection, but also further aggressive resuscitation. To eliminate these biased factors, we applied this factor as a variable in the analysis, and PS matching was considered an ideal method to compare the effectiveness of AAM alone.

Japan's unique prehospital delivery system should be taken into account when adapting our results for other countries. The AAM rate among nontraumatic OHCA patients varies widely in Japan,[26] and AAM use depends on a number of factors including transfer time, patient characteristics, EMS personnel skill, and physicians' discretion in charge region-specific online medical control.[27] Thus, the standard clinical criteria of AAM in Japan is not entirely established and could vary from region to region. Furthermore, treatments allowed for ELST differ in different regions/countries. Effectiveness of prehospital AAM use in different prehospital settings should be further discussed.

LIMITATIONS

OUR STUDY HAS several limitations. First, this is a retrospective study, which might cause information bias. Second, differentiation between ETI and SGA device use in the AAM group was not possible. Third, the time duration between OHCA onset and hospital admission could not be detected in this data. Finally, the etiology/nature of OHCA was not considered, although the causes of OHCA may often be complicated and complex.

CONCLUSIONS

PREHOSPITAL AAM AMONG traumatic OHCA patients was not associated with survival to discharge; however, it was associated with improvement of ROSC. This tendency was consistent through all subgroups categorized by body regions of the severe injuries. Emergency care providers should be aware that ROSC was achieved with prehospital AAM in some patient subgroups with traumatic OHCA.

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DISCLOSURE

APPROVAL OF THE research protocol with approval no. and committee name: Approved by the Okayama University Ethics Committee (K2007-002).

Informed consent: N/A.

Registry and registration no. of the study/trial: N/A.

Animal studies: N/A.

Conflict of interest: None.

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