Prehospital endotracheal intubation for traumatic out-of-hospital cardiac arrest and improved neurological outcomes

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ABSTRACT

Background Patients with traumatic out-of-hospital cardiac arrest (t-OHCA) require on-scene airway management to maintain tissue oxygenation. However, the benefits of prehospital endotracheal intubation remain unclear, particularly regarding neurological outcomes. Therefore, this study aimed to evaluate the association between prehospital intubation and favourable neurological outcomes in patients with t-OHCA.

Methods This retrospective cohort study used a Japanese nationwide trauma registry from 2019 to 2021. It included adult patients diagnosed with traumatic cardiac arrest on emergency medical service arrival. Glasgow Outcome Scale (GOS) scores, survival at discharge and presence of signs of life on hospital arrival were compared between patients with prehospital intubation and those with supraglottic airway or manual airway management. Inverse probability weighting with propensity scores was used to adjust for patient, injury, treatment and institutional characteristics, and the effects of intubation on outcomes averaged over baseline covariates were shown as marginal ORs.

Results A total of 1524 patients were included in this study, with 370 undergoing intubation before hospital arrival. Prehospital intubation was associated with favourable neurological outcomes at discharge (GOS≥4 in 5/362 (1.4%) vs 10/1129 (0.9%); marginal OR 1.99; 95% CI 1.12 to 3.53; p=0.021) and higher survival to discharge (25/370 (6.8%) vs 63/1154 (5.5%); marginal OR 1.43; 95% CI 1.08 to 1.90; p=0.012). However, no association with signs of life on hospital arrival was observed (65/341 (19.1%) vs 147/1026 (14.3%); marginal OR 1.09; 95% CI 0.89 to 1.34). Favourable outcomes were observed only in patients who underwent intubation with a severe chest injury (Abbreviated Injury Score ≥3) and with transportation time to hospital >15 min (OR 14.44 and 2.00; 95% CI 1.89 to 110.02 and 1.09 to 3.65, respectively).

Conclusions Prehospital intubation was associated with favourable neurological outcomes among adult patients with t-OHCA who had severe chest injury or transportation time >15 min.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Effects of prehospital intubation on survival and neurological outcomes of patients with traumatic out-of-hospital cardiac arrest (t-OHCA) are unknown.

WHAT THIS STUDY ADDS

⇒ In this Japanese registry study involving 1524 patients with t-OHCA, prehospital intubation was associated with favourable neurological function (Glasgow Outcome Scale ≥4) at discharge among adult patients with t-OHCA. This benefit was observed only in patients with severe chest injury as opposed to those without severe chest injury, younger as opposed to older patients and those with transportation time >15 min as opposed to those with shorter transportation times.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Intubation appears beneficial in prehospital treatment of t-OHCA only when severe chest injury or prolonged transportation is present.

INTRODUCTION

Traumatic out-of-hospital cardiac arrest (t-OHCA) has dismal consequences with unfavourable neurological function even among survivors.[1–3] Severe head injury and massive torso haemorrhage are the major causes of death in patients with t-OHCA.[1 4] Thus, emergency temporary haemostasis with appropriate oxygenation to maintain organ function plays an important role in the resuscitation of patients with t-OHCA.[5] Although the available therapeutic options are limited in prehospital settings, optimal interventions before hospital arrival in patients with t-OHCA are necessary to ensure favourable outcomes.[6]

Although most patients with t-OHCA require on-scene airway management,[7] the benefits of prehospital intubation, rather than supraglottic airway devices or manual jaw-thrust manoeuvre, remain unclear with conflicting results.[8–10] A retrospective study of 2300 patients with t-OHCA showed that neither prehospital intubation nor supraglottic airway devices were associated with increased odds of survival.[8] Conversely, another study of patients with t-OHCA transported by a physician-staffed helicopter reported that prehospital intubation improved the likelihood of return of spontaneous circulation.[9]

In addition to the controversy about survival benefits, the literature is sparse regarding neurological outcomes of prehospital intubation, which has impeded the development of a uniform resuscitation protocol for emergency medical services

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(EMS). A recent study investigating EMS practice for traumatic cardiac arrest reported that endotracheal intubation was performed in only one-third of patients.[11] Moreover, optimal candidates for prehospital intubation have not yet been identified. Thus, it is necessary to identify patients who might benefit from prehospital intubation to enable simple decision-making in advanced airway management.

Therefore, this study examined Japanese nationwide trauma data to evaluate the association between prehospital endotracheal intubation and favourable neurological outcomes in patients with t-OHCA.

METHODS

Study design and setting

This was a retrospective cohort study using prospectively collected data from the Japan Trauma Data Bank (JTDB). The JTDB is a nationwide trauma registry established in 2003 by the Japanese Association for the Surgery of Trauma and the Japanese Association for Acute Medicine.[12] More than 250 tertiary care centres participated in the JTDB. As the JTDB is a database for patients with moderate to severe injury, those with non-severe injury following non-traumatic diseases, such as mild head injury after a fall due to non-t-OHCA, were not included. Prehospital and in-hospital data were collected by EMS personnel and treating physicians, respectively, and entered into the database at each hospital. Before initiating the study, all collaborating hospitals obtained individual local institutional review board approval to participate in the trauma database. The requirement for informed consent was waived by the institutional review board because of the anonymous nature of the data.

In Japan, the ambulance crew consists of three EMS personnel who can perform cardiopulmonary resuscitation according to the American Heart Association and International Liaison Committee on Resuscitation guidelines. Most EMS crews have an emergency life-saving technician certified to obtain intravenous access and place a supraglottic airway device. Additionally, in more than 80% of ambulances, the EMS crew has a paramedic who can perform endotracheal intubation. However, no EMS personnel are authorised to perform more invasive trauma life support interventions, such as intraosseous access or needle/tube thoracostomy.[12] Furthermore, a physician-staffed ambulance is available based on a regional medical system, which is usually dispatched from a tertiary care centre in a city. Physicians on ambulances can perform more invasive procedures depending on the available equipment and their skills. However, surgical haemostasis for major bleeding is not feasible in physician-staffed ambulances.[12]

In Japan, current practice recommends airway evaluation and management in all patients with t-OHCA, and airway management methods, such as endotracheal intubation, supraglottic device and manual jaw-thrust manoeuvre, are selected by EMS personnel. In-hospital resuscitation, including intubation, follows a management protocol developed by the Japanese Association for the Surgery of Trauma based on the Advanced Trauma Life Support training programme of the American College of Surgeons.[13]

Study population

Data from the JTDB on patients diagnosed with t-OHCA between 2019 and 2021 were retrospectively reviewed. This study included trauma patients aged ≥18 years with cardiac arrest at the scene (no measurable BP and unresponsive to any stimuli on EMS arrival at the scene) who required airway management (intubation, supraglottic device or any manual manoeuvre) before hospital arrival. Patients transported from another hospital and those with transportation time >60 min were excluded, whereas those with missing outcome values were not excluded.

Data collection and definitions

Data abstracted from the database included age, sex, Charlson Comorbidity Index score, activity of daily living (ADL) dependency, mechanism of injury, prehospital resuscitative procedures, such as fluid administration and transfusion, the presence of a physician at prehospital, Abbreviated Injury Scale (AIS) score, Injury Severity Score (ISS), transportation time, presence of signs of life on hospital arrival, emergency haemostatic procedures, including surgery and resuscitative endovascular balloon occlusion of the aorta (REBOA), days of ventilator use, length of intensive care unit (ICU) and hospital stay, and survival status and neurological function at hospital discharge, which was assessed using the Glasgow Outcome Scale (GOS).[14] Data on indications for prehospital intubation and the haemodynamic status during and after intubation were unavailable in the database.

Transportation time was the time from EMS arrival at the scene to hospital arrival. The presence of signs of life on hospital arrival, including pupillary response, spontaneous ventilation, extremity movement or cardiac electrical activity, was determined by the treating physician.

Outcome measures

The primary outcome was neurological function at discharge, which was evaluated using the GOS. The unfavourable function was defined as GOS≤3, with 1 indicating dead, 2 indicating vegetative state (unable to interact) and 3 indicating severe disability (unable to live independently), whereas the favourable function was defined as GOS≥4, with 4 indicating moderate disability (unable to return to work) and 5 indicating good recovery (able to return to work).[14] The secondary outcomes included survival at discharge, presence of signs of life on hospital arrival, days of ventilator use, length of ICU and hospital stay, and frequency of in-hospital treatment, including ED thoracotomy, aortic clamp, craniotomy, laparotomy and REBOA use.

Statistical analysis

The primary outcome was compared between patients with prehospital intubation and those with supraglottic airway or manual airway management. Inverse probability weighting (IPW) with propensity scores was used to adjust background characteristics between the two groups.[15] The propensity score for the average treatment effect was calculated using a logistic regression model fitted with generalised estimating equations to estimate the probability of conducting prehospital intubation and to account for within-institution clustering.[16,17] Before generalised estimating equation model development, missing non-outcome values were replaced with a set of substituted plausible values by creating five filled-in complete datasets using multiple imputations by the chained equation method. The estimated associations in each of the imputed datasets were averaged to obtain the overall estimated associations.[18]

Relevant covariates for the propensity score calculation were selected from known or possible predictors for performing prehospital intubation and predicting clinical outcomes in patients with t-OHCA.[16,19] These covariates included age, sex, Charlson Comorbidity Index, ADL, mechanism of injury, prehospital procedures (fluid administration and transfusion), presence of a physician at prehospital, transportation time and injury severity (ISS and AIS in each region).[1 8–10 20 21] IPW analysis was performed as an adjusted analysis in which the primary outcome was compared using the χ^2 test. The secondary outcomes were evaluated using the χ^2 test, ORs or differences in medians using the Hodges-Lehmann estimator. Furthermore, IPW analysis was performed as a sensitivity analysis by excluding patients with propensity score <1st percentile and >99th percentile to avoid extreme weight.[15] In addition, E-value was calculated for the OR for primary outcome to evaluate how sensitive the primary outcome is to residual confounding.[22]

Subgroup analysis was performed to investigate the association between prehospital intubation, clinical characteristics and neurological function at discharge. Targeted subgroups were selected based on previous research regarding t-OHCA, and the IPW of the primary outcome was repeated for each subgroup. Patients were divided into groups according to their age (<65 years vs ≥65 years), presence of severe head or chest injury (AIS in the head or chest <3 vs ≥3) and transportation time (≤15 min vs >15 min).

Descriptive statistics were presented as median (IQR) or number (percentage). Results were presented as a standardised difference and 95% CI, with a standardised difference <0.1 considered insignificant.[16] The hypothesis was tested on the primary and selected secondary outcomes, with a two-sided α threshold of 0.05 considered significant. All statistical analyses were performed using IBM Statistical Package for the Social Sciences V.29.0 (IBM).

Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

RESULTS

Patient characteristics

A total of 88 817 trauma patients were identified from the database during the study period. Among them, 1524 adult patients who were transported with a diagnosis of cardiac arrest at the scene and underwent airway management before hospital arrival were included in this study. Of the 1524 patients, 370 (24.3%) underwent prehospital intubation (figure 1).

Table 1 shows patient characteristics. Patients with prehospital intubation were older and had higher ISS and longer transportation time than those without prehospital intubation. Additionally, a greater number of patients with prehospital intubation had ADL dependency, were attended by a physician prehospital and received fluid/transfusion during transportation. The AIS scores for each body region were comparable between patients with and without prehospital intubation.

After missing values were imputed, a propensity model was developed to predict the likelihood of performing prehospital intubation. Patient characteristics after IPW are shown with standardised differences in table 1. Differences in covariates, including patient characteristics, prehospital resuscitation and injury severity, were successfully attenuated using the propensity score (standardised difference <0.1).

Figure 1 Patient flow diagram. A total of 88 817 trauma patients were identified from the database during the study period. Among them, 1524 adults who were diagnosed with cardiac arrest at the scene and underwent airway management before hospital arrival were included in this study. Of the 1524 patients, 370 (24.3%) underwent prehospital intubation.

Table 1 Patient characteristics

	Before IPW			After IPW		
	Prehospital intubation	No prehospital intubation	Standardised difference	Prehospital intubation	No prehospital intubation	Standardised difference
Case	370	1154				
Demographics						
Age, years, median (IQR)	67 (47–81)	61 (43–77)	0.190	68 (55–83)	62 (44–77)	0.077
Sex, male, n (%)	257 (70.0)	741 (64.6)	0.296	964 (65.1)	1010 (66.0)	0.018
Charlson Comorbidity Index, median (IQR)	0 (0–0)	0 (0–0)	0.094	0 (0–0)	0 (0–0)	0.046
Dependent ADL, n (%)	32 (9.2)	47 (4.5)	0.197	84 (5.7)	90 (5.9)	0.009
Mechanism of injury, blunt, n (%)	266 (93.7)	936 (94.4)	0.005	1373 (92.7)	1420 (92.7)	0.001
Prehospital treatment, n (%)						
Physician presence	170 (45.9)	111 (9.6)	1.113	286 (19.3)	290 (18.9)	0.010
Intravenous line/fluid administration	246 (66.5)	353 (30.6)	2.170	579 (39.1)	602 (39.3)	0.003
Transfusion	2 (0.5)	0 (0.0)	0.182	2 (0.1)	0 (0.0)	0.052
Injury Severity Score, median (IQR)	25 (22–41)	25 (17–36)	0.119	25 (25–38)	25 (17–38)	0.070
Abbreviated Injury Scale, median (IQR)						
Head/neck	3 (0–5)	3 (0–4)	0.014	3 (0–5)	3 (0–4)	0.044
Face	0 (0–0)	0 (0–0)	0.015	0 (0–0)	0 (0–0)	0.048
Chest	3 (0–5)	3 (0–4)	0.093	3 (0–5)	3 (0–4)	0.091
Abdomen	0 (0–0)	0 (0–0)	0.084	0 (0–0)	0 (0–0)	0.024
Extremity/pelvis	0 (0–3)	0 (0–3)	0.059	0 (0–2)	0 (0–3)	0.061
Surface	0 (0–0)	0 (0–0)	0.064	0 (0–0)	0 (0–0)	0.001
Transportation time*, min, median (IQR)	30 (23–42)	23 (18–31)	0.645	26 (18–34)	25 (19–34)	0.055

*Transportation time was the time from emergency medical service arrival at the scene to hospital arrival.
ADL, activity of daily living; IPW, inverse probability weighting.

Neurological function at discharge and secondary outcomes

The number of patients with favourable neurological function (GOS≥4) at discharge was higher among those with prehospital intubation than among those without (2.4% vs 1.2%; OR 1.99; 95% CI 1.12 to 3.53; p=0.021; table 2). Sensitivity analysis by IPW after excluding patients with propensity score <1st percentile and >99th percentile to avoid extreme weight revealed an association between prehospital intubation and more frequent favourable neurological outcomes (OR 2.28; 95% CI 1.29 to 4.01; online supplemental table S1). In addition, the E-value test for residual confounding was 3.39 for the primary outcomes (a strong confounder having OR >3.39 is needed to

Table 2 Prehospital intubation and clinical outcomes

	Prehospital intubation (n=370)	No prehospital intubation (n=1154)	P value	OR (95% CI)	Median difference (95% CI)
Favourable neurological function at discharge, GOS≥4					
Unadjusted, n/total (%)	5/362 (1.4)	10/1129 (0.9)			
IPW, %	2.4	1.2	0.021	1.99 (1.12 to 3.53)	
Survival to discharge, %					
Unadjusted, n/total (%)	25/370 (6.8)	63/1154 (5.5)			
IPW, %	8.1	5.8	0.012	1.43 (1.08 to 1.90)	
Signs of life* on hospital arrival, %					
Unadjusted, n/total (%)	65/341 (19.1)	147/1026 (14.3)			
IPW, %	17.2	15.9	0.376	1.09 (0.89 to 1.34)	
Length of treatment, days, mean, median (IQR)					
Hospital stay	19, 9 (4–31)	22, 10 (3–26)			0 (–1 to 4)
ICU stay	7, 5 (2–8)	8, 5 (2–10)			0 (–2 to 0)
Ventilator use	12, 7 (2–18)	17, 7 (2–16)			0 (–2 to 1)
In-hospital treatment, %					
ED thoracotomy	19.2	25.0		0.71 (0.60 to 0.84)	
Aortic clamp	17.4	23.0		0.70 (0.59 to 0.84)	
Craniotomy	1.1	1.2		0.92 (0.47 to 1.81)	
Laparotomy	1.0	1.7		0.62 (0.32 to 1.17)	
REBOA	14.5	12.3		1.21 (0.98 to 1.49)	

Secondary outcomes were compared using IPW analyses.
*Signs of life included pupillary response, spontaneous ventilation, palpable pulse, extremity movement or cardiac electrical activity.
GOS, Glasgow Outcome Scale; ICU, intensive care unit; IPW, inverse probability weighting; REBOA, resuscitative endovascular balloon occlusion of the aorta.

Table 3 Prehospital intubation and favourable neurological outcomes in subgroup analyses

	Prehospital intubation	No prehospital intubation	OR	95% CI
Age				
<65 years (n=705)	3.6% (2.2–4.9%)	0.7% (0.1–1.2%)	5.60	2.13 to 14.72
≥65 years (n=786)	1.2% (0.4–2.0%)	1.8% (0.9–2.8%)	0.61	0.25 to 1.47
Severe head injury, AIS≥3				
(+) (n=758)	1.5% (0.6–2.3%)	1.6% (0.7–2.4%)	0.88	0.38 to 2.05
(−) (n=677)	3.3% (2.0–4.6%)	0.8% (0.2–1.5%)	4.00	1.62 to 9.90
Severe chest injury, AIS≥3				
(+) (n=820)	1.6% (0.8–2.5%)	0.0% (0.0–0.0%)	14.44	1.89 to 110.02
(−) (n=615)	3.4% (2.0–4.9%)	2.9% (1.6–4.2%)	1.20	0.63 to 2.29
Transportation time*				
≤15 min (n=182)	1.7% (0.0–4.1%)	0.7% (0.0–1.9%)	3.32	0.30 to 36.98
>15 min (n=1275)	2.4% (1.6–3.2%)	1.3% (0.7–1.9%)	2.00	1.09 to 3.65

IPW analyses were performed for each subgroup.
*Transportation time was calculated as the time interval from emergency medical service arrival at the scene to hospital arrival.
AIS, Abbreviated Injury Scale; IPW, inverse probability weighting.

overturn the current results). Furthermore, an association was observed between prehospital intubation and higher survival to discharge (8.1% vs 5.8%; OR 1.43; 95% CI 1.08 to 1.90; p=0.012; table 2), whereas no difference in the frequency of the presence of signs of life on hospital arrival was observed between patients with and without prehospital intubation (17.2% vs 15.9%; OR 1.09; 95% CI 0.89 to 1.34; p=0.376; table 2).

The length of hospital and ICU stay and days of ventilator use were comparable between patients with and without prehospital intubation. Conversely, prehospital intubation was associated with fewer haemostatic procedures, such as ED thoracotomy and aortic clamp (OR 0.71; 95% CI 0.60 to 0.84 and OR 0.70; 95% CI 0.59 to 0.84, respectively; table 2), but not craniotomy, laparotomy and REBOA use.

Subgroup analysis

Subgroup analyses (table 3) revealed an association between prehospital intubation and more frequent favourable neurological outcomes (GOS≥4) at discharge in several subgroups: younger patients (<65 years) as opposed to older patients (≥65 years), those without severe head injury (head AIS<3) as opposed to those with severe head injury (head AIS≥3), those with severe chest injury (chest AIS≥3) as opposed to those without severe chest injury (chest AIS<3) and those with prolonged transportation time (>15 min) as opposed to those with shorter transportation times (≤15 min).

DISCUSSION

This study showed that prehospital intubation was associated with favourable neurological outcomes at discharge in patients with t-OHCA. This result was obtained after adjusting for background characteristics, including the mechanism and severity of injury, prehospital resuscitative procedures, transportation time and institutional characteristics. Notably, the beneficial effects of prehospital intubation were only observed in younger patients, those without severe head injury, those with severe chest injury and those with prolonged transportation time.

Several pathophysiological mechanisms could contribute to the study results. First, ventilation with endotracheal intubation, rather than with supraglottic devices or manual airway protection, can apply continuous positive pressure, alleviating pulmonary shunting and decreasing atelectatic alveoli.[23 24] As a severe chest injury involving pulmonary tissue often occurs in patients with t-OHCA, arterial oxygenation would potentially be improved by intubation in such patients. Second, prehospital intubation enables EMS personnel to access the trachea and suction blood originating from the lower respiratory tract or aspirated from oropharyngeal injury.[25 26] Although supraglottic devices with rapid and successful placement have shown superiority in non-traumatic cardiac arrest,[27] airway obstruction with haemorrhage and/or injury occurs in trauma patients and can be more effectively managed by endotracheal intubation than supraglottic devices. Notably, in this study, the neurological benefits of prehospital intubation were identified in patients with severe chest injury, but not in those with no or mild to moderate chest injury.

Subgroup analyses revealed that prehospital intubation was not associated with a more favourable outcome in older patients (as compared with younger patients) and in those with severe head injuries. This finding may be due to the vulnerability of these patients to insufficient cerebral perfusion during cardiac arrest.[28] Given that devastating neurological deficit would be expected even after the return of spontaneous circulation, relatively small benefits of intubation would not have become clinically apparent in these patients. However, the results of this study should be interpreted with caution because of the small sample sizes in the subgroups, particularly for the results with wide 95% CIs.

Given that patients with a short transportation time of less than 15 min did not benefit from prehospital intubation, it is necessary to carefully determine the balance between benefits and potential harms.[29] While any form of airway support may be sufficient for patients who can reach a hospital quickly, those with longer distances to hospital will need better airway management with intubation. As a useful clinical implication of the current results, prehospital intubation should be considered for patients with severe chest injury and those with prolonged transportation time.

This study has some limitations. First, this was a retrospective study, and the results must be interpreted within the context of the study design. Data from the JTDB do not record indications for prehospital intubation. Therefore, the results could have been different if the decision to perform prehospital intubation was made based on unrecorded strong prognostic factors, such as airway obstruction, severe hypoxia, particular type of injury, prehospital resuscitation process and skills of healthcare providers. Second, a predefined uniform airway management strategy is lacking. Therefore, whether a supraglottic device was used before intubation remains unknown and comparisons between different airway managements other than intubation could not be conducted. Third, details of haemodynamic status during and after prehospital intubation were unavailable. Although maintaining a secure airway and optimal tissue oxygenation would be reasons for favourable neurological outcomes in patients with t-OHCA, pathophysiological benefits could not be validated based on objective data. Moreover, treatments after successful return of spontaneous circulation were not fully examined in this study. The relationship between prehospital intubation and specific in-hospital treatment and/or particular cause of unfavourable neurological outcomes should be further analysed to elucidate who most benefits from prehospital intubation. Finally, this study was conducted in a specific region, Japan, with a certain trauma care system. Thus, the applicability of the findings to different healthcare systems and settings may be limited. Therefore, further studies are needed to examine the generalisability of the results.

In conclusion, the results of this study showed that prehospital intubation was associated with favourable neurological function at discharge among adult patients with t-OHCA. This benefit largely lies in patients with severe chest injury or transportation time (EMS arrival to hospital arrival) >15 min.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by the Institutional Review Board at Keio University School of Medicine, Tokyo, Japan, on 31 August 2020 (application number: 20090087) for conducting research with human subjects in accordance with the Declaration of Helsinki.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. The data used in this study are available from the Japanese Association for Trauma Surgery and the Japanese Association for Acute Medicine. However, restrictions apply to the availability of these data, which were used under licence for this study and are not publicly available. However, data are available upon reasonable request to the corresponding author (RY) and with permission of the Japanese Association for Trauma Surgery and the Japanese Association for Acute Medicine.

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