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Short paper

Association between signs of life and survival in traumatic cardiac arrest patients: A nationwide, retrospective cohort study

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Abstract

Background: The clinical impact of signs of life (SOLs) in traumatic cardiac arrest (TCA) remains to be elucidated. The aim of this study was to examine the association between SOLs and survival/neurological outcomes in TCA patients.

Methods: Retrospective data from the Japan Trauma Data Bank (2019–2021) was reviewed. TCA patients were assigned to one of two study groups based on the presence or absence of SOLs and compared. SOLs were defined as having at least one of following criteria: pulseless electrical activity >40 beats per minute, gasping, positive light reflex, or extremity/eye movement at hospital arrival. The primary outcome was survival at hospital discharge. The secondary outcome was favorable neurological status (Glasgow Outcome Scale score of 4 or 5) at hospital discharge.

Results: A total of 1,981 patients (114 with SOLs and 1,867 without SOLs) were included. Characteristics of patients were as follows: age (median age 60.0 years old [interquartile range: 41–80] years vs. 55.4 [38–75] years), gender (male: 76/114 (66.7%) vs. 1,207/1,867 (65.0%), blunt trauma (90/111 [81.1%] vs. 1,559/1,844 [84.5%]), Injury Severity Score (29.2 [22–41] vs. 27.9 [20–34]). Patients with SOLs showed higher survival (10/114 (8.8%) vs. 25/1,867 (1.3%), OR 1.96 [CI 1.20–2.72]) and higher favorable neurological outcomes (4/110 (3.5%) vs. 6/1,865 (0.3%), OR 2.42 [CI 1.14–3.70]) compared with patients without SOLs.

Conclusions: TCA patients with SOLs at hospital arrival showed higher survival and favorable neurological outcomes at hospital discharge compared with TCA patients without SOLs.

Keywords: Out-of-hospital cardiac arrest, Advanced trauma life support care, Wounds and injuries, Cardiopulmonary resuscitation

Introduction

Traumatic cardiac arrest (TCA) is associated with high mortality.[1] Recent studies have reported an overall TCA survival rate of between 5.1% and 7.7%.[2,3] However, patients who survive after TCA have been shown to have better neurological outcomes than those with non-traumatic causes of cardiac arrest.[4] Recently, several studies have reported advancements in survival rates due to progress in resuscitation techniques and the development of trauma care algorithms. These advancements involve actively identifying and treating the trauma that causes cardiac arrest.

The Joint Committee of the National Association of Emergency Medical Services Physicians (NAEMSP) and the American College of Surgeons Committee on Trauma (ACSCOT) stated that resuscitation efforts may be withheld in blunt trauma patients with apnea and pulseless and electrocardiogram (ECG) inactivity. In the statement, victims of penetrating trauma with signs of life (SOLs), defined as any organized ECG activity, spontaneous movement, or positive pupillary reflexes, were designated as patients to be transported to the trauma center.[5] These physiological responses, termed as SOLs during resuscitation, were considered positive prognostic signs for favorable outcomes.[6] SOLs have also been identified as favorable

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prognostic factors in non-traumatic cardiac arrest and extracorporeal cardiopulmonary resuscitation.[6–8]

The clinical impact of SOLs in TCA remains to be elucidated.[1,3] A previous study compared TCA patients with pulseless electrical activity (PEA) to those with asystole, but survival was not significantly different between the groups.[9,10] Outcomes of patients with other SOLs such as agonal respiration, light reflection, or eye/fine extremity movement have not yet been examined in TCA.

Therefore, this study aimed to examine whether the presence of SOLs in TCA patients upon arrival at the hospital is associated with survival and neurological outcome.

Methods

Study design

This was a multicenter, retrospective cohort study of data from the Japan Trauma Data Bank (JTDB). The JTDB is a prospective, multicenter, web-based national database started in 2003.[11] The data is collected via a web-based form and recorded by emergency physicians with medical assistants. The JTDB includes patient characteristics such as vital signs on admission, heart rate, systolic blood pressure, respiratory rate, incident type, Glasgow Coma Scale, transport time, Injury Severity Score (ISS), Abbreviated Injury Scale (AIS), Revised Trauma Score (RTS), hospital interventions (e.g., emergency blood transfusion, chest tube, thoracotomy, thoracic aortal occlusion), SOLs at admission, and survival and neurological status at discharge. This retrospective, observational cohort study complied with the principles of the Declaration of Helsinki. This study was approved by the Ethics Committee of Okayama University (K2304-025).

EMS system and treatments

The emergency medical services (EMS) system in Japan is described previously.[12] The public EMS is available 24 h every day. Almost all TCA transports are managed by public EMS. An EMS team of more than three ambulance crew members is dispatched from the closest fire station to care for the TCA patients. At least one emergency life-saving technician is required on the team. Emergency life-saving technicians are authorized to place supraglottic airways. Specially trained emergency life-saving technicians can perform tracheal intubation and administer intravenous adrenaline. Hospital treatment commonly follows cardiac arrest and trauma guidelines.

Participants, grouping, and definitions of SOLs

The study included patients with TCA (RTS = 0 at hospital arrival) between January 1, 2019, and December 31, 2021. The exclusion criteria were as follows: AIS score = 6 in any region (the maximum lethal level, indicating who would not survive with any treatment), burn injury, and missing data on SOLs or survival at hospital discharge. Eligible patients were categorized into two groups based on SOLs at hospital arrival: the “with SOLs group” or the “without SOLs group.” In this study, the definition of SOLs, introduced by the ACSCOT in 2001, included at least one of the following: PEA with electrical heart activity (>40 beats per minute), gasping, light reflex, or eye/extremity movement.[13]

Study outcomes

The primary outcome was survival at hospital discharge. The secondary outcome was favorable neurological status (Glasgow Outcome Scale [GOS] score of 4 or 5) at hospital discharge.[14]

Statistical analysis

We compared clinical characteristics and outcomes between patients with and without SOLs. Continuous variables were described as medians with interquartile ranges. Categorical variables are presented as numbers and percentages. To compare the two groups, we used the Mann-Whitney *U* test for continuous data and the Chi-square test for categorical data. We used univariable logistic regression to examine differences in survival and favorable neurolog-

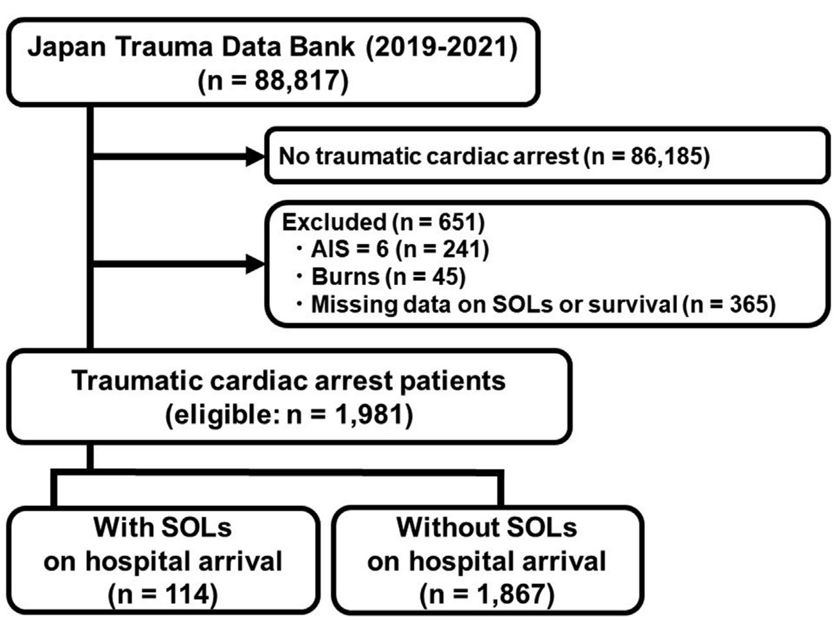

Fig. 1 – Flow chart showing the enrollment process for our study population.

Table 1 – Characteristics of traumatic cardiac arrest patients with or without signs of life (SOLs) on hospital arrival.

	With SOLs (*n* = 114)	Without SOLs (*n* = 1,867)
Pre-hospital information		
Age, median [*IQR*]	60.0 [41–80]	55.4 [38–75]
Age group, *n* (%)		
Infants/younger children (0–7 years old)	1 (0.9)	18 (1.0)
Children & teenagers (8–17 years old)	2 (1.8)	77 (4.1)
Adults (>18 years old)	111 (97.3)	1,772 (95.0)
Gender, male (%)	76 (66.7)	1,207 (65.0)
Incident type[a]		
Blunt, *n* (%)	90 (81.1)	1,559 (84.5)
Motor vehicle	16 (17.8)	143 (9.2)
Motor bicycle	13 (14.4)	144 (9.2)
Bicycle	8 (8.9)	66 (4.2)
Pedestrian	12 (13.3)	195 (12.5)
Fall	26 (28.9)	664 (42.6)
Tumble	1 (1.1)	22 (1.4)
Other blunt injury	14 (15.6)	312 (20.8)
Penetrating, *n* (%)	10 (9.0)	86 (4.7)
Other, *n* (%)	11(9.9)	199 (10.8)
Head injury, *n* (%)		
AIS 3	30 (26.3)	347 (18.6)
AIS 4	11 (9.7)	182 (9.8)
AIS 5	4 (3.5)	128 (6.9)
Chest injury, *n* (%)		
AIS 3	24 (21.1)	371 (19.9)
AIS 4	24 (21.1)	308 (16.5)
AIS 5	19 (16.7)	300 (16.1)
Abdominal injury, *n* (%)		
AIS 3	7 (6.1)	46 (2.5)
AIS 4	2 (1.8)	38 (2.0)
AIS 5	5 (4.4)	19 (1.0)
Pelvic injury, *n* (%)		
AIS 3	10 (8.8)	244 (13.1)
AIS 4	8 (7.0)	179 (9.6)
AIS 5	13 (11.4)	129 (6.9)
ISS, median [*IQR*]	29.2 [22–41]	27.9 [20–34]
Transportation time [*IQR*][b]	15.4 [7.5–19]	13.1 [7–16]
In-hospital information		
Emergency blood transfusion	45 (39.5)	316 (16.9)
Chest tube, *n* (%)	29 (25.4)	394 (21.1)
Pericardiocentesis, *n* (%)	2 (1.8)	5 (0.3)
Thoracotomy, *n* (%)	50 (43.9)	534 (28.6)
Thoracic aortal occlusion, *n* (%)	43 (37.7)	419 (22.4)
ECPR, *n* (%)	0 (0.0)	11 (0.6)

SOLs: Signs of life, IQR: interquartile range, AIS: Abbreviated Injury Scale, ISS: Injury Severity Score, ECPR: extracorporeal cardiopulmonary resuscitation.

[a] Evaluated in 1,955 patients.

[b] Time from emergency medical services call to arrival at the hospital.

ical outcome at presence of SOL ("with SOL"). Results are presented with odds ratios (OR) with 95% confidence intervals (CI).

We also conducted subgroup analyses based on age categories: age (infants and younger children [0–7 years old], children and teenagers [8–17 years old], adults [18 years old and older]), and incident type: blunt or penetrating. Then, association between in-hospital interventions (emergency blood transfusion, chest tube, thoracotomy, thoracic aortal occlusion, interventions) and survival was examined in patients with SOLs. We performed all statistical analyses using Stata Version 17 statistical software (Stata-Corp LP, College Station, TX, USA).

Results

Fig. 1 shows a flow diagram of the study population. Out of 88,817 documented patients during the study period, the final analysis included 1,981 patients. Among these, 114 (5.8%) were categorized in the patients with SOLs group, while 1,867 (94.2%) were in the patients without SOLs group.

The baseline clinical information of the patients is presented in Table 1. Penetrating trauma was more prevalent in the with SOLs group (9.0% vs. 4.7%). ISS did not differ between the with or without

Table 2 – Association between signs of life (SOLs) on hospital arrival and survival/favorable neurological outcome at discharge.

Variable	Case/*n* (%)	OR (95% CI)
Survival at discharge		
With SOL	10/114 (8.8)	1.96 (1.20–2.72)
Without SOL	25/1,867 (1.3)	ref
GOS score 4–5 at discharge[a]		
With SOL	4/110 (3.5)	2.42 (1.14–3.70)
Without SOL	6/1,865 (0.3)	ref

SOLs: signs of life, GOS: Glasgow Outcome Scale, OR: odds ratio, CI: confidence interval. The OR is the result of with SOLs against without SOLs, and higher OR indicates a better prognosis for "with SOL."

[a] Evaluated in 1,979 patients.

Table 3 – Associations between in-hospital interventions and survival.

	Survival	No Survival	*p*-Value*
Emergency blood transfusion, *n* (%)[a]			0.013
Yes	8/45 (17.8)	37/45 (82.2)	
No	2/60 (3.3)	58/60 (96.7)	
Chest tube, *n* (%)[b]			0.357
Yes	4/29 (13.8)	25/29 (86.2)	
No	6/76 (7.9)	70/76 (92.1)	
horacotomy, *n* (%)[c]			0.241
Yes	3/50 (6.0)	47/50 (94.0)	
No	7/55 (12.7)	48/55 (87.3)	
Thoracic aortal occlusion, *n* (%)[d]			0.459
Yes	3/43 (7.0)	40/43 (93.0)	
No	7/62 (11.2)	55/62 (88.7)	

SOLs: signs of life.

[a] Evaluated in 1,774 patients.

[b–d] Evaluated in 1,802 patients.

* Chi-square test.

SOLs groups (29.2 vs. 27.9). In-hospital interventions, including emergency blood transfusions, thoracotomies, and thoracic aorta occlusions, were more frequently performed in the with SOLs group (emergency blood transfusions: 39.5% vs. 16.9%, thoracotomies: 43.9% vs. 28.6%, thoracic aorta occlusions: 37.7% vs. 22.4%).

Notably, the with SOLs group demonstrated significantly higher survival rates at discharge (8.8% vs. 1.3%) and more favorable neurological outcomes (3.5% vs. 0.3%) (Table 2). The univariate analysis also highlighted the strength and statistical significance of these associations (survival: OR 1.96, 95% CI 1.20–2.72; GOS 4–5: OR 2.42, 95% CI 1.14–3.70). Subgroup analyses based on age group and incident type were conducted in the with SOL group. A trend toward a more favorable prognosis was observed in the adult (18 years old and older) and penetrating injury groups (Supplementary Table 1). In-hospital interventions were performed more frequently in patients with SOLs; however, only emergency blood transfusions were associated with survival (Table 3).

Discussion

In this study, using a large multi-institutional trauma database in Japan, we showed that SOLs upon hospital arrival were associated with both survival and favorable neurological states at hospital discharge in patients with TCA. Previous studies on the significance of SOLs in TCA have primarily focused on ECG activity upon hospital arrival.[9,10] To our knowledge, our study is the first to include a variety of signs such as gasping, light reflex, or eye/extremity movement to investigate their association with outcomes.

The evaluation and treatment of TCA remain a challenge for emergency medicine providers. Factors that predict survival after TCA include location of injury, mechanism of TCA, duration of cardiopulmonary resuscitation (CPR), and SOLs on arrival.[3,15] In 2003, the NAEMSP-ACSCOT consensus guidelines stated "termination of resuscitation (TOR) may be considered when there are no SOLs and there is no return of spontaneous circulation (ROSC) despite appropriate field EMS treatment that includes minimally interrupted CPR".[16] However, these guidelines were questioned, as survivors have been identified among patients in whom the guidelines suggested resuscitation may be terminated, particularly penetrating trauma patients who underwent on-scene thoracotomy.[3,17]

In 2013, the recommendations were updated, marking a change in the criteria for withholding resuscitation and TOR.[5] They announced that a more severe statement for TOR should include no evidence of SOLs, including no respiration, no blood pressure, no pulse, and no ROSC after emergency medical service providers initiate resuscitation. Thus, it is important to assess SOLs based on a variety of signs in TCA.

Potentially reversible causes of TCA include hypoxia, hypovolemia, cardiac tamponade, and tension pneumothorax.[18] Timely diagnosis and intervention for cardiac tamponade and tension pneumothorax are also suggested as strategies to potentially recover from TCA.[1,10] Indeed, the efficacy of resuscitative thoracotomy in trauma patients presenting with SOLs has been documented.[19] In this study, patients with SOLs may have undergone expanded resuscitative interventions, including emergency blood transfusions, chest tube insertions, thoracotomies, and thoracic aortic occlusions upon arrival in the emergency department.

Despite progress in trauma care, TCA patients who arrive at a hospital with no SOLs still have low survival rates.[20] SOLs are one crucial key factor in the decision-making process to continue/terminate resuscitation; mechanism of injury, duration of CPR, and the patient's physiological status should also be thoroughly considered.

The current study had several limitations. First, healthcare providers determined the presence or absence of SOLs upon the patient's hospital admission; however, it is unclear which physiological findings (PEA, gasping, light reflex, or eye/extremity movement) were considered SOLs. Second, because of the small number of TCA survivors in our study, multivariable logistic regression was not conducted; therefore, potential confounders between the groups may have been overlooked. However, there were no differences in ISS severity or types of injuries between groups. Finally, as with all retrospective studies, data validity, integrity, and ascertainment bias were potential limitations. Additionally, not all hospitals participate in the JTDB program, so our findings may lack generalizability.

Conclusion

We demonstrated that TCA patients with SOLs upon arrival at the hospital showed higher survival rates and favorable neurological states at hospital discharge compared with TCA patients without SOLs.

Ethics approval and consent to participate

This study conforms to the principles outlined in the Declaration of Helsinki and was approved by the ethics committee of the Okayama University Hospital, ID: K2304-025. Patient consent was waived for all participants enrolled in this study because of its retrospective study design.

Availability of data and materials

The datasets from this study are available from the corresponding author upon request.

CRediT authorship contribution statement

Takafumi Obara: Writing – original draft, Visualization, Methodology, Formal analysis, Conceptualization. **Tetsuya Yumoto:** Writing – review & editing, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Naofumi Bunya:** Writing – review & editing, Visualization, Methodology, Investigation, Conceptualization. **Tsuyoshi Nojima:** Writing – review & editing, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Tomohiro Hiraoka:** Writing – review & editing, Visualization. **Takashi Hongo:** Writing – review & editing, Visualization, Formal analysis. **Yoshinori Kosaki:** Writing – review & editing, Visualization. **Kohei Tsukahara:** Writing – review & editing, Visualization. **Takenori Uehara:** Writing – review & editing, Visualization. **Atsunori Nakao:** Writing – review & editing, Supervision, Project administration, Investigation. **Hiromichi Naito:** Writing – review & editing, Visualization, Supervision, Project administration, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary material to this article can be found online at https://doi.org/10.1016/j.resplu.2024.100701.

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