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Prehospital quick sequential organ failure assessment score to predict in-hospital mortality among patients with trauma

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ABSTRACT

Objective: The quick sequential organ failure assessment (qSOFA) score is calculated from three variables measured at the scene of trauma—systolic blood pressure, respiratory rate and consciousness. This study aimed to evaluate the discriminative ability of the prehospital qSOFA score for in-hospital mortality in patients with trauma.

Methods: This retrospective multicenter study used data from 42,722 patients with trauma included in a Japanese nationwide trauma registry. All included patients were aged ≥18 years old and transferred to hospitals from the scenes of injury. The primary outcome was in-hospital mortality.

Results: The included patients had a mean age of 59.4 ± 21.5 years and a male predominance (63%). In-hospital mortality occurred in 2612 patients (6%), while 2-day mortality occurred in 1189 of 42,339 patients (3%). When patients were stratified by qSOFA scores, in-hospital mortality rates of 0.9% (105/11783), 5% (941/17839), 12% (1280/11132) and 15% (286/1968) were associated with qSOFA scores of 0, 1, 2 and 3, respectively ($P < 0.0001$ for trend). The area under the receiver operating characteristics curve of the qSOFA score for in-hospital mortality was 0.70 (95% confidence interval: 0.69–0.71). A qSOFA score cutoff value ≥1 yielded a sensitivity and specificity of 0.96 and 0.29, respectively, overall, and a sensitivity of 0.99 in patients younger than 65 years.

Conclusions: The prehospital qSOFA score was strongly associated with in-hospital mortality in patients with trauma. A prehospital qSOFA score cutoff of ≥1 can be used to identify patients at a very low risk of death, especially in younger age groups.

1. Introduction

The outcomes of patients with major trauma may improve if early surgical control of hemorrhage (i.e., within 1 h) is provided after the incident [1]. As such intervention involves the transport of patients to medical centers, on-scene mortality prediction is essential to ensuring that all severe trauma patients are transferred to tertiary hospitals (e.g., trauma centers) while minimizing the unnecessary transport of less severe patients to these hospitals. Furthermore, prehospital triage tools should very sensitively identify severe trauma patients to avoid under-triage. To date, several prehospital triage tools, such as the Triage Revised Trauma Score (T-RTS), have been developed to address these needs [2]. However, the T-RTS might not identify major trauma patients requiring emergent intervention with sufficient sensitivity [3].

The quick sequential organ failure assessment (qSOFA) score was recently developed to predict patients with infection who are at a high risk of death [4]. This relatively new scoring system is easy to remember, as it comprises only three binary variables. The qSOFA has also been used to predict mortality in patients without infection [5]; it was shown to correlate well with in-hospital mortality in patients with trauma and to predict patients at a very low-risk-of-death in prehospital settings [6,7].

To date, few published studies have evaluated the discriminatory ability of the prehospital qSOFA score in patients with trauma, and the abovementioned observations of high sensitivity have not been externally validated. Therefore, conclusions cannot be drawn regarding whether the prehospital qSOFA score is a useful triage predictor of trauma patients facing a very low risk of death. We therefore conducted this study to evaluate the association between the prehospital qSOFA score and in-hospital mortality, as well as the ability of this score to identify patients at a very low risk of death, in a cohort of patients registered in the Japan Trauma Data Bank (JTDB), a nationwide trauma registry.

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2. Materials and methods

This retrospective multicenter study used data from the JTDB, a Japanese nationwide trauma registry established in 2003. As of March 2017, 264 institutes throughout Japan participated in the JTDB, and all traumatic patients admitted to these institutions with an Abbreviated Injury Score (AIS) ≥3 were registered. The AIS data were recorded using AIS 90 Update 98 [8]. We analyzed patients' demographic and outcome data (e.g., age, sex, cause of trauma, prehospital vital signs, injury severity score, hospital mortality) included in an anonymized dataset from the JTDB. This study was approved by the institutional review board at Wakayama Medical University, which waived the requirement for informed consent because of the retrospective nature of the study. This trial was registered in UMIN-CTR, UMIN000034928 (Registered 28 November 2018, https://upload.umin.ac.jp/cgi-open-bin/ctr/ctr_view.cgi?recptno=R000039828).

In this study, we included trauma patients aged ≥18 years old who were registered between 2004 and 2016. We excluded patients who had been transferred from other hospitals, presented with burn injuries, were <18 years old or exhibited cardiopulmonary arrest on the scene, as well as those with missing data for age, discharge outcome or vital signs at the scene, including the respiratory rate (RR), Japan Coma Scale (JCS) score or systolic blood pressure (SBP). We included the first measured vital signs during prehospital medical examinations in the analysis. The JCS score was used to evaluate consciousness; a score of 0 indicated alertness, while a scores of 1–20, 30–200 and 300 indicated responsiveness to voice, responsiveness to pain and unresponsiveness, respectively [9].

The qSOFA score comprises three variables: non-alert consciousness (JCS ≥ 1), SBP ≤ 100, and RR ≥ 22. One point was awarded for each variable that met the criterion; otherwise 0 points were given. Accordingly, the total qSOFA score ranged from 0 to 3, with a higher score indicating more severe disease [4].

The primary outcome of this study was in-hospital mortality, and the secondary outcome was 2-days mortality after admission. We investigated the associations of the qSOFA score with these outcomes. We also evaluated the association between the qSOFA score and mortality according to age (<65 or ≥65 years) in accordance with a previous study that identified age as an additionally important variable with which to identify low-risk patients [10].

2.1. Statistical analysis

Continuous variables are presented as means ± standard deviations or medians and interquartile ranges, while categorical variables are presented as numbers and percentages (%). We compared survivors and non-survivors using the chi-square test for categorical variables and the *t*-test or Wilcoxon rank-sum test for continuous variables. We used the Cochrane–Armitage trend test to analyze the association between the qSOFA score and mortality. Additionally, we used the area under the receiver operating characteristics curve (AUROC) to determine the discriminatory ability of the qSOFA score regarding mortality. For all analyses, a two-sided P value of <0.05 was considered statistically significant. All analyses were performed using JMP Pro software (version 12.2; SAS Institute Inc., Cary, NC, USA).

3. Results

This study included 42,722 patients with trauma who were registered in the JTDB between 2004 and 2016 (Fig. 1). The patients' characteristics are shown in Table 1. Overall, the patients had a mean age of 59.4 ± 21.5 years and a male predominance (n = 27,069, 63%). Blunt injury was the most frequent mechanism of injury (97%). Approximately 80% of patients had at least one serious injury in each anatomical region, and the most frequent site of injury was head (33%), followed by the lower extremities or pelvis (25%) and thorax (22%) (Supplementary Table S1). The median qSOFA score was 1.

In-hospital mortality occurred in 2612 patients (6%), while 2-day mortality occurred in 1189 of 42,339 patients (3%; relevant data were missing for 383 patients). When patients were stratified by the qSOFA score, the in-hospital mortality rates were 0.9% (105/11783), 5% (941/17839), 12% (1280/11132) and 15% (286/1968) for scores of 0, 1, 2 and 3, respectively (P < 0.0001 for trend). Similarly, the corresponding 2-day mortality rates were 0.1% (15/11690), 2% (359/17679), 6% (624/11032) and 10% (191/1938), respectively (P < 0.0001 for trend). Fig. 2 depicts the in-hospital mortality of patients in each category corresponding to the three criteria in the qSOFA (Fig. 2).

We present the receiver operating characteristics curves for the qSOFA score and outcomes in Fig. 3. The operating characteristics for each determined qSOFA score threshold and mortality are shown in Tables 2 and 3. Here, a qSOFA score cutoff ≥1 yielded a sensitivity of 0.96 (95% confidence interval [95% CI] 0.95–0.97) and 0.99 (95% CI 0.98–0.99) for predicting in-hospital mortality and 2-day mortality, respectively.

We further stratified the patients by age and reanalyzed the association between the qSOFA score and mortality, as shown in Table 4. Among younger patients (age < 65 years), the in-hospital mortality rate among patients with a qSOFA score of 0 was 0.3% (13/5053). By contrast, elderly patients (age ≥ 65 years) in this qSOFA category had a relatively higher in-hospital mortality rate of 1.4% (92/6730). The operating characteristics of the qSOFA score according to age are shown in Supplementary Tables S2–S5. The above-determined qSOFA score cutoff of ≥1 yielded sensitivity values of 0.99 (95% CI 0.98–0.99) and 0.95 (95% CI 0.94–0.96) for hospital mortality in young and elderly patients, respectively. Similarly, this cutoff yielded sensitivity values of 1.00 (95% CI 0.99–1.00) and 0.98 (95% CI 0.97–0.99) for 2-day mortality in these age groups, respectively.

4. Discussion

In this study, we demonstrated a clear association of the prehospital qSOFA score with in-hospital mortality in patients with trauma. Notably, patients with a prehospital qSOFA score of 0 had in-hospital and 2-day mortality rates of only 0.9% and 0.1%, respectively. Furthermore, we identified a prehospital qSOFA score cutoff of ≥1 that could predict in-hospital and 2-day mortality at a high level of sensitivity (0.96 and 0.99, respectively). Among

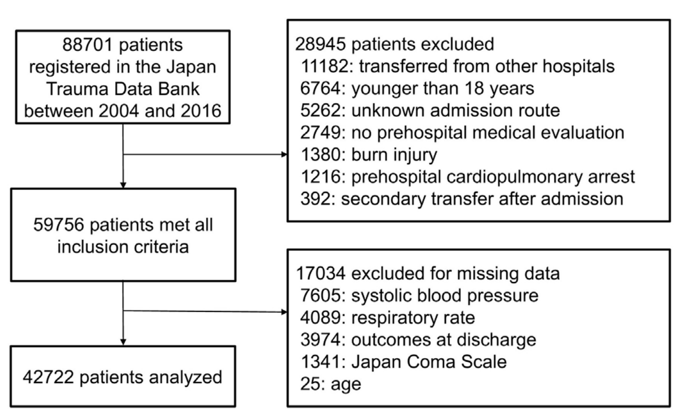

Fig. 1. Flowchart of patient selection.

Table 1
Patients' characteristics.

Characteristics	All patients (n = 42,722)	Survivor (n = 40,110)	Non-survivor (n = 2612)	P value
Age, y, mean ± SD	59.4 ± 21.5	58.8 ± 21.5	68.3 ± 18.7	<0.0001
Male, number (%)[a]	27,069 (63)	25,316 (63)	1753 (67)	<0.0001
Mechanisms of injury[b]				<0.0001
Blunt, number (%)	40,722 (97)	38,228 (97)	2494 (98)	
Penetrating, number (%)	1399 (3)	1357 (3)	42 (2)	
Transportation type[c]				<0.0001
Ambulance, number (%)	39,499 (93)	37,185 (93)	2314 (89)	
Helicopter with physician, number (%)	2209 (5)	2044 (5)	165 (6)	
Ambulance with physician, number (%)	845 (2)	729 (2)	116 (4)	
Cause of injury[d]				<0.0001
Accident, number (%)	36,069 (86)	33,912 (86)	2157 (88)	
Suicide, number (%)	2049 (5)	1901 (5)	148 (6)	
Assault, number (%)	710 (2)	688 (2)	22 (1)	
Workplace injuries, number (%)	2527 (6)	2422 (6)	105 (4)	
Others, number (%)	498 (1)	477 (1)	21 (1)	
Injury severity score, median (IQR)[e]	12 (9–19)	10 (9–17)	25 (18–34)	<0.0001
Consciousness				<0.0001
Alert, number (%)	20,200 (47)	19,947 (50)	253 (10)	
Responding to voice, number (%)	17,688 (41)	16,876 (42)	812 (31)	
Responding to pain, number (%)	2958 (7)	2257 (6)	701 (27)	
Unresponsive, number (%)	1876 (4)	1030 (3)	846 (32)	
Respiratory rate, breaths/min, mean ± SD	21.8 ± 5.5	21.8 ± 5.4	23.1 ± 6.9	<0.0001
Respiratory rate ≥ 22 breaths/min, number (%)	18,094 (42)	16,648 (42)	1446 (55)	<0.0001
Systolic blood pressure, mm Hg, mean ± SD	137.9 ± 32.5	137.8 ± 31.7	139.5 ± 42.5	0.008
Systolic blood pressure ≤ 100 mm Hg, number (%)	5391 (13)	4837 (12)	554 (21)	<0.0001
Pulse rate, beats/min, mean ± SD[f]	85.3 ± 18.7	85.0 ± 18.2	88.6 ± 25.0	<0.0001
qSOFA score, median (IQR)	1 (0–2)	1 (0–2)	2 (1–2)	<0.0001
0, number (%)	11,783 (28)	11,678 (29)	105 (4)	
1, number (%)	17,839 (42)	16,898 (42)	941 (36)	
2, number (%)	11,132 (26)	9852 (25)	1280 (49)	
3, number (%)	1968 (5)	1682 (4)	286 (11)	

SD: standard deviation, IQR: interquartile range, qSOFA: quick sequential organ failure assessment.
[a] Sex was missing for eight patients.
[b] Mechanism of injury was missing for 601 patients.
[c] Transportation type was missing for 169 patients.
[d] Cause of injury was missing for 869 patients.
[e] Injury severity score was missing for 438 patients.
[f] Pulse rate was missing for 250 patients.

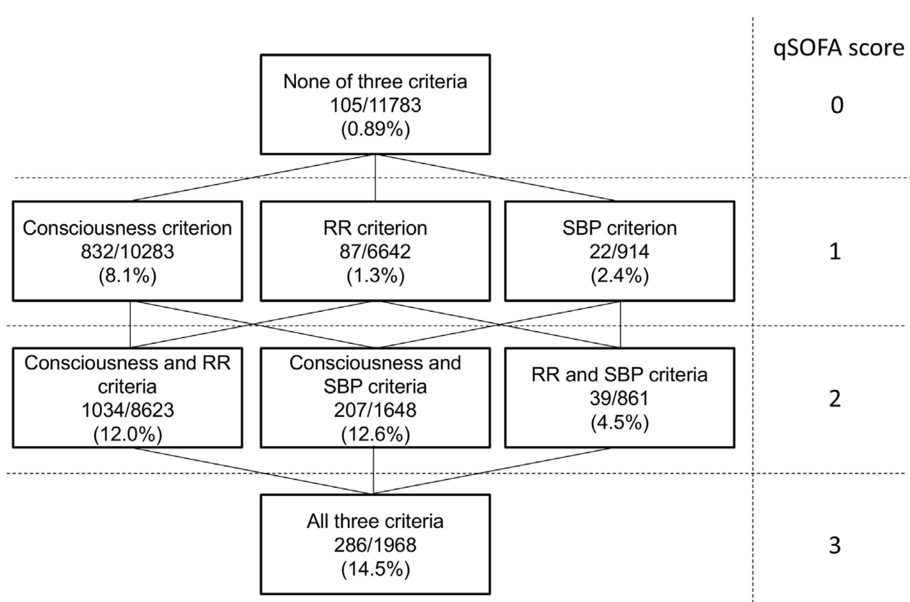

Fig. 2. Details of in-hospital mortality among patients who met the three variables of the qSOFA.Abbreviations: qSOFA, quick sequential organ failure assessment score; RR, respiratory rate; SBP, systolic blood pressure.

trauma patients younger than 65 years, this cutoff also very sensitively predicted in-hospital and 2-day mortality (0.99 and 1.00, respectively).

The qSOFA score was originally developed and validated in patients with suspected infection [11,12] and was found to yield accurate in-hospital mortality prognoses in an emergency depart-

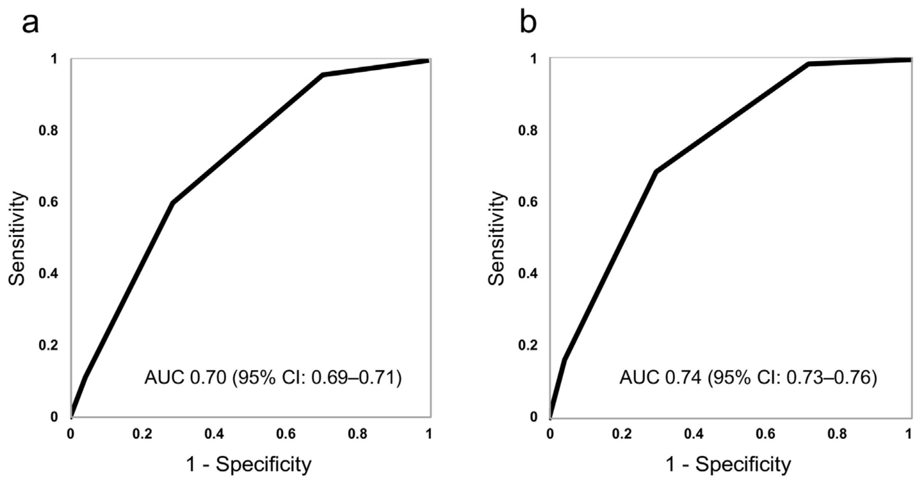

Fig. 3. Analysis of the areas under the receiver operating characteristics curves for the quick sequential organ failure assessment score. a. In-hospital mortality. b. Two-day mortality.Abbreviations: qSOFA, quick sequential organ failure assessment score; AUC, area under the receiver operating characteristics curve; 95% CI, 95% confidence interval.

Table 2
Operating characteristics for each quick sequential organ failure assessment score threshold on hospital mortality.

	≥1	≥2	3
Patients ($n = 42{,}722$)			
True positive	2507	1566	286
False positive	28,432	11,534	1682
True negative	11,678	28,576	38,428
False negative	105	1046	2326
Operating characteristics			
Sensitivity	0.96 (0.95–0.97)	0.60 (0.58–0.62)	0.11 (0.10–0.12)
Specificity	0.29 (0.29–0.29)	0.71 (0.71–0.71)	0.96 (0.96–0.96)
Positive likelihood ratio	1.35 (1.34–1.37)	2.09 (2.01–2.16)	2.61 (2.32–2.94)
Negative likelihood ratio	0.14 (0.11–0.17)	0.56 (0.54–0.59)	0.93 (0.92–0.94)

Data are shown with 95% confidence intervals.

Table 3
Operating characteristics for each quick sequential organ failure assessment score threshold on 2-day mortality.

	≥1	≥2	3
Patients ($n = 42{,}339$)			
True positive	1174	815	191
False positive	29,475	12,155	1747
True negative	11,675	28,995	39,403
False negative	15	374	998
Operating characteristics			
Sensitivity	0.99 (0.98–0.99)	0.69 (0.66–0.71)	0.16 (0.14–0.18)
Specificity	0.28 (0.28–0.28)	0.71 (0.70–0.71)	0.96 (0.96–0.96)
Positive likelihood ratio	1.38 (1.37–1.39)	2.32 (2.23–2.41)	3.78 (3.29–4.34)
Negative likelihood ratio	0.04 (0.03–0.07)	0.45 (0.41–0.49)	0.88 (0.85–0.90)

Data are shown with 95% confidence intervals.

ment setting (AUROC: 0.80) [11]. A previous retrospective study also demonstrated that the qSOFA score could accurately predict in-hospital mortality in patients with trauma in an emergency department setting (AUROC: 0.73) [6]. Regarding prehospital settings, the qSOFA score was also shown to predict in-hospital mortality accurately in trauma patients transported by physician-staffed helicopters (AUROC: 0.75) [7]. Therefore, our results from the present study are consistent with those of previous studies and further confirm the good discriminative ability of the prehospital qSOFA for in-hospital mortality in patients with trauma (AUROC: 0.70). Accordingly, the qSOFA score can be applied to patients with trauma, as well as patients with suspected infection, in the prehospital setting.

In the present study, crude mortality appeared to be higher among patients who met the consciousness criterion but not the RR or the SBP criterion within the same qSOFA score category. In contrast, Pearson et al. reported similar associations of all three physiologic criteria (GCS, RR and SBP) with mortality in patients with traumatic brain injury [13]. Currently, it remains unclear whether this difference is attributable to differences in the study population or the cutoff point.

In a prehospital triage setting, however, the sensitivity is a more important measure in terms of minimizing under-triage and determining the appropriate level of medical facility for subsequent patient care. We recently reported that the qSOFA score is highly sensitive (1.00) in this capacity when applied to patients with trauma [7]. In the present study, we observed a nearly identical sensitivity (0.96) for predicting in-hospital mortality when the same cutoff was applied, and this level appears to be adequately high for a triage setting. By contrast, although a higher qSOFA score cutoff of ≥2 yielded a better balance between the sensitivity and specificity (0.60 and 0.71, respectively), the sensitivity would be suboptimal for the purpose of prehospital triage.

As noted above, age may also be an important component of sensitivity. A previous retrospective study reported a high level of sensitivity (0.94) for a modified qSOFA score (i.e., qSOFA score + age ≥ 65) when predicting clinically important outcomes in patients with community-acquired pneumonia [10]. Similarly, we observed an extremely high level sensitivity (0.99) among patients younger than 65 years. The effect of age may be confounded. Jawa et al. reported that patients with a qSOFA score of 0 were older than those with a score >0 [6], suggesting that this score may be a more reliable measure of severity in younger patients.

This high level of sensitivity for identifying patients at a very low risk of death suggests that the qSOFA score would be a useful prehospital trauma triage tool. This usefulness is enhanced by the simplicity of the score, which comprises only three binary variables (RR, consciousness, SBP). Therefore, the qSOFA score appears most reliable for the triage of non-elderly patients at a very low risk of death.

This study had several limitations of note. First, we were unable to compare the discriminatory ability of the prehospital

Table 4
Mortality associated with each qSOFA score according to age.

qSOFA score	0	1	2	3
Age < 65 y (*n* = 22,587)				
In-hospital mortality, *n* (%)	13/5053 (0.26%)	252/9407 (2.7%)	478/6737 (7.1%)	131/1390 (9.4%)
24-hour mortality, *n* (%)[a]	1/5011 (0.02%)	107/9325 (1.2%)	241/6681 (3.6%)	91/1371 (6.6%)
Age ≥ 65 y (*n* = 20,135)				
In-hospital mortality, *n* (%)	92/6730 (1.4%)	689/8432 (8.2%)	802/4395 (18.3%)	155/578 (26.8%)
24-hour mortality, *n* (%)[b]	14/6679 (0.21%)	252/8354 (3.0%)	383/4351 (8.8%)	100/567 (17.6%)

qSOFA: quick sequential organ failure assessment.
[a] Data were missing for 199 patients.
[b] Data were missing for 184 patients.

qSOFA with that of other triage systems such as the T-RTS or the physiologic criteria included in the Centers for Disease Control and Prevention (CDC) guideline for field triage [2,14], as the JTDB does not record the prehospital Glasgow Coma Scale (GCS). The T-RTS and the physiologic criteria in the CDC guideline include same variables also used in the qSOFA score. However, a full T-RTS score or the physiologic criteria in the CDC guideline requires a RR < 30, GCS ≥ 13, and SBP ≥ 90 or a RR < 30, GCS ≥ 14, and SBP ≥ 90, respectively [2,14], which are less stringent criteria than those required for a full qSOFA score (RR < 22, GCS 15, and SBP ≥ 100). In other words, the sensitivity of the T-RTS is intrinsically lower than that of the qSOFA score, as previously stated [7]. In this context, Newgard et al. proposed stricter cutoff values for these three physiologic variables to enable field triage units to identify serious injuries [15]. The proposed cutoff values were nearly identical to those set by the qSOFA score. Furthermore, a recent study suggested that the GCS could be replaced with simpler measurements, such as "patient does not follow commands," in a prehospital trauma triage setting [16]. Therefore, we do not consider the lack of the prehospital GCS to be a major flaw. Second, our study cohort may have included relatively older patients, compared to other studies [6,17]. Moreover, although the JTDB is a nationwide trauma registry, it mainly covers tertiary hospitals. Therefore, the cohort from this registry might comprise patients with more severe conditions who were treated more aggressively than patients sent to non-tertiary hospitals. Accordingly, the results of our study might not be generalizable to other circumstances (e.g., non-tertiary hospitals). Our results should be validated in an external cohort that includes patients admitted to non-tertiary hospitals.

5. Conclusions

The prehospital qSOFA score was strongly associated with in-hospital mortality in patients with trauma. Notably, a qSOFA score of 0 predicted a very low rate of in-hospital mortality rate. A prehospital qSOFA score cutoff of ≥1 can be used to identify patients at a very low risk of death, especially among those younger than 65 years.

Abbreviations

T-RTS	triage revised trauma score
qSOFA	quick sequential organ failure assessment
JTDB	Japan Trauma Data Bank
RR	respiratory rate
JCS	Japan Coma Scale
SBP	systolic blood pressure
95% CI	95% confidence interval
AUROC	area under receiver operating characteristics curve
CDC	Centers for Disease Control and Prevention
GCS	Glasgow Coma Scale

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajem.2019.03.007.

Declarations

Ethics approval and consent to participate

This study was conducted at Wakayama Medical University and was approved by the Institutional Review Boards of the university. Informed consent was waived because of the retrospective nature of the study.

Consent for publication

Not applicable.

Competing interests

Dr. Miyamoto reports the receipt of lecture fees from Becton Dickinson and Maruishi Pharmaceutical.

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Availability of data and materials

The datasets generated and analyzed in this study are not publicly available because of privacy concerns and institutional policy.

Author contribution

KM conceived the study idea, designed the study, and performed the data analysis. NS, AO, TN, and SK helped to draft and revise this manuscript. All authors read and approved the final manuscript.

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