

On-scene time-dependent probability of a favorable functional outcome in cases of out-of-hospital cardiac arrest with an initial shockable rhythm: a retrospective study using the national Utstein data in Japan

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Abstract

Background: Out-of-hospital cardiac arrest (OHCA) is a major public health issue, and the survival rate in cases of OHCA with an initial shockable rhythm has been reported to be 20–30% all over the world. In cases in which emergency medical services (EMS) performs resuscitation at the scene, a longer on-scene time has been reported to be associated with a poor prognosis. However, there is a trade-off between leaving the scene early for further advanced resuscitation with veno-arterial extracorporeal membranous oxygenation and staying to continue on-scene resuscitation, and the acceptable on-scene time still needs to be explored.

Methods:

We conducted a retrospective study using a dataset that combined the Japanese national Utstein data and emergency transport data including the time of the emergency call, age, sex, and area. Of the OHCA cases recorded between January 2017 to December 2022, 22,383 with an initial shockable rhythm were included. We examined the time-dependent probabilities of achieving return of spontaneous circulation (ROSC) with a favorable functional outcome at each minute of on-scene time.

Results: On-scene ROSC was achieved in 5,095 cases, and favorable functional outcomes at 1 month were obtained in 3,182 cases. In this group, the time-dependent probabilities were <20% and <5% when the on-scene time exceeded 5 and 10 min, respectively. Sex, witness status, and bystander cardiopulmonary resuscitation (CPR) were not associated with the time-dependent probabilities; however, an age of ≤ 75 years was associated with a higher probability of a longer on-scene time.

Conclusions: Under the current EMS resuscitation practices in Japan, the probability of achieving ROSC within 10 min of arrival in cases of OHCA with an initial shockable rhythm is <10% and decreases to $\leq 5\%$ after 20 min. The candidates for continued on-scene resuscitation, regardless of witness status or bystander CPR, would be individuals under 75 years of age.

Background

Out-of-hospital cardiac arrest (OHCA) is a major public health issue. The percentages of associated survival with favorable neurological outcomes remain at 3.5% and 8.1% in Japan and the US, respectively, despite the various initiatives undertaken [1, 2]. Furthermore, the survival rate for OHCA with an initial shockable rhythm is 20 to 30% [1, 2], and improving the outcomes in this context is an urgent issue. Public access defibrillation has been reported to be effective in such cases of OHCA; however, its frequency remains < 20% [2, 3], and defibrillation by emergency medical services (EMS) accounts for the majority of prehospital defibrillations. Regarding cases in which EMS performs on-scene resuscitation, a longer on-scene time is associated with a poor prognosis [4–6]. In particular, several studies have suggested that early transport to extracorporeal cardiopulmonary resuscitation (ECPR)-capable centers may be considered in selected patients with refractory shockable OHCA [7–9]. However, other studies have reported the benefits of remaining at the scene and continuing resuscitation [10–12]. Therefore,

there is a trade-off between leaving the scene early for VA-ECMO application and staying to continue on-scene resuscitation, and the acceptable on-scene time and its associated factors require further consideration. In this study, we examined the time-dependent probabilities at the scene for favorable neurological outcomes of OHCA with an initial shockable rhythm by using nationwide Utstein data in Japan. We further investigated the background factors associated with OHCA cases that favor staying on scene to continue resuscitation rather than leaving the scene early.

Methods

Study Designs

This retrospective study used a database comprising two datasets: Japan's national Utstein database and all emergency transport records.

EMS System in Japan

Japan's emergency medical system, organized by local governments, uses a nationwide unified 119 emergency call system that dispatches the nearest available ambulance from the local fire departments. Ambulances carry an EMS crew of three, at least one of whom is a nationally certified emergency life-saving technician (ELT). An ELT can perform intravenous access, administer epinephrine intravenously, and establish an advanced airway under the direction of an online physician. All resuscitation procedures by EMS are regulated by local medical control protocols that are based on national resuscitation protocols issued by the Fire and Disaster Management Agency of the Ministry of Internal Affairs and Communications of Japan.

Data Collection

Data from Japan's Utstein database and emergency transport records between January 2017 and December 2022 were collected from all fire departments in Japan. Utstein dataset were recorded along with the Utstein guidelines. Both datasets include patients' age, sex, area codes, and time of the emergency call; however, the Utstein dataset does not include on-scene time. To evaluate on-scene time for OHCA, the datasets were merged based on emergency call acceptance date/time, age, sex, and area codes. Duplicate data were excluded.

Inclusion and Exclusion Criteria

Adults (patient age of 18 years or more) and cardiogenic OHCA with an initial shockable rhythm were included. Cases where bystander defibrillation was performed and advanced procedures were done by physicians at the scene were excluded. Cases with missing data on time, return of spontaneous circulation (ROSC), and outcome at 1 month were also excluded.

Outcome

The outcome assessed was survival and a favorable functional outcome, defined as cerebral performance category (CPC) 1 or 2 at 1 month.

Statistical Analysis

Data are presented as medians and interquartile ranges (IQRs) for continuous variables and numbers and percentages for categorical variables. The group with favorable functional outcomes (CPC 1/2 at 1 month) was compared with the non-favorable group (CPC 3/4/5 at 1 month) by using the Mann-Whitney *U* test and chi-square test, with a significance threshold of $p < 0.05$. Additionally, the time-dependent probabilities for favorable functional outcomes were evaluated. As reported by Okubo et al. [10], for each subsequent minute, the probability of achieving the outcome was calculated by setting the time point of EMS contact with the patient as 0 min, with the number of patients receiving resuscitation at each minute as the denominator, and the number of patients who achieved ROSC and a favorable neurological outcome at each minute as the numerator. Further, differences in these probabilities were examined based on sex, age of ≥ 75 years or less, witness status, and presence or absence of bystander CPR. The age cutoff was set at 75 years, based on the commonly accepted indication threshold for extracorporeal cardiopulmonary resuscitation (ECPR) [14]. Since the time to the first defibrillation shock can significantly affect the on-scene time, sensitivity analysis was performed for cases in which defibrillation was performed by EMS within 1 min.

Results

Of the 631,562 OHCA during the study period, 22,383 OHCA were included for further analysis (Fig. 1). The characteristics of the study subjects are shown in Table 1. Among these, 5,095 cases achieved ROSC at the scene (group with on-scene ROSC) and 17,288 did not (group without on-scene ROSC). The group with on-scene ROSC, compared to the group without on-scene ROSC, was younger (66 years vs 69 years, $p < 0.001$), had cases that were more likely to be witnessed (4,483 [88.0%] vs 13,655 [79.0%], $p < 0.001$), and had cases where patients were more likely to receive bystander chest compressions (3,552 [69.7%] vs 10,246 [59.3%], $p < 0.001$). On the other hand, prehospital airway device placement and epinephrine administration were frequent in the group without on-scene ROSC (9,196 [53.2%] vs 1,461 [28.7%], $p < 0.001$, and 7,885 [45.6%] vs 925 [18.2%], $p < 0.001$, respectively). The median prehospital time intervals (response time, on-scene time, and transport time) were comparable between the two groups (group with on-scene ROSC vs group without on-scene ROSC: 7 min vs 8 min, 13 min vs 12 min, and 9 min vs 9 min, respectively). A favorable functional outcome, defined as CPC 1/2, was achieved in 4,983 cases, and was more frequent in the group with on-scene ROSC (3,182 [62.4%] vs 1,801 [10.4%], $p < 0.001$).

Table 1
Characteristics of the study participants

	Total	On-scene ROSC	Non-ROSC	p-values
	(n = 22,383)	(n = 5,095)	(n = 17,288)	
Male sex, n (%)	17,881 (79.9)	4,025 (79.0)	13,856 (80.1)	0.07
Age, years (IQR)	69 (57–78)	66 (55–75)	69 (58–79)	< 0.001
Witness, n (%)	18,138 (81.0)	4,483 (88.0)	13,655 (79.0)	< 0.001
Bystander chest compressions, n (%)	13,798 (61.6)	3,552 (69.7)	10,246 (59.3)	< 0.001
Prehospital use of				
advanced airway devices, n (%)	10,657 (47.6)	1,461 (28.7)	9,196 (53.2)	< 0.001
Epinephrine administration, n (%)	8,810 (39.4)	925 (18.2)	7,885 (45.6)	< 0.001
Response time, min (IQR)	8 (6–10)	7 (6–9)	8 (6–10)	< 0.001
On-scene time, min (IQR)	12 (9–16)	13 (10–17)	12 (9–16)	< 0.001
Transport time, min (IQR)	9 (6–14)	9 (6–14)	9 (6–14)	< 0.001
Survival at 1 month, n (%)	7,509 (33.5)	3,987 (78.3)	3,522 (20.4)	< 0.001
Favorable neurological outcome, n (%)	4,983 (22.2)	3,182 (62.4)	1,801 (10.4)	< 0.001

IQR, interquartile range; ROSC, return of spontaneous circulation

Figure 2 shows the probabilities for ROSC at the scene. The probability was less than 20% when the time from EMS contact exceeded 5 min, and less than 5% after 10 min. The probabilities for favorable functional outcomes show similar trends (Fig. 2b). Figure 3 shows the results of a subanalysis of probabilities for on-scene ROSC with respect to sex (male vs female, Fig. 3a), age (under 75 years vs 75 years or older, Fig. 3b), witness status (Fig. 3c), and presence/absence of bystander chest compressions (Fig. 3d). The probabilities were comparable between the groups for sex, witness status, and bystander status where the chances for on-scene ROSC decreased below 20% over 10 min. However, the impact of age was significant. Regarding OHCA in individuals aged 75 years or older, the probability of achieving ROSC was < 10% if the EMS contact happened at 10 min, while that for achieving ROSC in cases of OHCA among individuals aged < 75 years was approximately 30% for the same 10-min response interval.

Figure 4 shows the time distribution for the first defibrillation by EMS peaked at 1 min, and the proportion of the defibrillations within 1 min was 63.6% (2026 cases). Sensitivity analysis focusing on these 2026 cases in which defibrillation was performed within 1 min revealed that the time-dependent probabilities remained unchanged (supplementary data).

Discussion

This study demonstrates that in OHCA with an initial shockable rhythm, the probability of achieving ROSC after 10 min of the time from EMS contact under current resuscitation practice is $< 10\%$ and decreases to $\leq 5\%$ after 20 min. Furthermore, the effects of witness and bystander CPR, which generally are reported to be associated with a favorable outcome, were virtually eliminated when the on-scene time exceeded 5 min. However, this study demonstrated that patients younger than 75 years of age are more likely to be candidates for prolonged on-scene resuscitation efforts. When focusing on the cases in which early defibrillation was achieved (within 1 min from EMS contact), the results remained unchanged.

Previous studies have examined the optimal on-scene response times for OHCA, indicating a limit of approximately 20 min [4–6]. Our findings in patients with initial shockable rhythms are consistent with these reports. When the first defibrillation fails, the chances of ROSC decrease with an increase in defibrillation attempts [15, 16]. For individuals with OHCA unresponsive to the initial defibrillation, the use of ECMO has become more common in recent years [7–9].

Yannopoulos et al. conducted a phase 2 trial on early ECMO initiation. In the trial, patients aged 18–75 years with ventricular fibrillation or pulseless ventricular tachycardia who failed to achieve ROSC after three defibrillation attempts and had an estimated transport time of less than 30 min were enrolled. The trial showed that early ECMO was associated with improved survival and favorable neurological outcomes [9]. However, ECMO should be initiated as early as possible [17–19].

Conversely, several studies indicate that neurological outcomes are better in cases in which ROSC is achieved at the scene [10–12]. Grunau et al. compared intra-arrest transport with continued on-scene resuscitation by using propensity score matching in 43,969 OHCA cases from the Resuscitation Outcome Consortium (ROC) Cardiac Epidemiologic Registry. They reported no advantage for intra-arrest transport, and this trend was consistent even in cases of OHCA with an initial shockable rhythm [10]. Furthermore, in a study of OHCA in Japan with propensity score matching, Yoshimura et al. reported no difference in neurological outcomes between cases involving intra-arrest transport and on-scene resuscitation. However, the study showed favorable outcomes for intra-arrest transport when the on-scene duration exceeded 20 min among OHCA cases with an initial shockable rhythm [11]. A recent randomized controlled trial on early transport versus on-scene retention by Burns et al. also showed no overall advantage afforded by early transport in OHCA. Similarly, for OHCA with an initial shockable rhythm, while no significant difference was found, the proportion of OHCA with an initial shockable

rhythm for which favorable neurological outcomes were achieved at 1 and 6 months was higher in cases of early transport than in those with continued on-scene resuscitation [12].

From the perspective of determining “how long EMS should remain on scene for OHCA with an initial shockable rhythm,” this study evaluated time-dependent probabilities. This study clarifies that factors traditionally recognized as favorable prognostic indicators, such as bystander CPR and witnessed cardiac arrest, do not support prolonged on-scene resuscitation efforts. Instead, patient age of 75 years or less emerges as the primary factor influencing an extended on-scene duration. Several studies indicate a favorable prognosis for OHCA in patients younger than 75 years of age [20, 21]. Generally, pre-existing comorbidities increase with age, and the prognosis for OHCA in older adults is thought to be poorer. However, the relationship between pre-existing comorbidities and OHCA prognosis remains inconclusive [21, 22]. This study could not examine pre-existing comorbidities owing to a lack of data collection. However, it is reasonable to assume that younger individuals can tolerate a cardiac arrest for a longer duration compared to older individuals. Funada et al. reported that in cases in which prehospital ROSC was achieved, the low-flow time threshold for reaching CPC 1/2 tended to be longer in younger patients [20]. Furthermore, while no difference was observed between bystander CPR and witnessed cases, Huang et al. reported that these factors were associated with a favorable prognosis in younger patients [21].

This study indicates that the on-scene trend for OHCA with an initial shockable rhythm would remain the same until the resuscitation practice changes in Japan. The key factor that can possibly alter the trend is the quality of CPR, a factor that could not be evaluated in our study cohort. Several animal experiments [23, 24] and human observational studies [25–27] indicate that the quality of peri-defibrillation CPR, such as high chest compression fraction and minimized perishock pause, can increase the chance of defibrillation success. Further advances in resuscitation quality could potentially alter the acceptable on-scene time.

This study has some limitations. First, because this was a retrospective observational study, establishing strict causality was difficult, and uncontrollable confounding factors may exist. Second, especially in urban areas, high-rise buildings and apartments are common. It is expected that more time is required for patient transportation in cases involving high-rise buildings and apartments, which account for the majority of on-scene time in some regions. Third, a total of 1,244 cases (approximately 5%) were excluded owing to missing data on time variables or EMS defibrillation. This exclusion may have introduced bias that could have affected the study results. Finally, because this study was based on a nationwide registry, differences in treatment protocols existing across regions may have affected the results.

Conclusions

Our study suggests that under current EMS resuscitation practices in Japan, the probability of achieving ROSC within 10 min of arrival for OHCA with an initial shockable rhythm is < 10% and decreases to $\geq 5\%$

or less after 20 min. Candidates for continued on-scene resuscitation, regardless of witness status or bystander CPR, would be patients under 75 years of age. However, in this study cohort, only 63.6% of patients received the first defibrillation within 1 min. Further promotion of early defibrillation could potentially alter the acceptable framework for on-scene resuscitation time.

Abbreviations

OHCA

Out-of-hospital cardiac arrest

EMS

Emergency medical services

VA-ECMO

Veno-arterial extracorporeal membranous oxygenation

ELS

Emergency life-saving technician

ROSC

Return of spontaneous circulation

CPC

Cerebral performance category

Declarations

Ethics approval and consent to participate

The study was approved by the ethics committee of Nara Medical University Hospital (approval number: 3933). The requirement for informed consent was waived for all enrolled patients because the study used anonymized public-domain data. The study was conducted in accordance with the tenets of the Declaration of Helsinki.

Consent for publication

Not applicable. This study used anonymized retrospective data, and no individual person's data in any form (including individual details, images, or videos) are included. The requirement for informed consent was waived by the ethics committee.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare no competing interests.

Funding

None.

Authors' contribution

Keita Miyazaki: Conceptualization, Methodology, Statistical analysis, Investigation, Data Curation, Writing-Original Draft, Writing-Review & Editing, Visualization, and Project administration. Arisa Kinoshita: Writing-Review & Editing. Keisuke Tsuruta: Writing-Review & Editing. Hideki Asai: Investigation and Writing-Review & Editing. Yasuyuki Kawai: Writing-Review & Editing. Keigo Saeki: Methodology, Statistical analysis, and Writing-Review & Editing. Hidetada Fukushima Writing-Review and Finalizing the manuscript.

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Figures

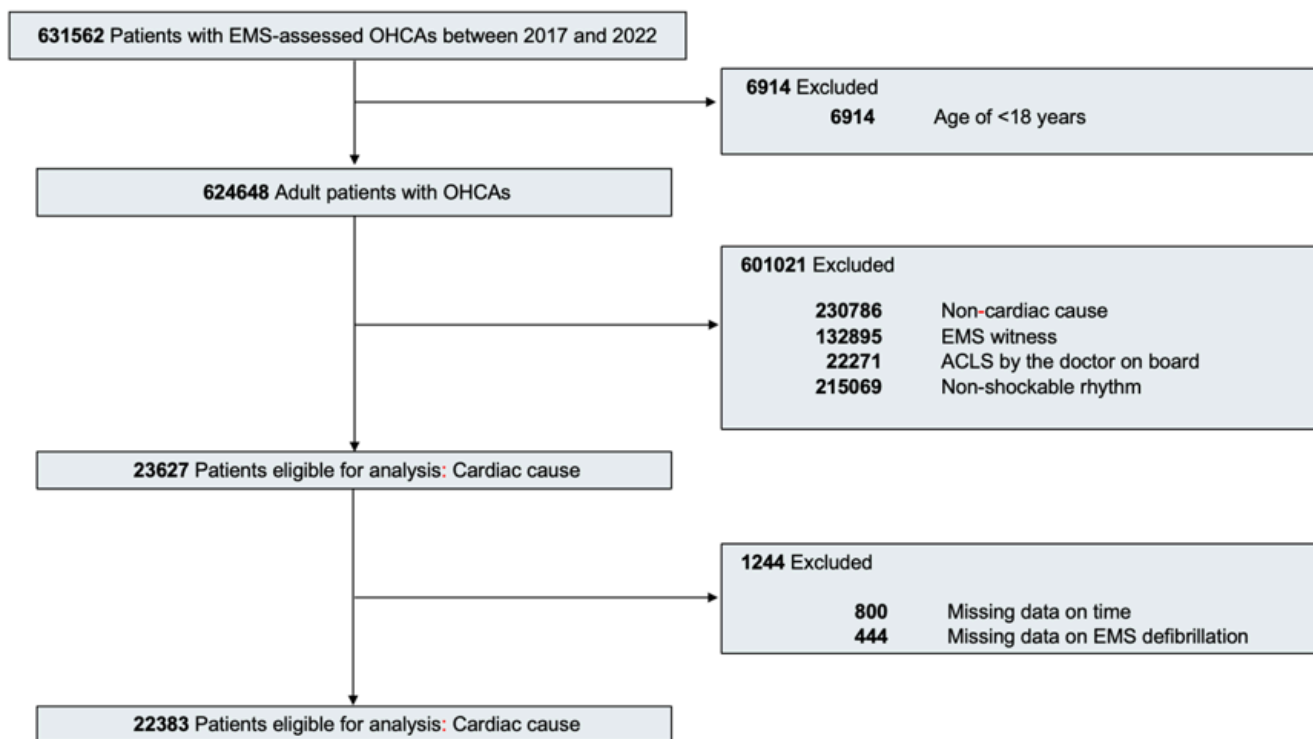


Figure 1

Flowchart of study participants with cardiogenic out-of-hospital cardiac arrest eligible for defibrillation.

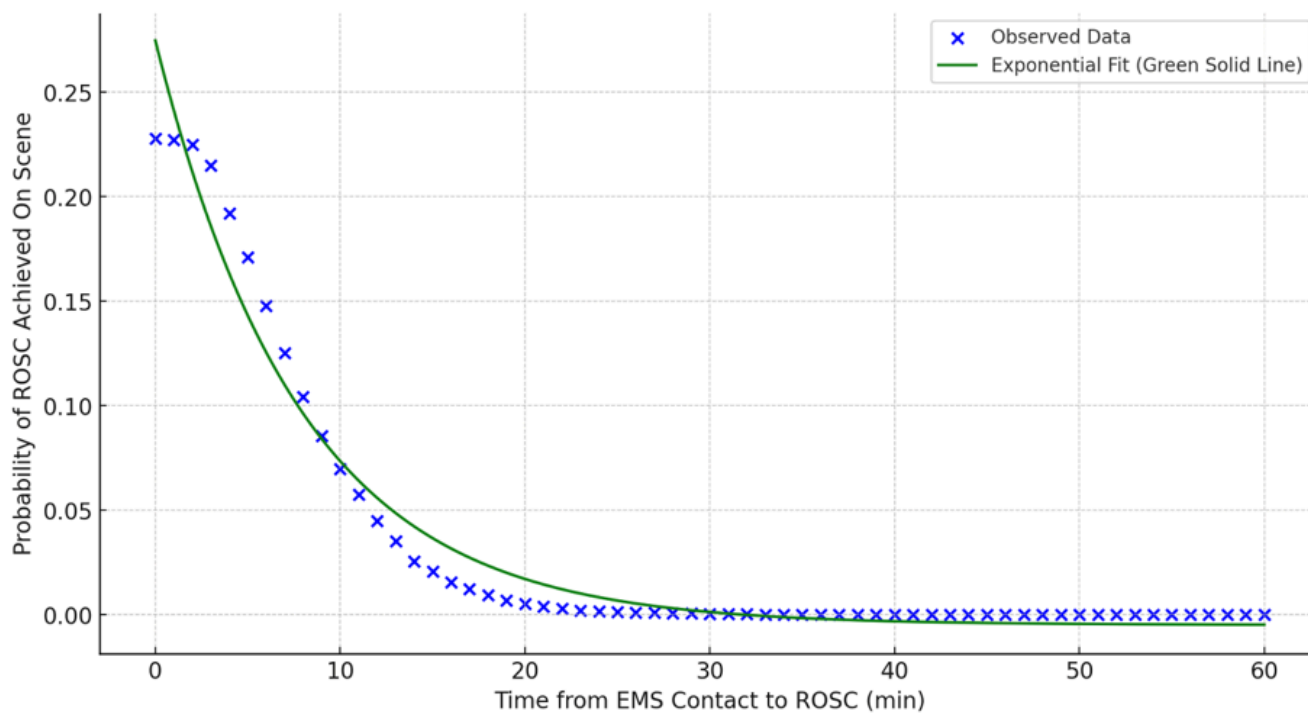


Figure 2

Probability of ROSC achieved on scene vs. time from EMS contact to ROSC

ROSC: return of spontaneous circulation; EMS: emergency medical services

The figure shows the exponential decay relationship between the probability of achieving on-scene ROSC and the time from EMS contact to ROSC among 22,383 patients with defibrillation-eligible OHCA.

OHCA: out-of-hospital cardiac arrest; ROSC: return of spontaneous circulation; EMS: emergency medical services

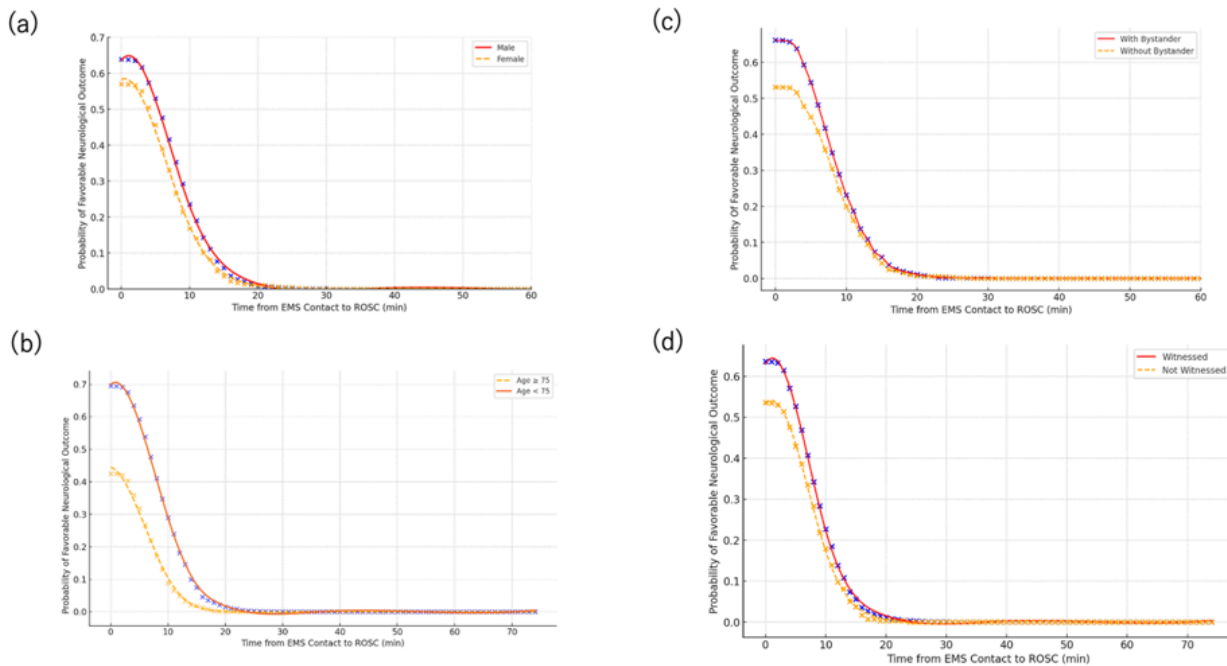


Figure 3

Time-dependent probability of on-scene ROSC with favorable neurological outcomes under various conditions. a: male vs female patients, b: presence/absence of bystander CPR, c: patient age of 75 years or more vs patient age of <75 years, d: witnessed/non-witnessed cases

ROSC: return of spontaneous circulation; CPR: cardiopulmonary resuscitation

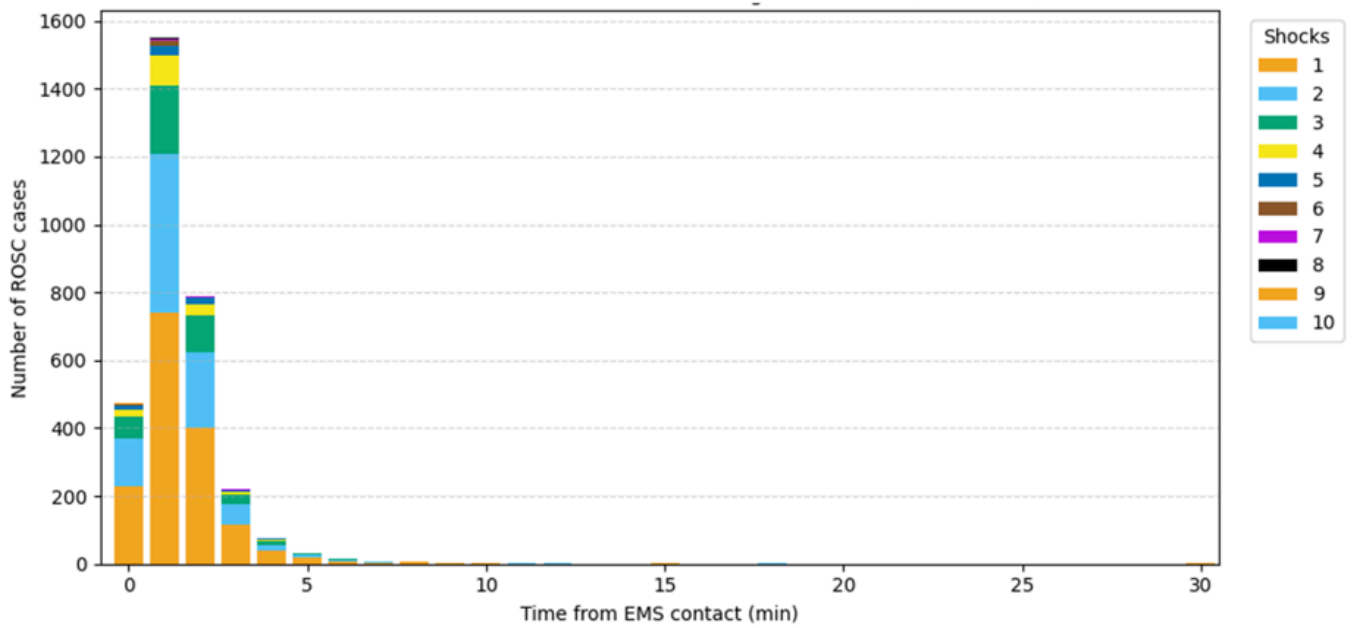


Figure 4

Distribution of the number of defibrillation attempts among ROSC cases

The figure shows the distribution of the number of defibrillation attempts among patients who achieved on-scene ROSC with favorable neurological outcomes. The peak time to the first defibrillation after EMS arrival was 1 min.

ROSC: return of spontaneous circulation; EMS: emergency medical services

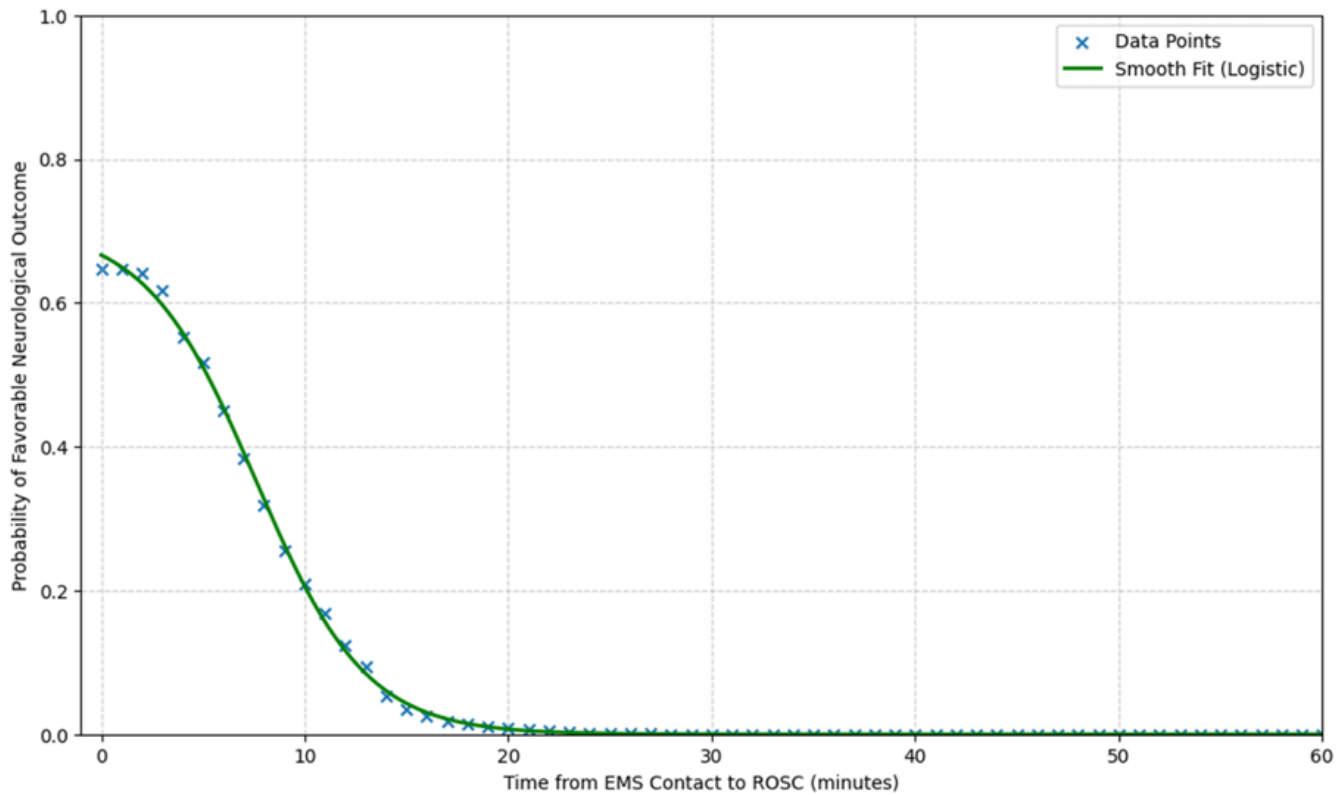


Figure 5

Probability of favorable neurological outcome vs. time from EMS contact to ROSC

The figure shows the relationship between time from EMS contact to ROSC and favorable neurological outcomes among patients who achieved on-scene ROSC and received their first defibrillation within 1 min. No significant difference was observed compared to that in the analysis including patients with a time to first defibrillation of 1 min or longer.

ROSC: return of spontaneous circulation; EMS: emergency medical services

Supplementary Files

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