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ORIGINAL ARTICLE
Epidemiology

Association Between Resuscitative Time on the Scene and Survival After Pediatric Out-of-Hospital Cardiac Arrest

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Background: The optimal timing for transporting pediatric patients with out-of-hospital cardiac arrest (OHCA) who do not achieve return of spontaneous circulation (ROSC) is unclear. Therefore, we assessed the association between resuscitation time on the scene and 1-month survival.

Methods and Results: Data from the All-Japan Utstein Registry from 2013 through 2015 for 3,756 pediatric OHCA patients (age <18 years) who did not achieve ROSC prior to departing the scene were analyzed. Overall, the proportion of 1-month survival for on-scene resuscitation time <5, 5–9, 10–14, and ≥15 min was 13.6% (104/767), 10.2% (170/1,666), 8.6% (75/870), and 4.0% (18/453), respectively. Among specific age groups, the proportion of 1-month survival for on-scene resuscitation time of <5, 5–9, 10–14, and ≥15 min was 12.6% (54/429), 8.7% (59/680), 8.6% (23/267), and 6.8% (8/118), respectively, for patients aged 0 years; 16.4% (38/232), 11.0% (52/473), 11.9% (23/194), and 7.1% (6/85), respectively, for those aged 1–7 years; and 11.3% (12/106), 11.5% (59/513), 7.1% (29/409), and 1.6% (4/250), respectively, for those aged 8–17 years.

Conclusions: Longer on-scene resuscitation was associated with decreased chance of 1-month survival among pediatric OHCA patients without ROSC. For patients aged <8 years, earlier departure from the scene, within 5 min, may increase the chances of 1-month survival. Conversely, for patients aged ≥8 years, continuing on-scene resuscitation for up to 10 min would be reasonable.

Key Words: Emergency medical services; Out-of-hospital cardiac arrest; Pediatrics

Annually, over 350,000 individuals in the US and 127,000 in Japan experience out-of-hospital cardiac arrest (OHCA) with high mortality, highlighting the public health burden of OHCA.[1,2] Pediatric patients in particular constitute a vulnerable population because of the greater number of lost years of life per victim.

Emergency medical services (EMS) play a crucial role in OHCA care as a link in "the chain of survival".[3] Prior studies on pediatric OHCA investigated the effects of EMS practices and interventions, such as EMS response time, advanced airway management (AAM), and epinephrine (adrenaline) administration.[4–7] However, how long resuscitative efforts should be continued in pediatric patients who do not achieve a return of spontaneous circulation (ROSC) before departing the scene and transporting the patient to hospital has not been fully investigated. This gap in knowledge results in uncertainty in the optimal timing of when pediatric patients with OHCA without ROSC should be transported from the scene to hospital. Therefore, in the present study we evaluated the association between the duration of resuscitation time at the scene and survival among pediatric patients with OHCA who did not have ROSC prior to transport.

Methods

Study Design and Setting

This historical cohort study undertook a secondary analysis of the All-Japan Utstein Registry of the Fire and Disaster Management Agency (FDMA). The details of this registry

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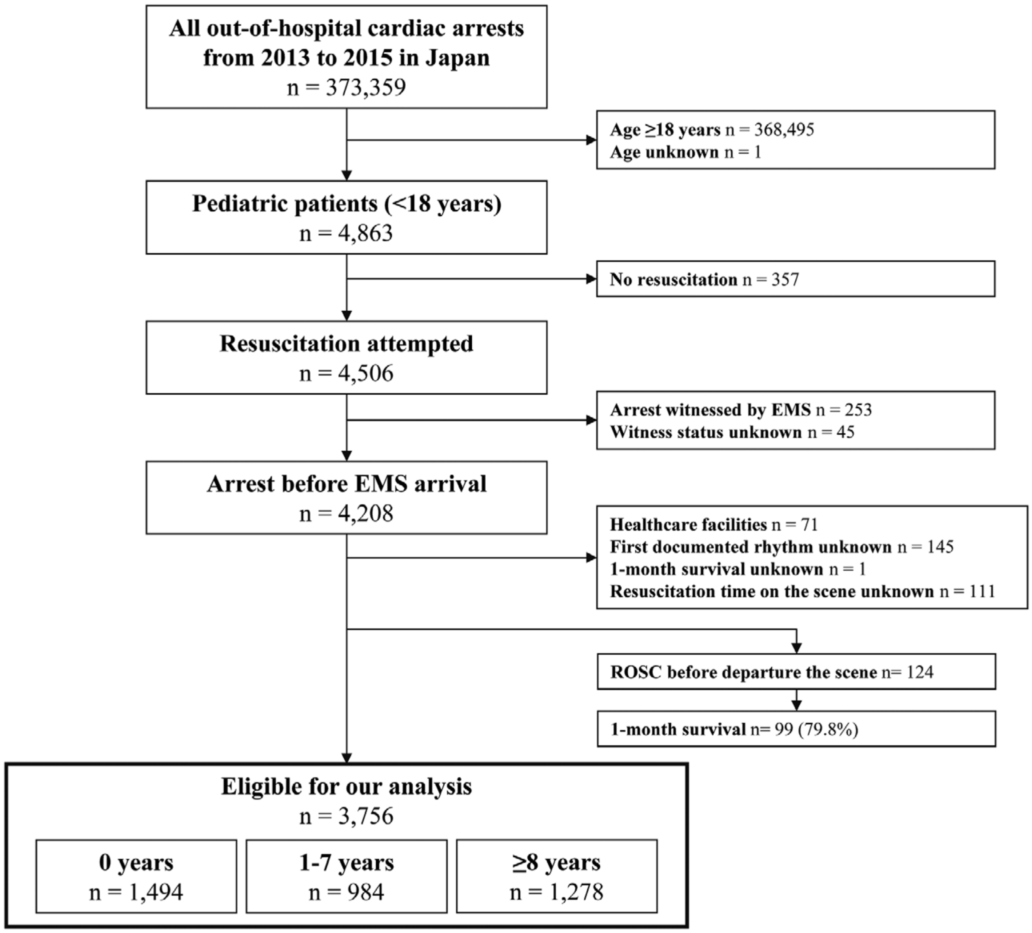

Figure. Study flowchart for the selection of patients with out-of-hospital cardiac arrest between January 1, 2013 and December 31, 2015. EMS, emergency medical services; ROSC, return of spontaneous circulation.

have been described previously.[8] In this prospective nationwide population-based OHCA registry, cardiac arrest is defined as lack of cardiac mechanical activity confirmed by a lack of clinical evidence of circulation based on the Utstein Resuscitation Registry Template.[9] The All-Japan Utstein Registry includes information on patient age, sex, date of cardiac arrest, arrest location, etiology, witness status, first monitored rhythm, layperson cardiopulmonary resuscitation (CPR), dispatcher CPR instructions, public access automated external defibrillator (AED) shock delivery, prehospital AAM, prehospital epinephrine administration, resuscitation time course, and outcome measurements.[8] In addition to the data items included as per the international Utstein template, from January 2013 the FDMA started collecting detailed information on the location where the OHCA occurred. According to the current international Utstein standardized template, the location of cardiac arrest is classified as either home/residence, industrial/workplace, sports/recreation event, street/highway, public building, assisted living/nursing home, educational institution, other, or unknown/not recorded.[8] The resuscitation time course variables include each EMS time stamp of the emergency call, vehicle arrival on the scene, patient contact, initiation of chest compression, departure from the scene, and hospital arrival.[8]

EMS System in Japan

In Japan, EMS are provided by regional governments; in 2015, there were 750 fire departments with dispatch centers throughout Japan. Emergency life-saving technicians (ELSTs), who are highly trained emergency care providers, are allowed to insert an intravenous line and an adjunct airway, as well as to use semi-AEDs for OHCA patients. Specially trained ELSTs are allowed to intubate and administer epinephrine. Basically, each ambulance has a crew of 3 emergency providers including at least 1 ELST. Treatment for cardiac arrest was conducted based on the Japanese CPR guidelines.[9] EMS providers collect the data and integrate it into the registry system on the FDMA database server. The entered data receive logical consistency checks. If the data are missing or flagged for inconsistency, the FDMA contacts the reporting EMS and instructs them to enter or correct the data. EMS providers initiate resuscitation, except in the case of obvious death (e.g., decapitation, incineration, decomposition, rigor mortis, or dependent cyanosis), and are not legally permitted

Table 1. Characteristics of Patients According to Age Group

	Total (n=3,756)	Age (years) 0 (n=1,494)	1–7 (n=984)	8–17 (n=1,278)	P value
Resuscitation time on scene (min)	8.7±5.5	7.6±5.2	8.0±5.0	10.7±5.7	<0.001
Category of resuscitation time on the scene					<0.001
<5 min	767 (20.4)	429 (28.7)	232 (23.6)	106 (8.3)	
5–9 min	1,666 (44.4)	680 (45.5)	473 (48.1)	513 (40.1)	
10–14 min	870 (23.2)	267 (17.9)	194 (19.7)	409 (32.0)	
≥15 min	453 (12.1)	118 (7.9)	85 (8.6)	250 (19.6)	
Male sex	2,280 (60.7)	866 (58.0)	577 (58.6)	837 (65.5)	<0.001
Layperson witnessed arrest	951 (25.3)	211 (14.1)	313 (31.8)	427 (33.4)	<0.001
Location of arrest					<0.001
Residential place	2,812 (74.9)	1,313 (87.9)	710 (72.2)	789 (61.7)	
Recreational/sporting area	38 (1.0)	8 (0.5)	15 (1.5)	15 (1.2)	
Public place	118 (3.1)	24 (1.6)	39 (4.0)	55 (4.3)	
Educational institution	108 (2.9)	21 (1.4)	24 (2.4)	63 (4.9)	
Street/highway	298 (7.9)	13 (0.9)	86 (8.7)	199 (15.6)	
Other	382 (10.2)	115 (7.7)	110 (11.2)	157 (12.3)	
VF as first documented rhythm	148 (3.9)	17 (1.1)	29 (2.9)	102 (8.0)	<0.001
Cardiac origin	1,256 (33.4)	670 (44.8)	339 (34.5)	247 (19.3)	<0.001
Dispatcher CPR instructions	2,418 (64.4)	1,078 (72.2)	642 (65.2)	698 (54.6)	<0.001
Layperson CPR	2,224 (59.2)	875 (58.6)	622 (63.2)	727 (56.9)	0.008
Shock delivery by public access AED	32 (0.9)	0 (0.0)	2 (0.2)	30 (2.3)	<0.001
Shock delivery by EMS before transport	127 (3.4)	13 (0.9)	19 (1.9)	95 (7.4)	<0.001
Epinephrine administration before transport	62 (1.7)	3 (0.2)	1 (0.1)	58 (4.5)	<0.001
Advanced airway management before transport	348 (9.3)	46 (3.1)	53 (5.4)	249 (19.5)	<0.001
Time from call to initiation of CPR by EMS personnel (min)	9.5±4.8	8.8±3.2	9.5±4.6	10.4±6.3	<0.001

Unless indicated otherwise, data are presented as the mean±SD or as n (%). AED, automated external defibrillator; CPR, cardiopulmonary resuscitation; EMS, emergency medical service; VF, ventricular fibrillation.

to terminate resuscitation in the field. Therefore, most patients who EMS providers resuscitated are transferred to receiving hospitals.

Study Participants

This study included pediatric patients (age <18 years) with OHCA in whom EMS providers initiated resuscitation between January 2013 and December 2015 and who were subsequently transported to hospitals (the most recent publicly available data as of May 2020, the time of the analysis). We defined initiated resuscitation as external shock delivery (by laypersons or EMS providers) or chest compression by EMS providers.[10] We excluded: (1) EMS-witnessed arrest; (2) OHCA with unknown witness status; (3) OHCA at healthcare facilities; (4) OHCA with unknown first monitored rhythm; (5) OHCA with unknown 1-month survival; (6) OHCA with unknown resuscitation time on the scene; and (7) patients with ROSC prior to scene departure. We excluded patients with ROSC prior to scene departure because our aim was to evaluate the timing of the initiation of transport with ongoing chest compression. A similar methodology, excluding those with ROSC before transport, was used to study the duration of on-scene resuscitative efforts for adult patients.[11] The timing of the departure from the scene was at the discretion of EMS providers.

Exposure

The main exposure variable was resuscitation time on the scene, defined as the interval between the initiation of chest compression by EMS providers and scene departure. Resuscitation time was categorized based on its distribution and clinical relevance (i.e., <5, 5–9, 10–14, and ≥15 min).

Outcome

The outcome measurement was 1-month survival.

Statistical Analyses

Characteristics of the study population are reported as the mean±SD for continuous variables and as counts and proportions for categorical variables. The significance of differences in characteristics across age groups (0, 1–7, and 8–17 years) was evaluated using one-way analysis of variance for continuous variables and Chi-squared tests for categorical variables. The age categories used in this study were chosen on the basis of prior knowledge.[12] To assess the association between resuscitation time on the scene and 1-month survival, we fit 2 multivariable logistic regression models. The first model (Model A) adjusted for sex, arrest location, etiology, witness status, first monitored rhythm, layperson CPR, dispatcher CPR instructions, public access AED shock delivery, and the interval between the emergency call and the initiation of chest compression by EMS providers. The second model (Model B) further adjusted for EMS interventions such as shock delivery by EMS providers, intravenous epinephrine administration, and AAM prior to scene departure in addition to the covariates in Model A. Compared with shorter resuscitative duration on the scene, a longer resuscitative duration theoretically

Table 2. Association Between Resuscitation Time on Scene and 1-Month Survival After Out-of-Hospital Cardiac Arrest

	Total	Resuscitation time on scene (min)				P value for trend
		<5	5–9	10–14	≥15	
Total						
1-month survival, n/N (%)	367/3,756 (9.8)	104/767 (13.6)	170/1,666 (10.2)	75/870 (8.6)	18/453 (4.0)	
Crude OR (95% CI)		Ref.	0.72 (0.56–0.94)	0.60 (0.44–0.82)	0.26 (0.16–0.44)	<0.001
Adjusted OR (95% CI)[A]		Ref.	0.65 (0.49–0.85)	0.56 (0.40–0.79)	0.21 (0.12–0.37)	<0.001
Adjusted OR (95% CI)[B]		Ref.	0.64 (0.49–0.85)	0.57 (0.41–0.81)	0.23 (0.13–0.40)	<0.001
0 years old						
1-month survival, n/N (%)	144/1,494 (9.6)	54/429 (12.6)	59/680 (8.7)	23/267 (8.6)	8/118 (6.8)	
Crude OR (95% CI)		Ref.	0.66 (0.45–0.98)	0.66 (0.39–1.09)	0.51 (0.23–1.09)	0.010
Adjusted OR (95% CI)[A]		Ref.	0.59 (0.39–0.89)	0.54 (0.31–0.94)	0.30 (0.13–0.69)	<0.001
Adjusted OR (95% CI)[B]		Ref.	0.60 (0.39–0.91)	0.56 (0.32–0.98)	0.31 (0.13–0.72)	0.001
1–7 years old						
1-month survival, n/N (%)	119/984 (12.1)	38/232 (16.4)	52/473 (11.0)	23/194 (11.9)	6/85 (7.1)	
Crude OR (95% CI)		Ref.	0.63 (0.40–0.99)	0.69 (0.39–1.20)	0.39 (0.16–0.95)	0.027
Adjusted OR (95% CI)[A]		Ref.	0.59 (0.37–0.95)	0.72 (0.40–1.30)	0.36 (0.14–0.92)	0.046
Adjusted OR (95% CI)[B]		Ref.	0.59 (0.37–0.95)	0.73 (0.40–1.32)	0.36 (0.14–0.92)	0.050
8–17 years old						
1-month survival, n/N (%)	104/1,278 (8.1)	12/106 (11.3)	59/513 (11.5)	29/409 (7.1)	4/250 (1.6)	
Crude OR (95% CI)		Ref.	1.02 (0.53–1.97)	0.60 (0.29–1.22)	0.13 (0.04–0.41)	<0.001
Adjusted OR (95% CI)[A]		Ref.	0.62 (0.30–1.27)	0.36 (0.17–0.78)	0.06 (0.02–0.20)	<0.001
Adjusted OR (95% CI)[B]		Ref.	0.62 (0.30–1.27)	0.38 (0.18–0.83)	0.07 (0.02–0.25)	<0.001

[A]Model A: adjusted for sex, witness status, location of arrest, first documented rhythm, etiology of arrest, dispatcher cardiopulmonary resuscitation (CPR) instructions, layperson CPR, shock delivery by public access automated external defibrillator (AED), and time from call to initiation of CPR by emergency medical services (EMS) personnel. [B]Model B: adjusted for sex, witness status, location of arrest, first documented rhythm, etiology of arrest, dispatcher CPR instructions, layperson CPR, shock delivery by public access AED, time from call to initiation of CPR by EMS personnel, shock delivery by EMS before transport, epinephrine administration before transport, and advanced airway management before transport. CI, confidence interval; OR, odds ratio.

relates to opportunities to provide advanced life support (ALS) interventions (e.g., epinephrine administration and AAM) and high-quality CPR. We constructed the 2 models because we attempted to unpack these 2 aspects potentially related to on-scene resuscitation time; that is, the first model demonstrated the effect of combining these 2 components and the second eliminated the effect of epinephrine and AAM. Using these models, we calculated odds ratios (ORs) with 95% confidence intervals (CIs) for survival. We also performed the above multivariable analyses for each age group. All tests were 2-tailed and P<0.05 was considered significant. Statistical analyses were conducted using SPSS version 26.0 (IBM Corp., Armonk, NY, USA).

Results

The study flowchart for the selection of patients with pediatric OHCA without ROSC is shown in the **Figure**. Excluding patients meeting the exclusion criteria left 3,756 patients eligible for this study. There were 1,494 (39.8%), 984 (26.2%), and 1,278 (34.0%) OHCA patients aged 0, 1–7, and 8–17 years, respectively. The baseline characteristics of the patients stratified by age group are presented in **Table 1**. Overall, the number of patients with a resuscitation time on the scene of <5, 5–9, 10–14, and ≥15 min was 767 (20.4%), 1,666 (44.4%), 870 (23.2%), and 453 (12.1%), respectively. Younger patients were more likely to receive shorter resuscitation time on the scene (P<0.001).

Table 2 presents 1-month survival after OHCA by age group. Overall, 367 of 3,756 patients (9.8%) survived 1 month after OHCA. The proportion of patients surviving 1 month for on-scene resuscitation times of <5, 5–9, 10–14, and ≥15 min was 13.6% (104/767), 10.2% (170/1,666), 8.6% (75/870), and 4.0% (18/453), respectively. In the multivariable analysis adjusting for sex, arrest location, etiology, witness status, first monitored rhythm, layperson CPR, dispatcher CPR instructions, public access AED shock delivery, and time from call to initiation of chest compression by EMS providers (Model A), compared with patients who underwent resuscitation for <5 min, 1-month survival was inversely associated with on-scene resuscitation time for 5–9 min (OR 0.65, 95% CI 0.49–0.85), 10–14 min (OR 0.56, 95% CI 0.40–0.79), and ≥15 min (OR 0.21, 95% CI 0.12–0.37). Additional adjustment for EMS interventions (Model B) showed similar results.

In the stratified analysis by age group (**Table 2**), among patients aged 0 years, the proportion of 1-month survival for on-scene resuscitation times of <5, 5–9, 10–14, and ≥15 min was 12.6% (54/429), 8.7% (59/680), 8.6% (23/267), and 6.8% (8/118), respectively. For patients aged 1–7 years, the proportion of 1-month survival for on-scene resuscitation times of <5, 5–9, 10–14, and ≥15 min was 16.4% (38/232), 11.0% (52/473), 11.9% (23/194), and 7.1% (6/85), respectively, and for those aged 8–17 years the proportion was 11.3% (12/106), 11.5% (59/513), 7.1% (29/409), and 1.6% (4/250), respectively. In the multivariable analysis, among patients aged 0 and 1–7 years, the proportion of 1-month survival was significantly decreased when the resuscitation time on the scene exceeded 5 min. Conversely, among patients aged ≥8 years, the proportion of 1-month survival did not decrease significantly until the resuscitation time on the scene exceeded 10 min. The results of the multivariable analyses for all variables according to age group are provided in the **Supplementary Table**.

Discussion

The present study evaluated the association between resuscitation time on the scene and 1-month survival among pediatric OHCA patients who did not achieve ROSC prior to transport in Japan. Overall, the results showed that longer resuscitation time on the scene was associated with lower chance of 1-month survival. However, the association between resuscitation time on the scene and survival rate was not consistent across age groups. Although the survival rate decreased significantly when the resuscitation time on the scene exceeded 5 min among patients aged <8 years, the survival rate did not decrease significantly until the resuscitation time on the scene exceeded 10 min among patients of ≥8 years. Thus, the results suggest that if ROSC cannot be archived during initial resuscitation, departure from the scene within 5 min with ongoing resuscitation may increase the chances of 1-month survival for patients <8 years of age. Conversely, continuing on-scene resuscitation for up to 10 min may be reasonable for patients >8 years of age.

Our findings are not consistent with those of a secondary analysis of the Resuscitation Outcomes Consortium (ROC) dataset, a multicenter OHCA registry in the US and Canada.[13] The ROC study demonstrated that the highest survival to hospital discharge (10.2%) was observed with a time on scene of 10–35 min for pediatric patients (age ≤19 years) compared with an on-scene time of <10 min (5.3%) and >35 min (6.9%).[12] The potential reasons for the differences in findings between the present and the previous study include differences in the frequency of provision of ALS interventions (e.g., epinephrine administration and AAM, such as supraglottic airway device insertion and endotracheal intubation). In the present study, EMS providers administered epinephrine and performed AAM in 1.7% and 9.3% of patients, respectively, with EMS-resuscitated OHCA; in comparison, in the ROC study, 68.2% of patients received epinephrine and 64.6% underwent endotracheal intubation.[12] This suggests that EMS providers in the ROC study more often stayed on the scene for ALS interventions than EMS providers in Japan.

Study Limitations

First, because of the observational nature of the study design, we could not assess the causality between time on scene and survival, only the association. Second, the duration of resuscitative efforts for those without ROSC before transport could have correlated with time to ROSC (i.e., those with longer on-scene resuscitation may have had a longer time to achieve subsequent ROSC). This could have biased longer on-scene resuscitation towards harmful effects.[14] Third, although the data for the present study were collected throughout Japan, the EMS systems, public awareness and training of laypeople, and post-resuscitation care vary according to countries and regions. Therefore, our results may not be generalizable to other areas in the world. Fourth, we were unable to obtain some information about several individual factors associated with the prognosis of cardiac arrests, such as the activities of daily living at the time of arrest, comorbidities, quality of CPR, and in-hospital post-resuscitation care. These unmeasured factors may have affected our results. Thus, the present study has a number of limitations because of the study design. However, given the low incidence of pediatric OHCAs and the paucity of studies assessing the duration of resuscitative efforts, we believe that our results using a nationwide dataset are informative and provide new knowledge.

Conclusions

In this secondary analysis of the prospective nationwide population-based OHCA registry in Japan, longer on-scene resuscitation was associated with decreased chance of 1-month survival among pediatric patients who did not have ROSC before transport. For patients aged <8 years, departure from the scene within 5 min with ongoing resuscitation may increase the chance of 1-month survival, whereas for patients aged ≥8 years departure from the scene within 10 min may be beneficial.

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Disclosures

All authors have no conflicts of interest to declare.

IRB Information

This study was approved by the Osaka University Hospital Ethical Review Committee (Reference no. 14147-2).

Data Availability

No additional data will be made available.

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Supplementary Files

Please find supplementary file(s);
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