Subsequent Shockable Rhythm During Out-of-Hospital Cardiac Arrest in Children With Initial Non-Shockable Rhythms: A Nationwide Population-Based Observational Study

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Background—The effect of a subsequent treated shockable rhythm during cardiopulmonary resuscitation on the outcome of children who suffer out-of-hospital cardiac arrest with initial nonshockable rhythm is unclear. We hypothesized that subsequent treated shockable rhythm in children with out-of-hospital cardiac arrest would improve survival with favorable neurological outcomes (Cerebral Performance Category scale 1–2).

Methods and Results—From the All-Japan Utstein Registry, we analyzed the records of 12 402 children (aged <18 years) with out-of-hospital cardiac arrest and initial nonshockable rhythms. Patients were divided into 2 cohorts: subsequent treated shockable rhythm (YES; n=239) and subsequent treated shockable rhythm (NO; n=12 163). The rate of 1-month cerebral performance category 1 to 2 in the subsequent treated shockable rhythm (YES) cohort was significantly higher when compared to the subsequent treated shockable rhythm (NO) cohort (4.6% [11 of 239] vs 1.3% [155 of 12 163]; adjusted odds ratio, 2.90; 95% CI, 1.42–5.36; all P<0.001). In the subsequent treated shockable rhythm (YES) cohort, the rate of 1-month cerebral performance category 1 to 2 decreased significantly as time to shock delivery increased (17.7% [3 of 17] for patients with shock-delivery time 0–9 minutes, 7.3% [8 of 109] for 10–19 minutes, and 0% [0 of 109] for 20–59 minutes; P<0.001 [for trend]). Age-stratified outcomes showed no significant differences between the 2 cohorts in the group aged <7 years old: 1.3% versus 1.4%, P=0.62.

Conclusions—In children with out-of-hospital cardiac arrest and initial nonshockable rhythms, subsequent treated shockable rhythm was associated with improved 1-month survival with favorable neurological outcomes. In the cohort of older children (7–17 years), these outcomes worsened as time to shock delivery increased. (J Am Heart Assoc. 2016;5:e003589 doi: 10.1161/JAHA.116.003589)

Key Words: cardiopulmonary resuscitation • defibrillation • epidemiology • heart arrest • resuscitation
Methods

Study Design

This investigation was a nation-wide population-based observational study in Japan of children with OHCA for whom resuscitation had been attempted between January 1, 2005 and December 31, 2012. Cardiac arrest was defined as the cessation of cardiac mechanical activity and was confirmed by the absence of signs of circulation. The cause of arrest was presumed to be cardiac, with the exception of those cases that showed evidence of external causes (eg, drowning, foreign body obstruction, hanging, mechanical suffocation, trauma, and accidental hypothermia), respiratory diseases, cerebrovascular diseases, malignant tumors, or any other noncardiac cause. The determination of the cause as noncardiac or cardiac was made by the physicians in charge in collaboration with the emergency medical services (EMS) personnel. This study was approved by the Ethics Committee of Kanazawa University. According to guidelines in Japan, informed consent from each patient to use secondary data such as that in this anonymous database is unnecessary. Therefore, the requirement for written informed consent was waived.

Study Setting

Japan has ≈127 million residents in an area of 378 000 km², approximately two thirds of which is uninhabited mountainous terrain. Municipal governments in Japan provide EMS through ≈800 fire stations with dispatch centers. The Fire and Disaster Management Agency (FDMA) of Japan supervises the nation-wide EMS system. During the study period, all EMS providers performed CPR according to guidelines of the Japan Resuscitation Council and the American Heart Association. Emergency life-saving technicians (ELSTs), who are EMS providers, are allowed to provide several resuscitation therapies, including use of an automated external defibrillator (AED), insertion of an airway adjunct, establishment of peripheral intravenous access, and administration of Ringer’s lactate solution. However, only specially trained ELSTs receiving online physician instruction are permitted to insert a tracheal tube and administer intravenous epinephrine in the field. Because EMS personnel in Japan are legally prohibited from terminating resuscitation in the field (except in specific situations such as decapitation, incineration, decomposition, rigor mortis, or dependent cyanosis), most patients with OHCA undergo CPR by EMS providers and are subsequently transported to the hospital. When EMS providers arrived at the scene, initiation of CPR and initial rhythm assessment through AED were generally performed simultaneously. An AED delivers a shock only when it detects a shockable rhythm. When initial nonshockable rhythm was identified, rhythm analysis was performed every 2 minutes by AED during CPR.

Data Collection and Quality Control

In January 2005, the FDMA launched a prospective, population-based, observational study including all OHCA patients who received EMS in Japan. EMS personnel at each center recorded OHCA patient data in cooperation with the physician in charge, using an Utstein-style template. The data were transferred to their fire stations and then integrated into the registry system on the FDMA database server. All data were stored in the nation-wide database developed by the FDMA for public use. The FDMA gave permission to analyze this database and provided all anonymous data to our research group.

The main variables included in the data set were as follows: sex, age, cause of arrest, bystander witness status, bystander-witnessed category (such as a family member, a layperson other than family, or EMS personnel), initially identified cardiac rhythm, presence and type of bystander CPR (compression only or compression with ventilation), use of AED (either by the public or by EMS providers), epinephrine administration, advanced airway management, time variables (collapse, emergency call, vehicle arrival, and CPR initiation), prehospital return of spontaneous circulation (ROSC), 1-month survival, and neurological outcomes 1 month after cardiac arrest. The neurological outcome was defined using the Cerebral Performance Category (CPC) scale: category 1, good cerebral performance; category 2, moderate cerebral disability; category 3, severe cerebral disability; category 4, coma or vegetative state; and category 5, death. The CPC categorization was determined by the physician in charge.

Study Endpoints

The primary study endpoint was 1-month survival with favorable neurological outcome (defined as a CPC score of 1 or 2). The secondary endpoints were prehospital ROSC and 1-month survival.

Statistical Analysis

The Wilcoxon and Kruskal–Wallis tests for continuous variables and the chi-square test for categorical variables were performed to compare the characteristics or outcomes of the cohorts. We further analyzed multivariate logistic regression models in order to clarify the relationship between subsequent shockable rhythm and outcomes. Multivariate logistic regression analyses including 7 variables were performed to assess the factors associated with increased odds of...
Prehospital ROSC, 1-month survival, and 1-month CPC 1 or 2 for all eligible patients. The potential prehospital confounders for the analytic model were selected based on biological plausibility and data from previous studies. Independent variables included age, bystander-witnessed arrest (yes or no), initial cardiac rhythm (PEA or asystole), presumed cardiac etiology (yes or no), prehospital epinephrine administration (yes or no), use of advanced airway management (yes or no), and subsequent treated shockable rhythm (yes or no). The call-to-response time was calculated as the time from receipt of the call to the time of vehicle arrival at the scene. Shock-delivery time was defined as the time interval between initiation of CPR by EMS personnel and the first EMS-administered shock.

Outcomes of patients with subsequent treated shockable rhythm were compared according to shock-delivery time and classified into 3 groups: 0 to 9, 10 to 19, and 20 to 59 minutes. The Cochran-Armitage trend test was applied to analyze these data. Moreover, after dividing patients into 2 groups according to age (age <7 years or age 7–17 years for elementary to high school children in Japan), the outcomes in the 2 groups were compared according to the presence of subsequent treated shockable rhythm and shock-delivery time.

Continuous variables are expressed as median with interquartile range (IQR) 1 to 3. Categorical variables are expressed as percentages. As an estimate of effect size and variability, odds ratios (ORs) or proportion of outcomes with 95% CIs were used. All statistical analyses were performed using the JMP statistical package (version 11 Pro; SAS Institute Inc., Cary, NC). All tests were 2-tailed, and a value of P<0.05 was considered statistically significant.

Results

During the 8-year study period, 925288 patients were documented in the database. Patients with initial shockable rhythms, those aged ≥18 years, and those with unknown initial rhythm or unknown 1-month outcome were excluded, so a total of 12402 (1.34% of the total patients in the database) children (aged <18 years) with initial nonshockable rhythms were enrolled in this study. Figure 1 shows a flow diagram depicting the inclusion and exclusion criteria for subjects in the present study. The overall prehospital ROSC, 1-month survival, and 1-month CPC 1 or 2 rates were 3.7% (n=461), 7.7% (n=953), and 1.3% (n=166), respectively. Patients were divided into 2 cohorts: subsequent treated shockable rhythm (YES; n=239) and subsequent treated shockable rhythm (NO; n=12 163). Those patients with initial nonshockable rhythm who converted to shockable rhythms were identified by shocks delivered later in the course of resuscitation; These were assigned to the subsequent treated shockable rhythm (YES) cohort. Thus, the delivery of subsequent shocks was used as a surrogate maker for conversion to a shockable rhythm. Conversely, the subsequent treated shockable rhythm (NO) cohort was composed of those patients who did not receive any shocks during resuscitation.

Table 1 shows the baseline characteristics and results of the analyses of the 2 cohorts. Age, rates of bystander-witnessed arrest, initial PEA, presumed cardiac etiology, epinephrine administration, and advanced airway management were significantly higher in the subsequent treated shockable rhythm (YES) cohort when compared to the subsequent treated shockable rhythm (NO) cohort. The subsequent treated shockable rhythm (YES) cohort had significantly higher rates of prehospital ROSC, 1-month survival, and 1-month CPC 1 or 2 than the subsequent treated shockable rhythm (NO) cohort (13.8% vs 3.5%, 15.9% vs 7.5%, and 4.6% vs 1.3%, respectively, P<0.001; Figure 2).

Table 2 shows the results of multivariate logistic regression analyses to determine factors associated with outcomes in all participants. Subsequent shockable rhythm was significantly associated with increased odds of prehospital ROSC (adjusted OR, 2.77; 95% CI, 1.81–4.12), 1-month survival (adjusted OR, 2.30; 95% CI, 1.56–3.29), and 1-month CPC 1 or 2 (adjusted OR, 2.90; 95% CI, 1.42–5.36). Bystander-witnessed arrest and initial PEA were significantly associated with improved 1-month survival and 1-month CPC 1 or 2.

Figure 3 shows the outcomes stratified by shock-delivery time in the subsequent treated shockable rhythm (YES) cohort. Shock-delivery times were calculated in 98.3% (235 of 239) of those patients. Rates of 1-month survival and 1-month CPC 1 or 2 decreased significantly as time to shock delivery increased (1-month survival: 23.5% for 0–9 minutes, 22.0% for 10–19 minutes, and 9.2% for 20–59 minutes; P<0.01 [for trend]; 1-month CPC 1 or 2: 17.7% for 0–9 minutes, 7.3% for 10–19 minutes, and 0% for 20–59 minutes; P<0.001 [for trend]).

Table 3 compares the characteristics and outcomes according to age group. The proportion of male sex, bystander-witnessed arrest, initial PEA, epinephrine administration, advanced airway management, and subsequent treated shockable rhythm were significantly higher in the group aged 7 to 17 years when compared with the group aged <7 years. The group aged 7 to 17 years had a significantly higher rate of prehospital ROSC compared to the group aged <7 years (5.8% vs 2.7%; P<0.001). However, no significant differences were found in the rates of 1-month survival and 1-month CPC 1 or 2 between the 2 groups (1-month survival: 8.0% for those aged <7 years vs 7.1% for those aged 7–17 years; P=0.08; 1-month CPC 1 or 2: 1.3% for those aged <7 years vs 1.4% for those aged 7–17 years; P=0.62).
Figure 4 shows the age-stratified outcomes according to subsequent treated shockable rhythm. In the group aged 7 to 17 years, outcomes in the subsequent treated shockable rhythm (YES) cohort were significantly better than for those in the subsequent treated shockable rhythm (NO) cohort (17.9% vs 5.3% for prehospital ROSC, 18.5% vs 6.6% for 1-month survival, and 6.0% vs 1.2% for 1-month CPC 1 or 2, respectively; \( P < 0.001 \)). However, in the group aged <7 years, no significant differences were found between the 2 cohorts.

Table 4 shows the age-stratified outcomes according to shock-delivery time in the subsequent treated shockable rhythm (YES) cohort (n=235). Rates of 1-month survival and 1-month CPC 1 or 2 in the group aged 7 to 17 years decreased significantly as time to shock delivery increased (1-month survival: 26.7% for 0–9 minutes, 26.0% for 10–19 minutes, and 9.6% for 20–59 minutes; \( P \) for trend=0.02; 1-month CPC 1 or 2: 20.0% for 0–9 minutes, 9.1% for 10–19 minutes, and 0% for 20–59 minutes; \( P \) for trend <0.01). However, significant differences were not found in the group aged <7 years.

**Discussion**

The present study of EMS-treated OHCA children with initial nonshockable rhythms in Japan shows that subsequent treated shockable rhythm is significantly associated with improved prehospital ROSC, 1-month survival, and 1-month survival with favorable neurological outcomes, when compared with no subsequent treated shockable rhythm. In patients with subsequent treated shockable rhythm, 1-month survival and 1-month survival with favorable neurological outcomes decreased as time to shock delivery increased. Moreover, these findings were only applicable to older children (aged 7–17 years for elementary to high school children in Japan).
The present study results are inconsistent with those of a previous pediatric in-hospital cardiac arrest study. In 2006, Samson et al demonstrated that the proportion of survival to hospital discharge in pediatric in-hospital cardiac arrest with subsequent shockable rhythm was significantly lower than that for those who did not convert to shockable rhythm.

### Table 1. Baseline Characteristics of the Study Cohorts According to Subsequent Shockable Rhythm

| Characteristics                | All Patients With Initial Nonshockable Rhythm, n (%) | Subsequent Treated Shockable Rhythm (YES), n (%) | Subsequent Treated Shockable Rhythm (NO), n (%) | P Value |
|--------------------------------|-----------------------------------------------------|-------------------------------------------------|-------------------------------------------------|---------|
| Total patients in each group   | 12,402 (100)                                       | 239 (1.9)                                       | 12,163 (98.1)                                   | <0.001  |
| Age, y, median (IQR, 1–3)      | 1 (0–1)                                            | 12 (5–16)                                      | 1 (0–10)                                       | <0.001  |
| <1 year                        | 5,154 (41.6)                                       | 26 (10.9)                                      | 5,128 (42.2)                                    | <0.001  |
| Male                           | 7,531 (60.7)                                       | 153 (64.0)                                     | 7,378 (60.7)                                    | 0.29    |
| Bystander-witnessed arrest     | 3,516 (28.4)                                       | 114 (47.7)                                     | 3,402 (28.0)                                    | <0.001  |
| Bystander CPR                  | 6,302 (50.8)                                       | 111 (46.4)                                     | 6,191 (50.9)                                    | 0.19    |
| Initial cardiac rhythm         |                                                    |                                                |                                                |         |
| Pulseless electrical activity  | 2,143 (17.3)                                       | 77 (32.2)                                      | 2,066 (17.0)                                    | <0.001  |
| Asystole                       | 10,259 (82.7)                                      | 162 (67.8)                                     | 10,097 (83.0)                                   | <0.001  |
| Presumed cardiac etiology      | 3,577 (28.8)                                       | 84 (35.2)                                      | 3,493 (28.7)                                    | 0.03    |
| Epinephrine administration     | 239 (1.9)                                          | 21 (8.8)                                       | 218 (1.8)                                      | <0.001  |
| Advanced airway management     | 3,449 (27.8)                                       | 94 (39.3)                                      | 3,355 (27.6)                                    | <0.001  |
| Call-to-response time, minute, median (IQR, 1–3), n=1,280 | 7.0 (5–9)                                          | 7.0 (5–9)                                      | 7.0 (5–9)                                      | 0.35    |
| Shock-delivery time, minute, median (IQR, 1–3), n=235 | 7.0 (5–9)                                          | 7.0 (5–9)                                      | 7.0 (5–9)                                      | 0.35    |

Values are reported as number (%), unless indicated otherwise. CPR indicates cardiopulmonary resuscitation; IQR, interquartile range.

*Time from the initiation of CPR by emergency medical services personnel to the first shock delivery.

The present study results are inconsistent with those of a previous pediatric in-hospital cardiac arrest study. In 2006, Samson et al demonstrated that the proportion of survival to hospital discharge in pediatric in-hospital cardiac arrest with subsequent shockable rhythm was significantly lower than that for those who did not convert to shockable rhythm.
rhythms (11% vs 27%; adjusted OR, 3.8; 95% CI, 1.8–7.6). They surmised that a delay in diagnosis of subsequent shockable rhythm, adverse effects of resuscitative interventions, and severity of the underlying myocardial condition might have contributed to these results. Unlike in Samson et al’s study, we enrolled only patients with OHCA and a subsequent shockable rhythm who were treated with shock delivery into the subsequent treated shockable rhythm (YES) cohort. Therefore, our study could both underestimate the frequency of development of subsequent shockable rhythm and overestimate favorable outcomes (survival and/or CPC 1 or 2). Moreover, most patients with in-hospital cardiac arrest are usually in a monitored setting and received shocks more quickly. Actually, the interval to first attempted defibrillation in Samson et al’s study was clearly shorter than the subsequent shock-delivery time in our study (median [IQR],

Table 2. Results of Multivariate Logistic Regression Analyses for Variables Associated With Outcomes in All Participants

| Variables                        | Adjusted OR (95% CI) | Prehospital ROSC | 1-Month Survival | 1-Month CPC 1 or 2 |
|----------------------------------|----------------------|-------------------|------------------|--------------------|
| Age*                             | 1.03 (1.02–1.05)     | 0.97 (0.96–0.98)  | 0.98 (0.95–1.00) |
| Bystander-witnessed arrest       | 1.74 (1.41–2.14)     | 1.60 (1.38–1.85)  | 2.85 (2.02–4.06) |
| Initial cardiac rhythm           |                      |                   |                  |                    |
| Pulseless electrical activity    | 4.87 (3.97–5.99)     | 2.99 (2.57–3.48)  | 4.62 (3.31–6.49) |
| Asystole                         | Reference            | Reference         | Reference        |
| Presumed cardiac etiology        | 0.54 (0.42–0.70)     | 0.61 (0.52–0.72)  | 0.77 (0.53–1.10) |
| Epinephrine administration       | 4.29 (2.93–6.18)     | 0.49 (0.25–0.87)  | 0.21 (0.01–0.97) |
| Advanced airway management       | 1.07 (0.86–1.31)     | 0.99 (0.85–1.15)  | 0.99 (0.69–1.38) |
| Subsequent treated shockable rhythm | 2.77 (1.81–4.12)     | 2.30 (1.56–3.29)  | 2.90 (1.42–5.36) |

CPC indicates Cerebral Performance Category; OR, odds ratio; ROSC, return of spontaneous circulation.

*Adjusted ORs are reported for unit odds.

![Figure 3](https://example.com/figure3.png)

**Figure 3.** Outcomes stratified by shock-delivery time in the subsequent treated shockable rhythm (YES) cohort. CPC indicates Cerebral Performance Category; ROSC, return of spontaneous circulation. Values are expressed with 95% confidence intervals. Shock-delivery time (minutes) was available for 235 patients.
Furthermore, CPR duration for patients with subsequent shockable rhythm was significantly longer than for those with no shockable rhythm in Samson et al’s study (median [IQR], 30 [15–53] vs 20 minutes [9–53]). Accordingly, the differences in outcomes between the present study of OHCA and Samson et al’s study of in-hospital cardiac arrest may be explained simply by the CPR duration. However, we could not analyze CPR duration because of lack of data for in-hospital CPR time.

Samson et al’s study of in-hospital cardiac arrest indicated that rates of survival to hospital discharge after initial shockable rhythm were significantly higher than those after subsequent shockable rhythm: 35% versus 11%; adjusted OR (95% CI), 2.6 (1.2–5.8). Table 5 compares the outcomes in patients with initial shockable rhythm (n=637; Figure 1) and those with subsequent treated shockable rhythm (n=239) in the present study. Rates of favorable outcomes in patients with initial shockable rhythm were significantly higher than in those with subsequent treated shockable rhythm (34.9% vs 15.9% for 1-month survival, 23.4% vs 4.6% for 1-month CPC 1 or 2; P<0.001). Patients with initial shockable rhythm had significant positive adjusted ORs for favorable outcomes compared to those with subsequent treated shockable rhythm (1-month survival: 2.23 [95% CI, 1.49–3.39]; 1-month CPC 1 or 2: 4.30 [95% CI, 2.31–8.79]; P<0.001). These results were consistent with those in Samson et al’s study. Moreover, in the present study, the finding that patients with initial shockable rhythm had 1-month outcomes superior to those with subsequent treated shockable rhythm was also observed when analyzed by age group (aged <7 years or aged 7–17 years).

In adult patients who experienced OHCA, Hallstrom et al noted a significant low adjusted OR of 0.18 for survival to hospital discharge in patients with subsequent shockable rhythms relative to those who did not receive shocks for nonshockable rhythms. Moreover, Thomas et al recently reported that increased survival to hospital discharge for OHCA patients was not associated with subsequent shockable rhythm and shock delivery during EMS resuscitation.
efforts (adjusted OR, 0.88; 95% CI, 0.60–1.30). However, other studies of OHCA adults demonstrated that subsequent treated shockable rhythm was associated with improved outcomes compared with no shock delivery after an initial nonshockable rhythm. Notably, Goto et al showed that subsequent shockable rhythm was significantly associated with increased adjusted odds of 1-month survival with favorable neurological outcomes when the shock-delivery time was <20 minutes. The present study on children with OHCA is consistent with those adult OHCA studies (Table 2). Earlier shock delivery (shock-delivery time <20 minutes) in children with OHCA and subsequent treated shockable rhythm, particularly in patients aged 7 to 17 years, was found to be superior to later shock delivery, as demonstrated by 1-month survival with favorable neurological outcomes (Figure 3; Table 4). However, we were unable to show the

Table 4. Age-Stratified Outcomes According to Shock-Delivery Time in the Subsequent Treated Shockable Rhythm (YES) Cohort

| Shock-Delivery Time* | 0 to 9 Minutes | 10 to 19 Minutes | 20 to 59 Minutes | P Value |
|----------------------|----------------|------------------|------------------|---------|
| Total patients in each group, n=235 | 17 | 109 | 109 | |
| Aged <7 years, n=70 | 2 | 32 | 36 | |
| Prehospital ROSC, n=3 | 0 (0.0) | 3 (9.4) | 0 (0.0) | 0.15 |
| 1-month survival, n=7 | 0 (0.0) | 4 (12.5) | 3 (8.3) | 0.75 |
| 1-month CPC 1 or 2, n=1 | 0 (0.0) | 1 (3.1) | 0 (0.0) | 0.54 |
| Aged 7 to 17 years, n=165 | 15 | 77 | 73 | |
| Prehospital ROSC, n=30 | 4 (26.7) | 13 (16.9) | 13 (17.8) | 0.66 |
| 1-month survival, n=31 | 4 (26.7) | 20 (26.0) | 7 (9.6) | 0.02 |
| 1-month CPC 1 or 2, n=10 | 3 (20.0) | 7 (9.1) | 0 (0.0) | <0.01 |

Values are reported as number (%), unless indicated otherwise. CPC indicates Cerebral Performance Category; ROSC, return of spontaneous circulation.

*Time from the initiation of cardiopulmonary resuscitation by emergency medical services personnel to the first shock delivery. Shock-delivery time (minutes) was available for 235 patients.
benefit of early shock delivery in patients with subsequent treated shockable rhythm on neurological outcomes in the multivariate logistic regression model, because an insufficient number of cases prevented further risk adjustment for outcomes.

In the present study, prehospital epinephrine administration was independently associated with increased odds of prehospital ROSC. However, it was independently associated with decreased odds of 1-month survival and 1-month CPC 1 or 2 (Table 2). Moreover, advanced airway management was not associated with prehospital ROSC, 1-month survival, or 1-month CPC 1 or 2. These results are consistent with those from previous studies on pediatric OHCAs.32,33

Eilevstjønn et al34 demonstrated that cardiac rhythms before subsequent shockable rhythm were related to the outcomes (ROSC). They found that PEA before shockable rhythm had a significantly higher ROSC rate than that of asystole. Their results were consistent with our previous study for adults27 and the present study for children. Moreover, they reported that median slope, which represents the average steepness of the VF waveform reflecting both the amplitude and frequency of the rhythm, might be a useful tool for predicting outcomes. We could not analyze subsequent VF waveforms because of lack of data. This lack of data was associated with our study design of a retrospective record review. Therefore, prospective studies are required to analyze the subsequent VF waveform and clarify the effect of subsequent shockable rhythm and shock delivery on outcomes in children with OHCA.

**Table 5. Outcomes in Patients With Initial Shockable Rhythm and Those With Subsequent Treated Shockable Rhythm**

| No. of Patients | 1-Month Survival | 1-Month CPC 1 or 2 |
|-----------------|-----------------|-------------------|
|                 |                 | Adjusted OR* (95% CI) | n (%) | Adjusted OR* (95% CI) | n (%) |
| Total patients with prehospital shockable rhythm | 876 | 260 (29.7) | 160 (18.3) |
| Initial shockable rhythm | 637 | 222 (34.9) | 2.23 (1.49–3.39) | 149 (23.4) | 4.30 (2.31–8.79) |
| Subsequent treated shockable rhythm | 239 | 38 (15.9) | Reference | 11 (4.6) | Reference |
| P value | <0.001 | <0.001 | <0.001 | <0.001 |
| Aged <7 years | 290 | 55 (19.0) | 23 (7.9) |
| Initial shockable rhythm | 219 | 48 (21.9) | 2.39 (1.02–6.41) | 22 (10.1) | 6.60 (1.18–124.9) |
| Subsequent treated shockable rhythm | 71 | 7 (9.9) | Reference | 1 (1.4) | Reference |
| P value | 0.02 | 0.04 | 0.02 | 0.03 |
| Aged 7 to 17 years | 586 | 205 (35.0) | 137 (23.4) |
| Initial shockable rhythm | 418 | 174 (41.6) | 2.26 (1.43–3.64) | 127 (30.4) | 4.17 (2.16–8.88) |
| Subsequent treated shockable rhythm | 168 | 31 (18.5) | Reference | 10 (6.0) | Reference |
| P value | <0.001 | <0.001 | <0.001 | <0.001 |

Values are reported as number (%), unless indicated otherwise. CPC indicates Cerebral Performance Category; OR, odds ratio.

*Adjusted variables for potential confounders were included 7 variables: age, bystander-witnessed arrest, bystander cardiopulmonary resuscitation, initial cardiac rhythm, presumed cardiac etiology, epinephrine administration, and advanced airway management.

**Study Limitations**

The potential limitations of the current analysis are as follows. First, we could not exclude patients who received shocks for the wrong indication or for unrecognized initial shockable rhythms attributed to electrical misreading when an AED was used while transporting a patient35 and/or when CPR was provided for a child with OHCA,36 which would result in an overestimation of favorable outcomes. In addition, our study population included only those patients with initial nonshockable rhythm who had a subsequent shockable rhythm that was treated with shock delivery. If a significant number of patients who developed a subsequent shockable rhythm never received a shock, their exclusion would mean that survival in our study population is falsely high. Second, our registry database lacked detailed data to permit further risk adjustment for outcomes: for example, comorbid disease of patients, location where the OHCA occurred, years of experience as a member of EMS personnel, the degree of regional differences among EMS centers,37,38 in-hospital medication, and the availability of specialists in emergency care (cardiologists and/or pediatric physicians). Regarding regional differences in outcomes post-OHCA in Japan, previous studies suggested there were regional disparities in prehospital care and in-hospital postresuscitation care.37,38 Low-spending regions had significantly worse neurological outcomes post-OHCA compared to medium-spending or high-spending regions.38 Moreover, although EMS providers delivered a shock according to guidelines during the study period,20–22
precise energy dose, shock frequency, and defibrillation mode (monophasic or biphasic) were unknown; therefore, we could not analyze those data in the present study. Third, though a uniform data collection procedure based on the Utstein-style guidelines for reporting cardiac arrest, a large sample size, and a population-based design was used, we cannot exclude the possibility of uncontrollable confounders. Fourth, as with all epidemiological studies, the integrity, validity, and ascertain- ment bias of the data were potential limitations. Fifth, we should note that caution must be exercised when generalizing these results to other countries or EMS systems. Finally, because we lacked precise data on the causes of cardiac arrest, it is possible that cardiac arrest in some patients may have been caused by sudden infant death syndrome, trauma, or respiratory disease.39

Conclusions
In children with OHCA and initial nonshockable rhythms, subsequent treated shockable rhythm during EMS resuscitation efforts was significantly associated with improved prehospital ROSC, 1-month survival, and 1-month survival with favorable neurological outcomes. In addition, in the cohort of older children (aged 7–17 years) with subsequent treated shockable rhythm, 1-month survival and 1-month survival with favorable neurological outcomes decreased as time to shock delivery increased.

Sources of Funding
This work was supported by the Japan Society for the Promotion of Science (KAKENHI Grant No.: 15K08543), which had no role in the design and implementation of the study, analysis and interpretation of the data, or approval of the manuscript.

Disclosures
None.

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