CLINICAL STUDY

# Poor Long-Term Survival of Out-of-Hospital Cardiac Arrest in Children

## A Multicenter, Prospective Registry in Osaka, Japan


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on behalf of the CRITICAL Study Group Investigators



**Summary**

The effect of post-cardiac arrest care in children with out-of-hospital cardiac arrest (OHCA) has not been adequately established, and the long-term outcome after pediatric OHCA has not been sufficiently investigated. We describe here detailed in-hospital characteristics, actual management, and survival, including neurological status, 90 days after OHCA occurrence in children with OHCA transported to critical care medical centers (CCMCs).

We analyzed the database of the Comprehensive Registry of Intensive Care for OHCA Survival (CRITICAL) study, which is a multicenter, prospective observational data registry designed to accumulate both pre- and in-hospital data on OHCA treatments. We enrolled all consecutive pediatric patients aged <18 years who had an OHCA and for whom resuscitation was attempted and who were transported to CCMCs between 2012 and 2016.

A total of 263 pediatric patients with OHCA were enrolled. The average age of the patients was 6.3 years, 38.0% were aged < 1 year, and 60.8% were male. After hospital arrival, 4.9% of these pediatric patients received defibrillation; 1.9%, extracorporeal life support; 6.5%, target temperature management; and 88.2% adrenaline administration. The proportions of patients with 90-day survival and a pediatric cerebral performance category (PCPC) score of 1 or 2 were 6.1% and 1.9%, respectively. The proportion of patients with a PCPC score of 1 or 2 at 90 days after OHCA occurrence did not significantly improve during the study period.

The proportion of pediatric patients with a 90-day PCPC score of 1 or 2 transported to CCMCs was extremely low, and no significant improvements were observed during the study period.



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Out-of-hospital cardiac arrest (OHCA) is one of the most significant problems in industrialized countries,[1-4] and pediatric patients who have an OHCA accounted for only a small percentage of the total patient population annually.[5,6] OHCA in children is rare compared with that in adults, but it has a significantly negative impact on the community in terms of life-years lost and healthcare costs in survivors and emotional burden of family members.[7] Therefore, assessing the characteristics, management, and survival of pediatric patients with OHCA is of help in the prevention of OHCA and improvement of survival after OHCA in children.

In cardiopulmonary resuscitation (CPR) guidelines, an immediate call for an ambulance and using automated external defibrillators (AEDs), as well as performing chest compressions,[1-3] were emphasized in "the chain of survival," and post-cardiac arrest care (PCAC) after hospital arrival was also one of the important factors in improving survival after pediatric OHCA.[1-3] Some advanced treatments, such as targeted temperature management (TTM), as PCAC in adults were effective in improving neurological outcome,[8] whereas the effect of PCAC on children with OHCA has not been adequately established.[9,10] Moreover, the long-term outcome after pediatric OHCA has not been sufficiently investigated.

To improve survival after OHCA by providing appropriate therapeutic strategies incorporating the criteria, such as the introduction and effectiveness of in-hospital advanced treatments, we have launched the Comprehensive Registry of Intensive Care for OHCA Survival (CRITICAL) study, a multicenter, prospective observational data registry in Osaka, Japan, designed to accumulate both pre- and in-hospital data on OHCA treatments in children and adults since 2012.[11] Using this database, we described detailed in-hospital characteristics, actual management, and survival including neurological status at 90 days after OHCA occurrence in children with OHCA transported to critical care medical centers (CCMCs).

## Methods

We analyzed the database of the CRITICAL study, which is a multicenter, prospective observational data registry, designed to accumulate both pre- and in-hospital data on OHCA treatments. A complete description of the study methodology was previously provided.[11]

**Population and settings:** The target area of the CRITICAL study is Osaka Prefecture in Japan, which has an area of 1897 km$^2$ with a residential population of 8,865,245 inhabitants as of 2010.[12] Men account for 48.3% of the population, 22.4% of whom are aged ≥ 65 years in 2012. Osaka had 535 hospitals (108,481 beds) in 2012.[13] A total of 276 hospitals accept emergency patients from ambulances. Of these, 15 hospitals have CCMCs that can accept severely ill emergency patients.[14] Thirteen CCMCs and one non-CCMC with an emergency care department in Osaka participated in the study. Approximately 30% of patients with OHCA in Osaka were transported to and treated in CCMCs.[15] The study was approved by the Ethics Committee of Osaka University and Kyoto University as the corresponding institution, and each hospital also approved the CRITICAL study protocol as necessary.

**Study patients:** In this study, we enrolled all consecutive pediatric patients aged < 18 years who had an OHCA and for whom resuscitation was attempted and who were then transported to a participating institution from July 1, 2012, to December 31, 2016. This study excluded patients with OHCA who did not receive CPR by physicians or those with a disagreement on our registry, by either family members or themselves. Additionally, patients with OHCA who were transported to a participating institution after receiving any procedures at another hospital were excluded. The requirement of obtaining individual informed consent for the reviews of patients' outcomes was waived.

**Emergency medical service (EMS) in Osaka:** Details of the EMS system in Osaka were described previously.[16,17] Briefly, the 119 emergency telephone number is accessible anywhere in Japan, including Osaka, and on receipt of a 119 call, an emergency dispatch center sends the nearest available ambulance to the site. EMSs are provided 24 hours; the system is single-tiered in 32 stations and two-tiered in two stations. Each ambulance includes a three-person unit providing life support. Most highly trained EMS personnel are called emergency life-saving technicians. Specially trained emergency life-saving technicians are allowed to conduct tracheal intubation and administer epinephrine to patients with OHCA. All EMS providers performed CPR basically according to the Japanese CPR guidelines during this study period.[4]

Prehospital resuscitation data were obtained from the All-Japan Utstein Registry of the Fire and Disaster Management Agency (FDMA) of Japan. Details of the registry were described in detail in our preceding paper.[18] Data were prospectively collected with the use of a data form based on the Utstein-style international guideline of reporting OHCA.[19,20] Collected data included the following: witness status, bystander-initiated CPR, shocks by public-access automated external defibrillators (AEDs), dispatcher instructions, first documented rhythm, shocks by EMS personnel, advanced airway management, intravenous fluid administration, adrenalin administration, and resuscitation time course.

**Data collection and quality control:** In this registry, we collected detailed information on patients with OHCA after hospital arrival. Anonymized data were fed into the Web form by physicians or medical staff in cooperation with physicians in charge of the patient, logically checked

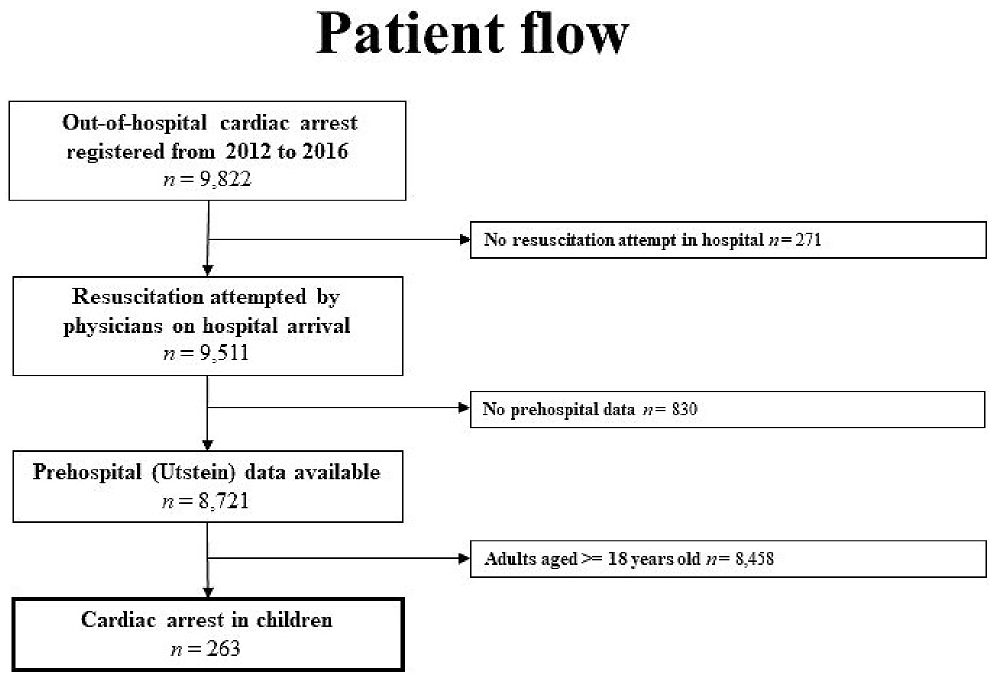


**Figure 1.** Overview of out-of-hospital cardiac arrests from 2012 to 2016 in the CRITICAL study.

by the system, and finally confirmed by the CRITICAL study working group. If the data form was incomplete, the working group returned it to the respective institution, and the data were completed. In-hospital data were systemically merged with Utstein-style prehospital data gathered from the FDMA by the working group, by the use of 5 items in both data: prefectures, emergency call time, age, sex, and cerebral performance category (CPC) score.

In-hospital data in patients with OHCA after hospital arrival were prospectively collected using an original report form. The cause of arrest was defined as having cardiac (acute coronary syndrome, other heart diseases, presumed cardiac cause) or non-cardiac (cerebrovascular diseases; respiratory diseases; malignant tumors; external causes including traffic injury, fall, hanging, drowning, asphyxia, drug overdose, or any other external causes; and suspected sudden infant death syndrome (SIDS) [only for infants aged < 1 year]) causes.[21] The category of presumed cardiac cause was a diagnosis by exclusion (i.e., the diagnosis was made when there was no evidence of a non-cardiac cause). Diagnoses of cardiac or non-cardiac origin were clinically made by the physician in charge. Other baseline data were as follows: treatment by pediatricians, return of spontaneous resuscitation (ROSC) after hospital arrival, and first documented rhythm after hospital arrival.

The reporting form also required actual detailed treatments for patients with OHCA (e.g., defibrillation, tracheal intubation, extracorporeal life support, intra-aortic balloon pumping, cardioangiography, percutaneous coronary intervention, target temperature management, drug administration during cardiopulmonary arrest [adrenalin, amiodarone, nifekalant, lidocaine, atropine, magnesium, and vasopressin]), arterial blood gases measured initially at hospital arrival before and after first ROSC (pH, PaCO2 [mmHg], PaO2 [mmHg], HCO3 [mEq/L], base excess [mEq/L], lactate level [mg/dL], and glucose level [mg/dl]), and laboratory data measured initially at hospital arrival (blood urea nitrogen [mg/dL], creatinine [mg/dL], total protein [g/dL], albumin [g/dL], sodium [mEq/L], potassium [mEq/L], and ammonia [μg/dL] levels).

Outcome data were also prospectively collected and included as follows:[22] condition after hospital arrival, 1-month and 90-day survival, and neurological status at 1 month and 90 days after OHCA occurrence using the pediatric CPC (PCPC) scale (category 1, normal cerebral performance; category 2, mild cerebral disability; category 3, moderate cerebral disability; category 4, severe cerebral disability; category 5, coma or vegetative state; category 6, death/brain death). Survivors were evaluated 1 month and 90 days after the event for neurologic assessment by the physician in charge.

**Statistical analysis:** Data are presented as the mean ± standard deviation for continuous values and percentages for categorical values. The $\chi^2$ test or Fisher's exact test and one-way analysis of variance were used to analyze statistical differences in in-hospital advanced treatments, drug administrations, and arterial blood gases according to 4 age groups (0 years, 1-4 years, 5-12 years, and 13-17 years based on previous studies[6]). Additionally, we analyzed trends in outcomes by year and age group. Furthermore, we performed a subgroup analysis for 90-day survival and PCPC score of 1 or 2 between pediatric OHCA patients with cardiac cause versus those with non-cardiac cause. All *P*-values were two-sided, and those < 0.05 were considered statistically significant. All statistical analyses were conducted using Stata MP version 15.0 software (StataCorp LP).

**Table I.** Baseline Characteristics

| | Total ($n$ = 263) |
|---|---|
| Age, years, mean (SD) | 6.3 (6.8) |
| Age group, $n$ (%) | |
| 0 years old | 100 (38.0) |
| 1-4 years old | 45 (17.1) |
| 5-12 years old | 37 (14.1) |
| 13-17 years old | 81 (30.8) |
| Male, $n$ (%) | 160 (60.8) |
| Cause, $n$ (%) | |
| Cardiac | 81 (30.8) |
| Acute coronary syndrome | 2 (0.8) |
| Other heart disease | 7 (2.7) |
| Presumed cardiac cause | 72 (27.4) |
| Non-cardiac | 182 (69.2) |
| Cerebrovascular disease | 1 (0.4) |
| Respiratory disease | 6 (2.3) |
| Malignant tumor | 0 (0.0) |
| External | 122 (46.4) |
| Traffic injury | 24 (9.1) |
| Fall | 30 (11.4) |
| Hanging | 23 (8.8) |
| Drowning | 17 (6.5) |
| Asphyxia | 11 (4.2) |
| Drug overuse | 3 (1.1) |
| Other external cause | 14 (5.3) |
| Others | 53 (20.2) |
| Suspected SIDS (only for infants < 1 year old) | 36 (13.7) |
| Departure of ambulance or helicopter with physicians, $n$ (%) | 50 (19.0) |
| ROSC status, $n$ (%) | |
| ROSC after hospital arrival | 61 (23.2) |
| ROSC before hospital arrival | 11 (4.2) |
| No ROSC | 191 (72.6) |
| First documented rhythm after hospital arrival, $n$ (%) | |
| VF/pulseless VT | 4 (1.5) |
| PEA | 36 (13.7) |
| Asystole | 213 (81.0) |
| Presence of pulse | 10 (3.8) |

SD indicates standard deviation; SIDS, sudden infant death syndrome; ROSC, return of spontaneous circulation; VF, ventricular fibrillation; VT, ventricular fibrillation; and PEA, pulseless electrical activity.

## Results

Figure 1 shows an overview of study patients. A total of 9,822 patients with OHCA were documented between July 2012 and December 2016. Excluding 271 patients who were not resuscitated by physicians after hospital arrival, 830 patients without prehospital data, and 8,458 adult patients, a total of 263 pediatric patients were eligible for our analysis.

Table I shows the baseline characteristics of 263 pediatric patients with OHCA. The mean age was 6.3 years, and 38.0% were aged < 1 year. Male patients accounted for 60.8%. The proportion of patients with cardiac cause was 30.8%, and that with external cause was 46.4%. A total of 36 (13.7%) infants aged < 1 year had suspected SIDS as the cause. The proportion of pediatric patients who had ROSC after hospital arrival was 23.2%, and that of those who had already received ROSC before hospital arrival was 4.2%. Of these, 1.5% had ventricular fibrillation (VF)/pulseless ventricular tachycardia (VT), and 81.0% had asystole as the first documented rhythm after hospital arrival.

Prehospital characteristics based on the Utstein template are shown in Table II. The proportion of patients with a time of hospital arrival of 18:00-23:59 was 31.2%. Approximately half of the pediatric patients received bystander-initiated CPR, but only 2 pediatric patients received shocks by public-access AEDs. VF/pulseless VT as the first documented rhythm was noted in 3.8%, pulseless electrical activity in 25.9%, and asystole in 66.9%. As for prehospital treatments by the EMS personnel, 5.3% received shocks, 18.6% intubation, and 1.9% adrenaline. The mean time interval from call to CPR initiation by the EMS personnel at the scene was 8.7 minutes and from call to hospital arrival was 33.0 minutes.

In-hospital advanced treatment, drug administration, and arterial blood gases by age group are presented in Table III. The proportion of patients receiving treatment by a

**Table II.** Prehospital Characteristics

| | Total ($n$ = 263) |
|---|---|
| Time of hospital arrival, $n$ (%) | |
| 0:00 - 5:59 | 51 (19.4) |
| 6:00 - 11:59 | 81 (30.8) |
| 12:00 - 17:59 | 49 (18.6) |
| 18:00 - 23:59 | 82 (31.2) |
| Witness status, $n$ (%) | |
| Witnessed by bystanders | 100 (38.0) |
| Family member | 63 (24.0) |
| Non-Family member | 37 (14.1) |
| Witnessed by EMS personnel | 11 (4.2) |
| Not witnessed | 152 (57.8) |
| Bystander-initiated CPR, $n$ (%) | 133 (50.6) |
| Shock by public-access AEDs, $n$ (%) | 2 (0.8) |
| Dispatcher instructions, $n$ (%) | 138 (52.5) |
| First documented rhythm at EMS arrival, $n$ (%) | |
| VF/pulseless VT | 10 (3.8) |
| PEA | 68 (25.9) |
| Asystole | 176 (66.9) |
| Others | 9 (3.4) |
| Shock by EMS personnel, $n$ (%) | 14 (5.3) |
| Advanced airway management, $n$ (%) | 49 (18.6) |
| Intravenous fluid, $n$ (%) | 19 (7.2) |
| Adrenaline administration, $n$ (%) | 5 (1.9) |
| Call to CPR started by EMS, minutes, mean (SD) | 8.7 (5.5) |
| Call to hospital arrival, minutes, mean (SD) | 33.0 (18.2) |

EMS indicates emergency medical service; CPR, cardiopulmonary resuscitation; VF, ventricular fibrillation; PEA, pulseless electrical activity; AED, automated external defibrillator; and SD, standard deviation.

pediatrician was higher in the infant group aged < 1 year than in the other age groups. After hospital arrival, 4.9% of the pediatric patients received defibrillation, 1.9% extracorporeal life support, 6.5% target temperature management, and 88.2% adrenaline. As for arterial blood gases and laboratory data measured initially upon hospital arrival, the mean values before ROSC were as follows: pH, 6.666; HCO3, 12.1 mEq/L; base excess, -24.4 mEq/L; and lactate level, 157 mg/dL. Values, such as pH, HCO3, base excess, and lactate level, were worse in the infant group aged < 1 year than in the other age groups irrespective of the measurement before and after ROSC.

Table IV shows the annual trends in the outcomes after pediatric OHCA occurrence. The percentages of patients with 1-month survival and a PCPC score of 1 or 2 at 1 month after OHCA were 7.2% and 1.9%, respectively. The percentages of patients with 90-day survival and a PCPC score of 1 or 2 at 90 days after OHCA were 6.1% and 1.9%, respectively. During the study period, the outcomes in pediatric patients with OHCA did not improve. Figure 2 shows the outcomes at 90 days after OHCA by age group. The percentage of patients with a 90-day PCPC score of 1 or 2 increased slightly from infants aged < 1 year (0.0%) to children aged 13-17 years (3.7%), which was statistically insignificant. In a subgroup analysis (Figure 3), pediatric OHCA patients with cardiac cause had better outcomes than those with non-cardiac cause (11.1% versus 4.9% in 90-day survival [$P$ = 0.046] and 3.9% versus 0.6% in 90-day PCPC score 1 or 2 [$P$ = 0.016]).

## Discussion

From the CRITICAL study in Osaka, Japan, this study described detailed in-hospital advanced treatments, drug administrations, and arterial blood gases after hospital arrival in children with OHCA. Regarding the outcomes after pediatric OHCA, we assessed the long-term neurological status at 90 days after OHCA occurrence. The proportion of patients with a PCPC score of 1 or 2 was very low and no significant improvements were observed during the study period. To our knowledge, this is the first study to report detailed information on in-hospital characteristics, actual management, and long-term outcome in pediatric patients with OHCA and would be of help in improving the outcomes after hospital arrival in pediatric resuscitation science.

In this study, the proportion of patients with a 90-day PCPC score of 1 or 2 who were transported to CCMCs was only 1.9%. Pediatric OHCA due to external causes accounted for 46.4% in this registry. This prevalence was higher compared with that in previous reports: 30.5% in Japan,[6] 17.2% in the United States,[23] and 34.2% in Australia.[24] Additionally, only two children received shocks delivered through a public-access AED. Thus, children with OHCA transported to CCMCs in this area did not have better resuscitation factors. Importantly, the proportion of patients with a 90-day PCPC score of 1 or 2 did not improve and remained low during the study period. The preceding studies that assessed neurological outcomes in pediatric OHCA over time also showed no improvements in the comparison of data between 2005-2007, 2008-2010, and 2011-2013 in the United States[23] and between 2005-2009 and 2010-2014 in Australia,[24] and these results were similar to those in our study. Therefore, in the future, further continuous monitoring is needed to improve survival after pediatric OHCA occurrence worldwide.

In this study, we assessed the proportions of pediatric patients with a PCPC score of 1 or 2 at 1 month and 90 days after OHCA occurrence and found they were similar. In a previous study comparing PCPC scores at discharge with those at the final follow-up in children with OHCA, 94% of patients were discharged with a PCPC score of 1 or 2 and maintained the score, while 54% were discharged with a PCPC score of 3-5 and died at the final follow-up,[25] which suggest that an improvement in the PCPC score at an early phase after OHCA occurrence would be important for better long-term outcome in children with OHCA. However, the improvement of procedures after hospital arrival would be important in the future.

However, treatments targeting brain resuscitation in pediatric patients with ROSC were insufficiently established. The effectiveness of target temperature management in pediatric OHCA was not evident in a randomized trial.[10] Indeed, the proportion of children with OHCA undergoing advanced procedures after hospital arrival was extremely low in this study, for example, 1.9% in extra-

**Table III.** In-Hospital Advanced Treatments, Drug Administrations, and Arterial Blood Gases by Age Group

| | Total ($n$ = 263) | Age group | | | | $P$ |
|---|---|---|---|---|---|---|
| | | 0 years old ($n$ = 100) | 1-4 years old ($n$ = 45) | 5-12 years old ($n$ = 37) | 13-17 years old ($n$ = 81) | |
| Treatment by pediatricians, n (%) | 75 (28.5) | 42 (42.0) | 15 (33.3) | 9 (24.3) | 9 (11.1) | < 0.001 |
| Defibrillation, $n$ (%) | 13 (4.9) | 2 (2.0) | 1 (2.2) | 6 (16.2) | 4 (4.9) | 0.006 |
| Tracheal intubation after hospital arrival, $n$ (%) | 205 (78.0) | 82 (82.0) | 37 (82.2) | 27 (72.9) | 59 (72.8) | 0.362 |
| Extracorporeal life support, $n$ (%) | 5 (1.9) | 1 (1.0) | 0 (0.0) | 3 (8.1) | 1 (1.2) | 0.027 |
| Intra-aortic balloon pumping, $n$ (%) | 1 (0.4) | 0 (0.0) | 0 (0.0) | 0 (0.0) | 1 (1.2) | 0.521 |
| Coronary angiography, $n$ (%) | 6 (2.3) | 0 (0.0) | 0 (0.0) | 1 (2.7) | 5 (6.2) | 0.030 |
| Percutaneous coronary intervention, $n$ (%) | 0 (0.0) | 0 (0.0) | 0 (0.0) | 0 (0.0) | 0 (0.0) | NA |
| Target temperature management, $n$ (%) | 17 (6.5) | 9 (9.0) | 2 (4.4) | 0 (0.0) | 6 (7.4) | 0.257 |
| Drug administration during cardiac arrest (multiple choice), n (%) | | | | | | |
| Adrenaline | 231 (88.2) | 91 (91.0) | 42 (93.3) | 35 (94.6) | 63 (78.8) | 0.009 |
| Amiodarone | 4 (1.5) | 1 (1.0) | 0 (0.0) | 2 (5.4) | 1 (1.2) | 0.199 |
| Nifekalant | 1 (0.4) | 1 (1.0) | 0 (0.0) | 0 (0.0) | 0 (0.0) | 0.823 |
| Lidocaine | 2 (0.8) | 1 (1.0) | 0 (0.0) | 1 (2.7) | 0 (0.0) | 0.409 |
| Atropine | 2 (0.8) | 1 (1.0) | 1 (2.2) | 0 (0.0) | 0 (0.0) | 0.521 |
| Magnesium | 2 (0.8) | 1 (1.0) | 0 (0.0) | 1 (2.7) | 0 (0.0) | 0.409 |
| Vasopressin | 0 (0.0) | 0 (0.0) | 0 (0.0) | 0 (0.0) | 0 (0.0) | NA |
| Arterial blood gases at hospital arrival, mean (SD)* | | | | | | |
| Before first ROSC | | | | | | |
| pH | 6.666 (0.265) | 6.515 (0.236) | 6.604 (0.222) | 6.740 (0.224) | 6.794 (0.258) | < 0.001 |
| PaCO2 (mmHg) | 118.9 (53.2) | 130.5 (59.8) | 120.8 (39.1) | 109.4 (49.0) | 110.8 (52.8) | 0.179 |
| PaO2 (mmHg) | 67.3 (112.5) | 90.0 (143.1) | 54.4 (140.0) | 52.8 (101.9) | 58.0 (79.7) | 0.321 |
| HCO3 (mEq/L) | 12.1 (5.9) | 8.1 (3.7) | 10.6 (4.9) | 13.8 (5.8) | 15.2 (6.0) | < 0.001 |
| Base excess (mEq/L) | -24.4 (9.3) | -28.5 (7.2) | -26.3 (7.1) | -23.9 (9.1) | -19.8 (10.4) | < 0.001 |
| Lactate (mg/dL) | 157 (63) | 185 (60) | 146 (64) | 152 (52) | 135 (64) | 0.001 |
| Glucose (mg/dL) | 245 (197) | 277 (216) | 269 (297) | 236 (129) | 204 (132) | 0.264 |
| After first ROSC | | | | | | |
| pH | 6.889 (0.264) | 6.757 (0.259) | 6.900 (0.300) | 6.912 (0.252) | 6.997 (0.218) | 0.057 |
| PaCO2 (mmHg) | 72.7 (37.9) | 86.7 (49.5) | 67.6 (34.9) | 68.7 (36.2) | 64.1 (24.2) | 0.323 |
| PaO2 (mmHg) | 258.4 (175.6) | 206.0 (161.6) | 228.9 (168.3) | 331.4 (229.2) | 286.0 (157.8) | 0.293 |
| HCO3 (mEq/L) | 12.1 (5.0) | 9.1 (3.8) | 11.3 (4.1) | 12.4 (4.4) | 15.0 (5.2) | 0.003 |
| Base excess (mEq/L) | -20.2 (7.9) | -24.0 (6.4) | -21.0 (7.3) | -20.1 (8.0) | -16.4 (8.2) | 0.037 |
| Lactate (mg/dL) | 125 (53) | 146 (48) | 106 (27) | 135 (53) | 108 (63) | 0.132 |
| Glucose (mg/dL) | 329 (147) | 347 (186) | 342 (144) | 311 (130) | 313 (115) | 0.885 |
| Laboratory data at hospital arrival, mean (SD)* | | | | | | |
| Blood urea nitrogen (mg/dL) | 12.9 (6.6) | 10.9 (7.1) | 12.2 (6.7) | 15.6 (7.2) | 13.6 (5.4) | 0.057 |
| Creatinine (mg/dL) | 0.61 (0.34) | 0.37 (0.17) | 0.38 (0.12) | 0.69 (0.25) | 0.90 (0.32) | < 0.001 |
| Total protein (g/dL) | 5.6 (1.3) | 4.9 (1.1) | 5.3 (1.4) | 5.9 (1.3) | 6.2 (1.1) | < 0.001 |
| Albumin (g/dL) | 3.4 (0.7) | 3.2 (0.6) | 3.2 (0.8) | 3.4 (0.8) | 3.7 (0.7) | 0.004 |
| Sodium (mEq/L) | 138.2 (6.8) | 135.7 (7.2) | 136.9 (7.2) | 141.2 (5.8) | 140.1 (5.6) | < 0.001 |
| Potassium (mEq/L) | 7.9 (4.3) | 8.6 (4.5) | 7.6 (4.2) | 7.0 (2.8) | 7.9 (4.8) | 0.461 |
| Ammonia (µg/dL) | 719 (1100) | 995 (758) | 370 (224) | 400 (286) | 797 (1665) | 0.452 |

EMS indicates emergency medical service; ROSC, return of spontaneous circulation; SD, standard deviation; and NA, not assessed. *Calculated only for patients with blood gases or laboratory data.

corporeal life support, 6.5% in target temperature management, and approximately 1% in drug administration excluding adrenaline. To achieve successful pediatric PCAC after hospital arrival, which is complex and requires the cooperation of several professionals, gathering children with OHCA in a specific center and/or training medical professionals with specialized skills is needed.[26)]

Importantly, approximately two-thirds of the 90-day survivors had major cerebral damage in this study. No in-hospital treatment strategy of pediatric OHCA has been established in the current CPR guidelines,[9)] but we must strive to reduce the number of survivors with major cerebral damage. In addition, considering that long-term outcomes were different between pediatric OHCA patients with cardiac cause versus those with non-cardiac cause, the establishment of treatment strategies based on the cause of arrest are also needed. Thus, more evidence regarding the effects of in-hospital treatments for pediatric OHCA patients is needed to reduce the number of survivors with cerebral damage. Furthermore, the proportion of children with asystole on the first documented rhythm at EMS arrival was about two-thirds in this study and the

**Table IV.** Outcomes by Year

| | Total (*n* = 263) | 2012 (*n* = 15) | 2013 (*n* = 61) | 2014 (*n* = 65) | 2015 (*n* = 61) | 2016 (*n* = 61) | *P* for trend |
|---|---|---|---|---|---|---|---|
| Admitted to ICU/ward, *n* (%) | 67 (25.5) | 6 (40.0) | 12 (19.7) | 19 (29.2) | 15 (24.6) | 15 (24.6) | 0.773 |
| One-month survival, *n* (%) | 19 (7.2) | 0 (0.0) | 2 (3.3) | 6 (9.2) | 5 (8.2) | 6 (9.8) | 0.096 |
| PCPC one month after OHCA, *n* (%) | | | | | | | |
| PCPC 1 or 2 | 5 (1.9) | 0 (0.0) | 0 (0.0) | 1 (1.5) | 3 (4.9) | 1 (1.9) | 0.222 |
| PCPC 1 | 5 (1.9) | 0 (0.0) | 0 (0.0) | 1 (1.5) | 3 (4.9) | 1 (1.6) | |
| PCPC 2 | 0 (0.0) | 0 (0.0) | 0 (0.0) | 0 (0.0) | 0 (0.0) | 0 (0.0) | |
| PCPC 3 | 3 (1.1) | 0 (0.0) | 1 (1.6) | 0 (0.0) | 1 (1.6) | 1 (1.6) | |
| PCPC 4 | 3 (1.1) | 0 (0.0) | 0 (0.0) | 1 (1.5) | 0 (0.0) | 2 (3.3) | |
| PCPC 5 | 8 (3.0) | 0 (0.0) | 1 (1.6) | 4 (6.2) | 1 (1.6) | 2 (3.3) | |
| PCPC 6 | 244 (92.8) | 15 (100.0) | 59 (96.7) | 59 (90.8) | 56 (91.8) | 55 (90.2) | |
| 90-day survival, *n* (%) | 16 (6.1) | 0 (0.0) | 2 (3.3) | 5 (7.7) | 4 (6.6) | 5 (8.2) | 0.167 |
| PCPC 90 days after OHCA, *n* (%) | | | | | | | |
| PCPC 1 or 2 | 5 (1.9) | 0 (0.0) | 1 (1.6) | 0 (0.0) | 3 (4.9) | 1 (1.6) | 0.394 |
| PCPC 1 | 4 (1.5) | 0 (0.0) | 0 (0.0) | 0 (0.0) | 3 (4.9) | 1 (1.6) | |
| PCPC 2 | 1 (0.4) | 0 (0.0) | 1 (1.6) | 0 (0.0) | 0 (0.0) | 0 (0.0) | |
| PCPC 3 | 1 (0.4) | 0 (0.0) | 0 (0.0) | 0 (0.0) | 1 (1.6) | 0 (0.0) | |
| PCPC 4 | 3 (1.1) | 0 (0.0) | 0 (0.0) | 1 (1.5) | 0 (0.0) | 2 (3.3) | |
| PCPC 5 | 7 (2.7) | 0 (0.0) | 1 (1.6) | 4 (6.2) | 0 (0.0) | 2 (3.3) | |
| PCPC 6 | 245 (93.2) | 15 (100.0) | 59 (96.7) | 59 (90.8) | 57 (93.4) | 55 (90.2) | |
| Unknown | 2 (0.8) | 0 (0.0) | 0 (0.0) | 1 (1.5) | 0 (0.0) | 1 (1.6) | |

ICU indicates intensive care unit; ED, emergency department; PCPC, pediatric cerebral performance category; and OHCA, out-of-hospital cardiac arrest.

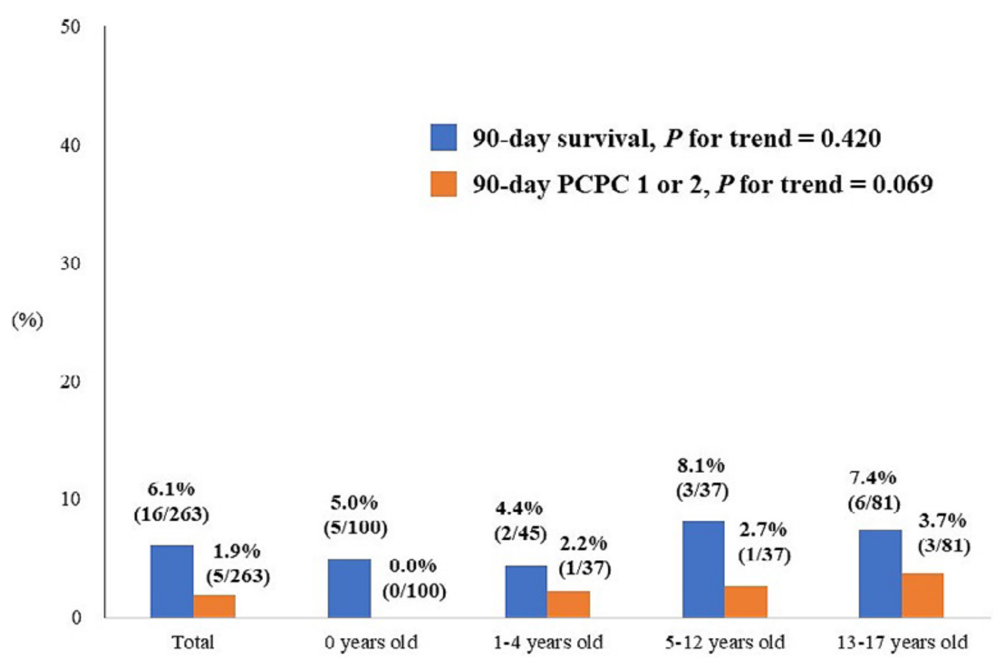


**Figure 2.** Outcomes at 90 days by age group.

average arrival time of EMS was 8 minutes in this study. Therefore, VF on the first documented rhythm at EMS arrival as well as subsequent outcome will increase if the EMS response time gets faster.

Furthermore, infants with OHCA aged 0 years accounted for 38.0% in this study, and none of them had a PCPC score of 1 or 2 at 90 days after OHCA occurrence. There were 36 infants suspected of having SIDS. Generally, survival after OHCA in infants is poor, regardless of the region, and infants with OHCA had a lower chance of survival than children aged ≥ 1 year in the United States[27] and Europe.[28] Therefore, the prevention of cardiac arrest is the most important in pediatric OHCA, especially preventive measures against SIDS, such as laying infants on their back and smoking cessation by family members.

This study has several limitations. First, we only assessed the neurological status at 1 month and 90 days after the arrest; a longer follow-up duration (e.g., 1 year af-

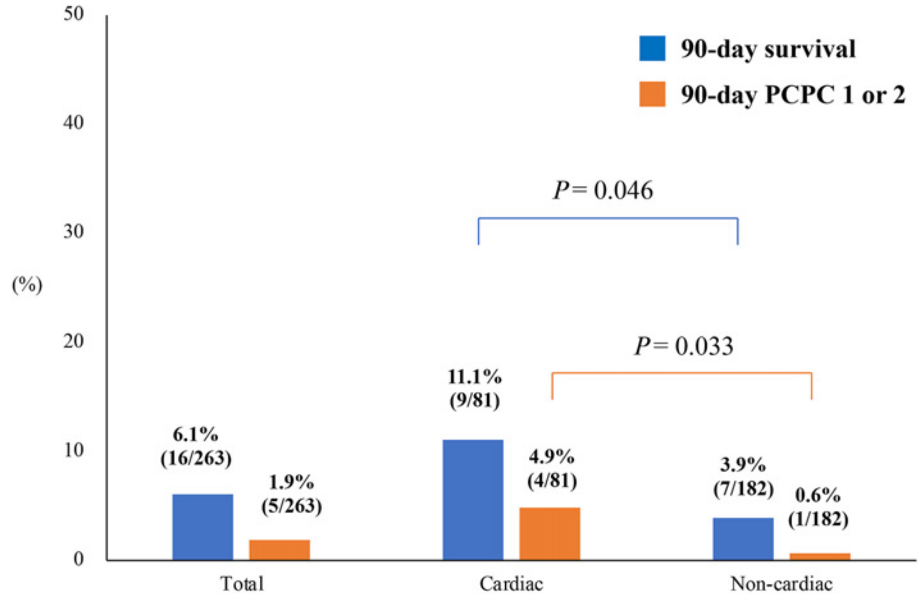


**Figure 3.** Outcomes at 90 days by cause of arrest

ter OHCA occurrence) was not available. Second, the category of presumed cardiac arrest is a diagnosis by exclusion (i.e., the diagnosis was made when there was no evidence of a non-cardiac cause), and information on detailed causes of cardiac OHCA and underlying diseases were not available in accordance with the Utstein-style international guidelines for cardiac arrest data reporting.[19,20] Third, this observational study lacks information on the distribution of public-access AEDs. Moreover, SIDS was clinically diagnosed and not confirmed by autopsy in this registry. Lastly, this study focused on pediatric patients with OHCA transported to CCMCs and did not provide information on patients transported to unregistered CCMCs or non-CCMCs.

## Conclusions

In this population, the proportion of pediatric patients with a 90-day PCPC score of 1 or 2 transported to CCMCs was extremely low, and no significant improvements were observed during the study period. In addition to the prevention of pediatric OHCA occurrence, the enhancement of prehospital interventions and development of advanced procedures after hospital arrival are needed to improve the outcomes of these patients.

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## Disclosure

**Conflicts of interest:** All authors declare that they have no competing interests.

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