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## Clinical paper

# Location of arrest and survival from out-of-hospital cardiac arrest among children in the public-access defibrillation era in Japan



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## Abstract

**Background:** Our objective was to assess the characteristics such as public-access defibrillation (PAD) by laypersons and the outcomes after pediatric out-of-hospital cardiac arrest by location in the PAD era.

**Methods:** From a nationwide, prospective, population-based registry of out-of-hospital cardiac arrest patients in Japan, we enrolled consecutive pediatric patients aged  $\leq 17$  years before emergency medical service (EMS) arrival between 2013 and 2015. The primary outcome measure was 1-month survival, with favorable neurologic outcome defined as cerebral performance category 1 or 2. Factors associated with favorable neurologic outcome were assessed using multivariable logistic regression analysis.

**Results:** Among 3991 eligible pediatric out-of-hospital cardiac arrests, the proportion of PAD was 0.2% (5/2888) at residence, 1.6% (2/125) in public areas, 0.9% (3/321) on streets/highways, 21.6% (11/51) at recreation/sports event areas, 46.1% (82/178) at education institutions, and 1.2% (5/428) in others. In the multivariable analysis, arrest witnessed by family members (adjusted odds ratio [AOR], 5.25; 95% confidence interval [CI], 3.22–8.58) and nonfamily members (AOR, 2.45; 95% CI, 1.26–4.77), first documented ventricular fibrillation (AOR, 12.29; 95% CI, 7.08–21.35), PAD (AOR, 2.63; 95% CI, 1.23–5.62), and earlier EMS response time (AOR for 1-min increment, 0.88; 95% CI, 0.81–0.94) were associated with improving outcome. As for locations, recreation/sports event areas (AOR, 3.43; 95% CI, 1.17–10.07) and education institutions (AOR, 3.03; 95% CI, 1.39–6.63) were also associated with favorable neurologic outcome.

**Conclusions:** In Japan, where public-access automated external defibrillators are well disseminated, characteristics such as PAD and outcomes for pediatric out-of-hospital cardiac arrest before EMS arrival differed substantially by location.

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## Introduction

Out-of-hospital cardiac arrest (OHCA) is an important public health problem among adults in industrialized countries.<sup>1–3</sup> The proportion of pediatric patients with OHCA accounted for fewer than 5% of all patients, and OHCA in children is rare when compared with that in adult patients.<sup>4,5</sup> However, it has a significantly negative impact on the social community in terms of life-years lost and healthcare costs for survivors<sup>6</sup> and emotional burden of family members.

To improve the OHCA outcome, it is exceedingly important for the general public to use an automated external defibrillator (AED) and perform cardiopulmonary resuscitation (CPR) in the chain of survival.<sup>1,2</sup> Many previous studies have demonstrated the effectiveness of shocks by a public-access AED on adults and children with OHCA,<sup>7–10</sup> and the use of public-access AEDs in prehospital settings is strongly recommended by current CPR guidelines.<sup>1,2</sup> On the other hand, some studies have assessed the relationship between the location of arrest and pediatric OHCA outcomes during a time when public-access AEDs were not well disseminated in public locations.<sup>5</sup>

In Japan, public use of AEDs has been legally permitted since July 2004,<sup>11</sup> and the cumulative number of public-access AEDs was more than 600,000 devices in 2015.<sup>12</sup> The All-Japan Utstein Registry,<sup>10,15</sup> a prospective, nationwide, population-based registry of OHCA patients in Japan, has been launched to collect information of OHCA locations since 2013.<sup>13</sup> Using this database, we aimed to assess the current situation such as bystander defibrillation and outcome after pediatric OHCA by location of arrest in the era of public-access defibrillation (PAD) in Japan.

## Methods

### *Study design, population, and settings*

Details of the All-Japan Utstein Registry of the Fire and Disaster Management Agency (FDMA) in Japan were previously described.<sup>8</sup> This population-based observational database is a prospective, nationwide OHCA registry based on the international Utstein-style.<sup>14,15</sup> We focused on pediatric patients aged 0–17 years with OHCA before emergency medical service (EMS) arrival, who were first resuscitated by bystanders or EMS personnel and then transported to medical institutions between January 1, 2013, and December 31, 2015. The Ethics Committee of the Osaka University Graduate School of Medicine approved this registry. The requirement of written informed consent was waived.

Cardiac arrest was defined as the cessation of cardiac mechanical activity as confirmed by the absence of circulation signs.<sup>14,15</sup> The arrest was classified into those of presumed cardiac origin and noncardiac origin such as respiratory disease, external cause, drowning, traffic accident, or any other noncardiac cause based on the Utstein-style template.<sup>15</sup> These diagnoses were determined clinically by the physician in charge, in collaboration with EMS personnel.

### *Emergency medical service systems in Japan*

The Japanese pediatric population aged 0–17 years was approximately 20 million in 2015,<sup>16</sup> with a geographic area of approximately 378,000 km<sup>2</sup>. EMS is provided by regional governments, and there were 750 fire stations with dispatch centers in 2015.<sup>13</sup> Emergency life-saving technicians (ELSTs), highly trained emergency care providers, are allowed to insert an intravenous line and an adjunct airway and to use semi-AEDs for OHCA patients. Specially trained ELSTs are allowed to intubate and administer adrenaline. Generally, each ambulance has a crew of three emergency providers including at least one ELST. Cardiac arrest treatments were based on the Japanese CPR guidelines.<sup>3</sup> Most OHCA patients treated by EMS personnel are usually transported to a hospital and registered in this registry because EMS providers are not permitted to terminate resuscitation in the field, excluding victims of decapitation, incineration, decomposition, rigor mortis, or dependent cyanosis.

### *Dissemination of public-access AEDs*

In Japan, public-access AEDs have been available to citizens since July 2004. Public-access AED deployment to public spaces such as nursing facilities, schools, sports/cultural facilities, workplaces, and transportation facilities depends on both private and public initiatives.<sup>12</sup> Excluding AEDs used in medical facilities and EMS institutions, the cumulative number of available public-access AEDs estimated from AED sales was 602,382 in 2015.<sup>12</sup> For example, at least one AED has been installed in almost all elementary, junior high, and high schools as of 2015 (approximately 45,000 schools throughout the country).<sup>17</sup> In addition, the proportion of schools that provided basic life support training to teaching staff including instructions on how to use an AED were reported to be approximately 90%.<sup>17</sup> The number of people in the general population who received any CPR training increased from 3,311,131 in 2005 to 4,402,343 in 2015.<sup>18</sup>

### *Data collection and quality control*

Data were prospectively gathered for resuscitation-related factors such as sex; age; date; cause of arrest; type of bystanders; first documented rhythm; time-course of resuscitation; type of bystander-initiated CPR; dispatcher instruction; PAD; epinephrine administration; advanced airway management; and patient outcomes, including prehospital return of spontaneous circulation (ROSC), 1-month survival, and neurological status 1-month after the event. A series of EMS event times such as call receipt, contact with the patient, and hospital arrival were recorded with the clock used by each EMS system. When bystanders provided shocks using a public-access AED, the victims' first documented rhythm was regarded as ventricular fibrillation (VF). Information of the time of collapse and initiation of bystander defibrillation or CPR was obtained by EMS review of the public-access AED records or interview of the bystander before leaving the scene. Importantly, in addition to the previously described data captured by the international Utstein-style,<sup>16,17</sup> the FDMA started collecting detailed information of the location of OHCA occurrence since January 2013. According to the current Utstein-style template, locations of arrest were classified into the following categories: residence, public area, streets/

highway, recreation/sports event areas, education institution, health-care facilities (clinic/nursing home), and others.<sup>14,15</sup>

All survivors were followed up for a 1-month period after OHCA occurrence by the EMS provider in charge. Neurological outcome was determined by the physician responsible for the care of the patient by a follow-up interview conducted 1-month after successful resuscitation, 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/brain death.<sup>14,15</sup>

The data form was filled out by EMS in cooperation with the physician in charge of the patient, and data were stored in the registry system on the FDMA database server. Data were logically checked through the computer system and were confirmed by the FDMA, and if the data form was incomplete, the FDMA returned it to the respective fire station, and the data were then corrected.

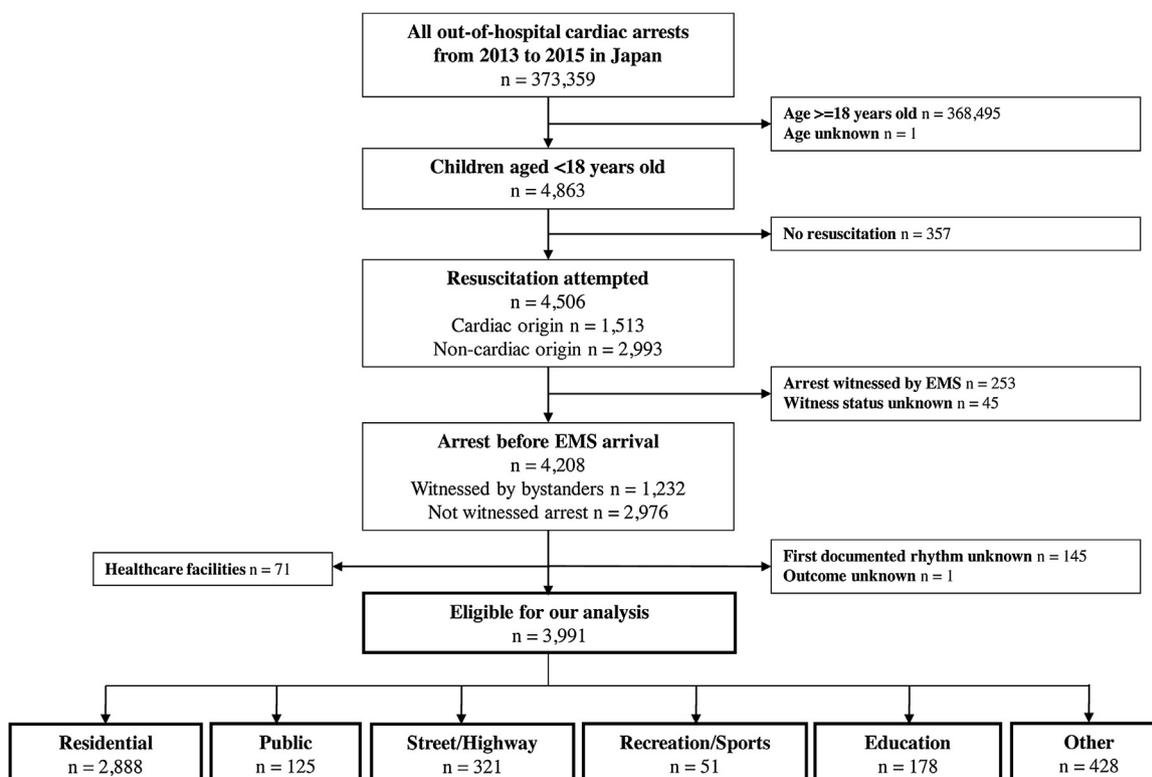
### Outcome measure

The primary outcome was a 1-month survival with a favorable neurologic outcome after OHCA, defined as CPC 1 or 2.<sup>14,15</sup> Secondary outcome measures were prehospital ROSC and a 1-month survival.

### Statistical analysis

Patient and EMS characteristics and their outcomes were compared between the groups using analysis of variance or *t*-test for numerical variables and chi-square test or Fisher's exact test for categorical variables. In this study, locations were divided into

the following 6 groups: residences, public areas, streets/highways, recreation/sports event areas, education institutions, and others. Others included areas such as work places, farm lands, sea shores, mountains, and unknown. Multivariable logistic regression analysis was applied to assess the factors associated with better neurological outcome among pediatric patients with OHCA before EMS arrival, and adjusted odds ratios (AORs) and their 95% confidence intervals (CIs) were calculated. As potential confounders, factors that were biologically essential and considered to be associated with clinical outcomes were included in the multivariable analyses based on previous studies.<sup>8,19,20</sup> These variables were age group (0, 1–4, 5–12, 13–17 years old), sex (female, male), cause (cardiac, noncardiac), arrest witnessed by bystander (not witnessed, witnessed by family members, witnessed by nonfamily members), location of arrest (of the 6 categories), first documented rhythm (non-VF, VF), dispatcher instruction (no, yes), PAD (no, yes), bystander-initiated CPR (no CPR, chest compression-only CPR, conventional CPR with rescue breathing), and EMS response time (time interval from call to contact with the patient). Among pediatric VF patients, the time from collapse to first shock (only for patients witnessed by bystanders) and outcomes between the PAD group and the no-PAD group were assessed in total and by location of arrest. Furthermore, we assessed PAD frequency and outcomes by age group (0, 1–3, 4–17 years old) among children with PAD. All analyses were conducted with STATA version 15.0MP software (StataCorp. LP). All tests were 2-tailed, and P values of <0.05 were considered statistically significant.



**Fig. 1 – Flowchart of patient recruitment.**  
EMS = emergency medical service.

## Results

Fig. 1 shows the flowchart of an overview of the pediatric study population recruitment based on the Utstein template. A total of 4863 pediatric arrests were documented during the 3-year period. Resuscitation was attempted in 4506 cases, and 1513 of them were presumed to be of cardiac origin. Among these patients, 4208 patients

had an arrest before EMS arrival. Excluding 145 victims whose first documented rhythms were unknown, 1 whose outcome was unknown, and 71 in whom arrest occurred in healthcare facilities, a total of 3991 children were eligible for our analysis. Among them, 2888 cases occurred at residence (72.4%), 125 in public areas (3.1%), 321 on streets/highways (8.0%), 51 at recreation/sports event areas (1.3%), 178 at education institutions (4.5%), and 428 in others (10.7%).

**Table 1 – Characteristics of Out-of-Hospital Cardiac Arrest among Children by Location of Arrest.**

	Total		Residential		Public		Street/ Highway		Recreation/ Sports		Education		Other		P value <sup>*</sup>
	(N = 3991)	(N = 2888)	(N = 125)	(N = 321)	(N = 51)	(N = 178)	(N = 428)								
Age, mean (SD)	5.8	(6.5)	4.6	(6.1)	8	(6.7)	11	(5.6)	8.5	(6.2)	10.5	(5.9)	7.1	(6.4)	<0.001
Age group, n (%)															<0.001
0 year old	1,513	(37.9)	1,329	(46.0)	25	(20.0)	13	(4.1)	8	(15.7)	21	(11.8)	117	(27.3)	
1–4 years old	759	(19.0)	589	(20.4)	30	(24.0)	39	(12.2)	10	(19.6)	20	(11.2)	71	(16.6)	
5–12 years old	668	(16.7)	380	(13.2)	22	(17.6)	101	(31.5)	15	(29.4)	39	(21.9)	111	(25.9)	
13–17 years old	1,051	(26.3)	590	(20.4)	48	(38.4)	168	(52.3)	18	(35.3)	98	(55.1)	129	(30.1)	
Male, n (%)	2,459	(61.6)	1,683	(58.3)	76	(60.8)	228	(71.0)	38	(74.5)	140	(78.7)	294	(68.7)	<0.001
Time of collapse, n (%)															<0.001
0:00–5:59	683	(17.1)	565	(19.6)	12	(9.6)	45	(14.0)	3	(5.9)	7	(3.9)	51	(11.9)	
6:00–11:59	1,279	(32.1)	989	(34.3)	26	(20.8)	73	(22.7)	17	(33.3)	69	(38.8)	105	(24.5)	
12:00–17:59	1,115	(27.9)	629	(21.8)	61	(48.8)	116	(36.1)	27	(52.9)	86	(48.3)	196	(45.8)	
18:00–23:59	914	(22.9)	705	(24.4)	26	(20.8)	87	(27.1)	4	(7.8)	16	(9.0)	76	(17.8)	
Weekday, n (%)	2,660	(66.7)	1,938	(67.1)	69	(55.2)	220	(68.5)	28	(54.9)	144	(80.9)	261	(61.0)	<0.001
Origin, n (%)															<0.001
Presumed cardiac origin	1,365	(34.2)	1,064	(36.8)	36	(28.8)	29	(9.0)	23	(45.1)	119	(66.9)	94	(22.0)	
Respiratory disease	588	(14.7)	509	(17.6)	16	(12.8)	4	(1.3)	2	(3.9)	13	(7.3)	44	(10.3)	
External cause	590	(14.8)	450	(15.6)	27	(21.6)	38	(11.8)	10	(19.6)	21	(11.8)	44	(10.3)	
Drowning	348	(8.7)	164	(5.7)	9	(7.2)	1	(0.3)	11	(21.6)	7	(3.9)	156	(36.5)	
Traffic accident	280	(7.0)	8	(0.3)	15	(12.0)	231	(72.0)	1	(2.0)	0	(0.0)	25	(5.8)	
Any other non-cardiac cause	820	(20.6)	693	(24.0)	22	(17.6)	18	(5.6)	4	(7.8)	18	(10.1)	65	(15.2)	
Witness status, n (%)															<0.001
Not witnessed	2,892	(72.5)	2,351	(81.4)	61	(48.8)	93	(29.0)	29	(56.9)	58	(32.6)	300	(70.1)	
Witnessed by family members	654	(16.4)	492	(17.0)	36	(28.8)	52	(16.2)	4	(7.8)	2	(1.1)	68	(15.9)	
Witnessed by non-family members	445	(11.2)	45	(1.6)	28	(22.4)	176	(54.8)	18	(35.3)	118	(66.3)	60	(14.0)	
Dispatcher instruction, n (%)	2,521	(67.3)	2,057	(74.6)	54	(47.8)	85	(31.6)	24	(50.0)	104	(62.3)	197	(50.0)	<0.001
First documented rhythm, n (%)															<0.001
VF	260	(6.5)	63	(2.2)	15	(12.0)	26	(8.1)	17	(33.3)	96	(53.9)	43	(10.1)	
PEA	587	(14.7)	371	(12.9)	32	(25.6)	105	(32.7)	10	(19.6)	22	(12.4)	47	(11.0)	
Asystole	3,144	(78.8)	2,454	(85.0)	78	(62.4)	190	(59.2)	24	(47.1)	60	(33.7)	338	(79.0)	
Bystander CPR, n (%)															<0.001
No CPR	1,623	(40.7)	1,082	(37.5)	73	(58.4)	218	(67.9)	12	(23.5)	28	(15.7)	210	(49.1)	
Chest compression-only CPR	1,763	(44.2)	1,370	(47.4)	28	(22.4)	90	(28.0)	23	(45.1)	89	(50.0)	163	(38.1)	
Conventional CPR with rescue breathing	603	(15.1)	436	(15.1)	24	(19.2)	13	(4.1)	15	(29.4)	60	(33.7)	55	(12.9)	
CPR type unknown	2	(0.1)	0	(0.0)	0	(0.0)	0	(0.0)	1	(2.0)	1	(0.6)	0	(0.0)	
Epinephrine, n (%)	155	(3.9)	90	(3.1)	3	(2.4)	26	(8.1)	5	(9.8)	9	(5.1)	22	(5.1)	<0.001
Advanced airway management, n (%)	532	(13.3)	390	(13.5)	16	(12.8)	58	(18.1)	5	(9.8)	10	(5.6)	53	(12.4)	0.006
Time from call to contact with the patient by EMS personnel, mins, mean (SD)	9.1	(4.8)	8.7	(3.2)	9.0	(5.3)	9.8	(5.9)	10.7	(6.1)	7.8	(2.6)	12.3	(9.5)	<0.001
Time from collapse to CPR by bystanders, mins, mean (SD) <sup>a</sup>	3.2	(5.1)	3.2	(5.6)	2.1	(3.0)	3.4	(3.6)	2.4	(2.9)	2.0	(2.9)	5.5	(7.2)	0.003
Time from collapse to shock by bystanders, mins, mean (SD) <sup>a</sup>	4.4	(3.4)	7.0	(1.4)	4.0	(4.2)	8.3	(7.6)	5.8	(5.7)	4.0	(2.8)	4.7	(1.5)	0.185
Time from call to hospital arrival, mins, mean (SD)	30.9	(14.3)	29.9	(13.1)	31.3	(16.0)	33.5	(16.3)	32.1	(14.3)	29.0	(12.7)	36.8	(18.2)	<0.001

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

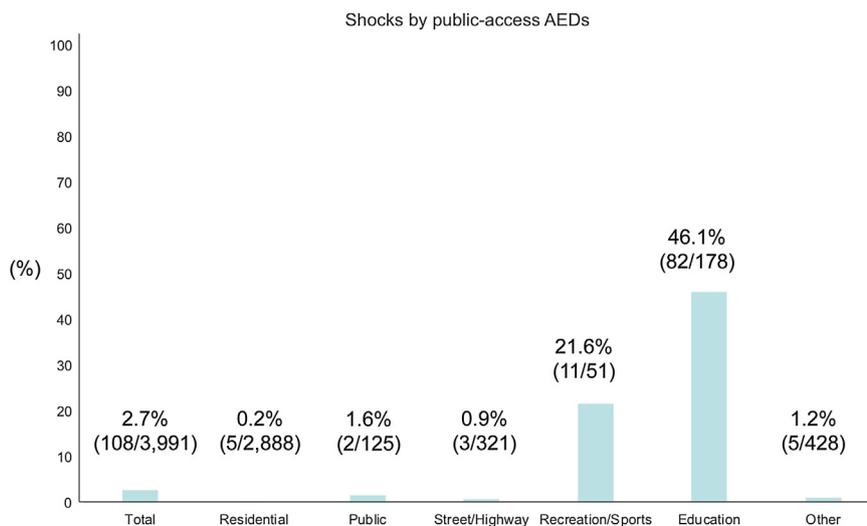
<sup>\*</sup> P values are calculated to test the homogeneity among the 6 location groups.

<sup>a</sup> Calculated only for children witnessed by bystanders.

Patient and EMS characteristics of pediatric OHCA patients according to location are shown in Table 1 and Fig. 2, and their outcomes are shown in Fig. 3. At residence, approximately half of the OHCA patients were <1 year old, and arrest occurred during 6:00 p.m. to 5:59 a.m., with 80% of the events not being witnessed. As for the origin of OHCA, on streets/highways, traffic accidents were the most frequent origin (72.0% [231/321]); at recreation/sports event areas, presumed cardiac origin was the most frequent (45.1% [23/51]) followed by drowning (21.6% [11/51]); and at education institutions, presumed cardiac origin was the most frequent (66.9% [119/178]). The proportion of public-access AED shocks by laypersons was 0.2% (5/2888) at residence, 1.6% (2/125) in public areas, 0.9% (3/321) on streets/highways, 21.6% (11/51) at recreation/sports event areas, 46.1% (82/178) at education institutions, and 1.2% (5/428) in others.

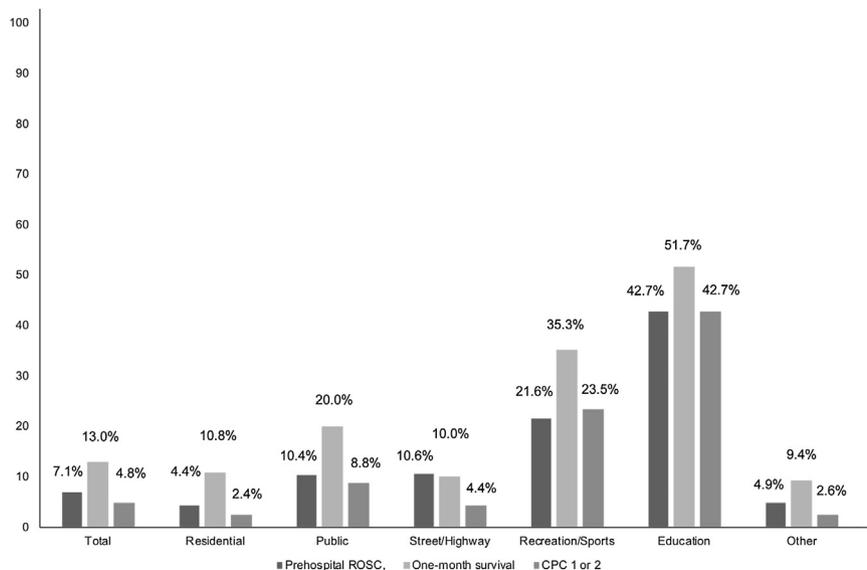
Among those who were witnessed by bystanders and received shocks with a public-access AED, mean time interval from collapse to shock was 4.4 min. The proportion of 1-month survival with a favorable neurologic outcome was 2.4% (68/2888) at residence, 8.8% (11/125) in public areas, 4.4% (14/321) on streets/highways, 23.5% (12/51) at recreation/sports event areas, 42.7% (76/178) at education institutions, and 2.6% (11/428) in others. In all of the locations except education, nearly half of 1-month survivors did not get ROSC before hospital arrival and more than half of one-month survivors did not have favorable neurological outcome, especially at residence.

Table 2 shows factors associated with 1-month survival and favorable neurologic outcome after pediatric OHCA. Arrest witnessed by family members (AOR, 5.25; 95% CI, 3.22–8.58) and nonfamily members (AOR, 2.45; 95% CI, 1.26–4.77), VF as the first



**Fig. 2 – Proportion of public-access AED shocks by laypersons among children with OHCA before EMS arrival according to the location.**

**AED = automated external defibrillator; OHCA = out-of-hospital cardiac arrest, EMS = emergency medical service.**



**Fig. 3 – The proportion of outcomes among children with OHCA before EMS arrival according to the location.**

**OHCA = out-of-hospital cardiac arrest, EMS = emergency medical service.**

**Table 2 – Factors Associated with Favorable Neurological Outcome after Out-of-Hospital Cardiac Arrest among Children.**

	CPC 1 or 2/Total		Univariable analysis			Multivariable analysis		
	n/N	(%)	OR	(95% CI)	P value	OR	(95% CI)	P value
<b>Age group</b>								
0 year old	23/1,513	(1.5)	Reference			Reference		
1–4 years old	21/759	(2.8)	1.84	(1.01–3.35)	0.045	0.91	(0.47–1.77)	0.781
5–12 years old	48/668	(7.2)	5.02	(3.02–8.32)	<0.001	1.48	(0.79–2.80)	0.222
13–17 years old	100/1,051	(9.5)	6.81	(4.30–10.80)	<0.001	1.60	(0.87–2.94)	0.131
<b>Gender</b>								
Female	49/1,532	(3.2)	Reference			Reference		
Male	143/2,459	(5.8)	1.87	(1.34–2.60)	<0.001	1.18	(0.77–1.82)	0.440
<b>Cause</b>								
Non-cardiac	70/2,626	(2.7)	Reference			Reference		
Cardiac	122/1,365	(8.9)	3.58	(2.65–4.85)	<0.001	0.91	(0.58–1.43)	0.670
<b>Arrest witnessed by bystanders</b>								
Not witnessed	45/2,892	(1.6)	Reference			Reference		
Witnessed by family members	55/654	(8.4)	5.81	(3.88–8.70)	<0.001	5.25	(3.22–8.58)	<0.001
Witnessed by non-family members	92/445	(20.7)	16.49	(11.35–23.95)	<0.001	2.45	(1.26–4.77)	0.008
<b>Location of arrest</b>								
Residential	68/2,888	(2.4)	Reference			Reference		
Public	11/125	(8.8)	4.00	(2.06–7.77)	<0.001	1.67	(0.74–3.78)	0.215
Street/Highway	14/321	(4.4)	1.89	(1.05–3.40)	0.033	0.77	(0.35–1.72)	0.526
Recreation/Sports	12/51	(23.5)	12.76	(6.40–25.45)	<0.001	3.43	(1.17–10.07)	0.025
Education	76/178	(42.7)	30.90	(21.09–45.28)	<0.001	3.03	(1.39–6.63)	0.005
Other	11/428	(2.6)	1.09	(0.57–2.09)	0.785	0.66	(0.31–1.39)	0.273
<b>First documented rhythm</b>								
Non-VF	67/3,731	(1.8)	Reference			Reference		
VF	125/260	(48.1)	50.64	(35.94–71.35)	<0.001	12.29	(7.08–21.35)	<0.001
<b>Dispatcher CPR instruction, n (%)</b>								
No	74/1,226	(6.0)	Reference			Reference		
Yes	107/2,521	(4.2)	0.69	(0.51–0.94)	0.018	0.87	(0.56–1.34)	0.519
<b>Shocks by public-access AEDs, n (%)</b>								
No	115/3,883	(3.0)	Reference			Reference		
Yes	77/108	(71.3)	81.38	(51.57–128.44)	<0.001	2.63	(1.23–5.62)	0.012
<b>Bystander-initiated CPR, n (%)</b>								
No CPR	50/1,623	(3.1)	Reference			Reference		
Chest compression-only CPR	81/1,763	(4.6)	1.52	(1.06–2.17)	0.023	0.82	(0.50–1.36)	0.443
Conventional CPR with rescue breathing	60/603	(10.0)	3.48	(2.36–5.12)	<0.001	1.68	(0.95–2.96)	0.073
EMS response time (per one-minute increment)	–		0.90	(0.85–0.95)	<0.001	0.88	(0.81–0.94)	<0.001

CPC indicates cerebral performance category; OR, odds ratio; CI, confidence interval; EMS, emergency medical service; CPR, cardiopulmonary resuscitation; VF, ventricular fibrillation; AED, automated external defibrillator.  
Two cases with unknown CPR type were excluded in these models.

documented rhythm (AOR, 12.29; 95% CI, 7.08–21.35), shocks by a public-access AED (AOR, 2.63; 95% CI, 1.23–5.62), and earlier EMS response time (AOR for 1-minute increment, 0.88; 95% CI, 0.81–0.94) were associated with improved favorable neurologic outcome. As for locations, recreation/sports event areas (AOR, 3.43; 95% CI, 1.17–10.07) and education institutions (AOR, 3.03; 95% CI, 1.39–6.63) were associated with favorable neurologic outcome. In the subgroup analysis (Supplementary Table S1), the PAD group had quicker first shock time (4.4 min vs. 12.6 min,  $p < 0.001$ ) and higher proportion of favorable neurologic outcome (71.3% [77/108] vs. 31.6% [48/152],  $p < 0.001$ ) than the no-PAD group. Similar results were also observed by location. In the subgroup analysis by age among pediatric patients with PAD (Supplementary Table S2), the proportion of PAD was 0.0% (0/1513) in the group aged 0 year old, 0.5% (3/652) in those aged 1–3 years old, and 5.8% (105/1,826) in those aged 4–17 years old. In those aged 4–17 years old, the proportion of one shock and favorable neurologic outcome was 67.6% and 72.4%.

## Discussion

From the All-Japan OHCA Registry in Japan, where public-access AEDs were well disseminated, we demonstrated that PAD worked effectively among children with OHCA before EMS arrival, but their characteristics and outcomes differed substantially even within locations. Particularly, PAD worked extensively well at education institutions and recreation/sports event areas. This nationwide population-based registry with location data as well as massive dissemination of public-access AEDs enabled us to evaluate the impact of PAD for pediatric OHCA in real-world settings. This study revealed the actual situations of public-access AED shock for pediatric OHCA in the PAD era and provides important clues for improving the pediatric OHCA outcome and implementing the appropriate placement of public-access AEDs.

Strategies for appropriate public-access AED deployment in public locations has been insufficiently established worldwide, although the

PAD program works effectively for OHCA in educational institutions in Japan. A method to improve survival after OHCA is to increase the number of people in the general public who know how to use an AED.<sup>1–3</sup> Only 5% of the general public who live in high-risk areas know where or how to find their nearest public-access AEDs.<sup>21</sup> Because the proportion of VF arrests decreases as the rhythm assessment by defibrillators is delayed,<sup>22</sup> more patients with OHCA would benefit from PAD if public-access AED pads were attached earlier. These efforts could lead to increased implementation of CPR and AED use by laypersons, which result in an increase in the number of survivors with favorable neurological outcome.

This study revealed that the proportion of PAD and favorable neurologic outcome after OHCA among children was higher at education institutions than at other locations. Several previous studies reported that OHCA victims at education institutions had a better outcome,<sup>23,24</sup> which is consistent with our results. Considering that almost all elementary, junior high, and high schools have installed at least one AED and approximately 90% of schools have provided systemic training of basic life support to instruct school staff on how to perform chest compressions and use an AED,<sup>17</sup> the PAD program at education institutions worked effectively in Japan. However, based on a statement “aiming for zero deaths; prevention of sudden cardiac death in schools” published by the Japan Circulation Society,<sup>25</sup> our final goal will be zero deaths in school settings. Therefore, advocating the importance of “the chain of survival” such as earlier recognition of OHCA and deploying multiple AEDs in pools and gymnasiums would be of help for achieving this aim.<sup>26</sup> In addition, the Japanese CPR guidelines recommend applying AED pads and initiating chest compressions immediately, even if laypersons cannot judge appropriately whether a collapsed person has cardiac arrest or not.<sup>27</sup> This policy (we called the ASUKA model) will also lead to improving the pediatric OHCA outcome at education institutions.

This study also underscored that the proportion of PAD, and favorable neurologic outcome after OHCA among children, was high at recreation/sports event areas. Because these areas are more equipped with public-access AEDs and their staff had more CPR skills, a collapsed child would likely be quickly discovered and treated properly during an OHCA. Indeed, the guidelines for appropriate placement of public-access AED in Japan strongly recommend deploying a public-access AED at sports facilities.<sup>28</sup> On the other hand, to further improve the outcome from OHCA at these areas, implementation of pre-exercise screening tests and/or school health examinations more aggressively would be needed.<sup>29,30</sup> In addition, the proportion of drowning as the cause of OHCA was high at these areas, and while this study did not obtain more detailed information of locations, OHCA due to drowning would occur in pools.<sup>31</sup> Therefore, it is essential to implement preventive measures against drowning in pools (e.g., increasing the number of lifeguards and reinforcing video monitoring systems).

Pediatric OHCA occurred frequently at residences, which accounted for two-thirds of all OHCA. It is notable that approximately 80% of OHCA occurring at these areas were not witnessed, and the proportion of favorable neurologic outcome was lowest in these locations. These findings were similar to those from previous studies assessing the outcomes of adult OHCA in residential versus public areas.<sup>32–34</sup> At residence, approximately half of OHCA cases occurred in infants aged <1 year and frequently occurred from night to morning. Considering these results, and because most OHCA are due to sudden infant death syndrome (SIDS) occurring at residences,<sup>35</sup> it is essential for parents to thoroughly conduct preventive measures against SIDS such as laying infants on their back and smoking

cessation by family members.<sup>36</sup> In addition, measures must be taken to increase bystander-delivered CPR at residences such as encouraging family members who have children at high risk of OHCA (e.g., congenital heart diseases) to receive CPR training.<sup>37</sup>

In this study, multivariable analysis indicated that pediatric OHCA with access to PAD had approximately a 2-fold AOR in favor of neurologic outcome compared with those without access to PAD. PAD is an essential factor in the prehospital setting to achieve favorable neurologic outcome after OHCA,<sup>10</sup> which is why it is important to further disseminate the PAD program. Although the Japanese guideline for appropriate AED deployment did not focus on pediatric OHCA,<sup>3</sup> it is expected to increase the use of public-access AEDs for pediatric OHCA and subsequently improve their outcomes worldwide, based on our data.

Importantly, the number of 1-month survivors without favorable neurological outcome was very large in this study. In pediatric patients, many patients who received ROSC by in-hospital intensive care after hospital arrival survived one month after OHCA. However, treatments targeting brain resuscitation for pediatric patients with ROSC would be insufficiently established. For example, the effectiveness of target temperature management for pediatric OHCA was not evident in a randomized trial.<sup>38</sup> Thus, further progress of brain resuscitation in advanced intensive care for pediatric OHCA with ROSC is needed. In addition, the number of one-month survivors without favorable neurological outcome was large at residence, which was one of the important public health issues for Japan or the world. A more focused approach to the characteristics and care of these patients in an effort to approach reducing this burden on parents and society is also needed.

Moreover, the proportion of children with OHCA who received bystander CPR was approximately 60% in this study, and a previous study also reported that the proportion of parents who could perform appropriate CPR was approximately 70%.<sup>39</sup> Therefore, mothers and all family members including fathers should receive the CPR training at the opportunity such as the health check-ups at 1 month after birth, which is one of the regular medical check-ups for all babies in Japan.<sup>40</sup> Furthermore, it is necessary to continuously provide systemic CPR training to teachers, lifeguards, and medical professionals who have high opportunity to encounter pediatric OHCA.

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## Limitation

This study has some inherent limitations. First, this observational study lacks information of activities at the time of arrest, past medical history, and the distribution of public-access AEDs. Second, this study included only patients with OHCA to whom shocks were administered by public-access AEDs, and therefore, it lacked information of those for whom attempts were made to use an AED. Third, the potential variability in postarrest care was not addressed in this Utstein-based registry. Fourth, there are some public-access AEDs with infant paddles or energy controls in Japan, but detailed information of devices was not available in this nationwide database. Fifth, there may be unmeasured confounding factors that influenced the association between locations and outcomes.

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## Conclusion

In Japan, where public-access AEDs were well disseminated, the PAD program worked effectively for pediatric OHCA before EMS

arrival, but their characteristics and outcomes differed substantially within locations. Our findings from this nationwide population-based database reinforce the importance of a PAD program for pediatric OHCA in prehospital settings.

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### Disclosures

None declared.

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### Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.resuscitation.2019.04.045>.

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