lacking. The aim of this study was to analyze the characteristics and outcomes of pediatric OHCA (defined as ≤ 18 yr old). We also focused on the impact of bystander-performed CPR and public access–automated external defibrillator (PAD) use on the outcomes of pediatric OHCA events.

MATERIALS AND METHODS

Study Design and Data Source

The Fire and Disaster Management Agency (FDMA) of Japan administers the EMS, providing the only ambulance service system in Japan, and this service can be accessed by all citizens. All OHCA cases transported to hospital by the EMS are recorded in a national OHCA database by the FDMA. In this study, we extracted data from the national database to perform a nationwide, population-based observational study of all recorded cases of OHCA in Japan over a 4-yr period from January 2005 to December 2008.

Data were gathered by EMS personnel and input into local fire department databases throughout Japan (12, 13). All data were verified, and personal information was removed. Data were then transferred and stored in the national OHCA database at the FDMA. We analyzed this database with the permission of the FDMA. The study was approved by the Ethical Committee of Nara Medical University (Authorization Code: 260).

Patient Details and Outcome of the Database

The OHCA data entry form was largely based on the Utstein form (14) and extended to include details of OHCA of all origins, including noncardiac cases, such as stroke, asphyxia, and trauma, as well as nonwitnessed cases (12, 15).

The main patient data gathered from the database were as follows: age, sex, the cause of OHCA (cardiac or noncardiac), the initially identified cardiac rhythm, whether OHCA was bystander witnessed, whether bystander CPR was performed, bystander category (family member, layperson other than family or EMS personnel), the interval from a call to arrival of the EMS (min), and the outcome in terms of survival and cerebral performance level 1 month after OHCA. The etiology of cardiac arrest was determined clinically by the physician in charge, in collaboration with EMS personnel. The initial cardiac rhythm data were categorized by EMS personnel as ventricular fibrillation (VF), pulseless ventricular tachycardia (VT), pulseless electrical activity (PEA), or asystole. We also recorded whether bystander CPR maneuvers had specifically included chest compressions and mouth-to-mouth ventilation. Outcomes, including the 1-month survival and favorable neurological status, were collected by EMS personnel from the hospitals that received the patients, in cooperation with the physicians in charge of the patients.

Subjects

During the 4-yr study period, data from the 431,950 patients who suffered an OHCA were included in the national database. Of these, 8,556 patients were 18 yr old or younger (defined as pediatric OHCA in this study). To determine the characteristics of pediatric OHCA, we selected pediatric OHCA patients with cases of an interval between the call to the EMS and their arrival on the scene of ≤ 60 min and excluded cases with EMS personnel as a bystander. In total, we analyzed the data of 7,624 pediatric OHCA patients from a nationwide population-based database in Japan from 2005 to 2008, involving more than 100,000 patients per year. To assess the characteristics of pediatric OHCA patients, we stratified the cases into five age groups as follows: infants (< 1 yr), preschool (1–5 yr), elementary school (6–12 yr), junior high school (13–15 yr), and high school (16–18 yr).

Data Analysis

For each patient, we determined the sex, whether the collapse was witnessed, whether specific bystander CPR maneuvers (chest compression and mouth-to-mouth ventilation) were performed, whether an initial VF/VT cardiac rhythm was exhibited, whether the cause of cardiopulmonary arrest was cardiac or noncardiac in origin, and whether PAD was performed. We also determined bystander type (family or nonfamily), time of call to EMS dispatcher center, and day of the call (Monday–Friday or Saturday and Sunday). We measured outcomes in terms of the 1-month survival and favorable neurological outcome at 1 month in the five groups. "Favorable neurological outcome" was defined as category 1 (good cerebral performance) or 2 (moderate cerebral disability) of the cerebral performance categories (CPC [16]). The statistical significance of differences was determined using the Student *t* test after analysis of variance testing or the chi-square test, as appropriate.

Logistic regression analyses were performed to identify the relationships between age categories on and the rates of performance of specific bystander CPR maneuvers (chest compression and mouth-to-mouth ventilation), using the preschool category as a reference. Infants (< 1 yr old) were excluded for the logistic regression analyses because of their susceptibility to sudden infant death syndrome. Potential confounding factors included time of call to the EMS dispatcher center, day of the call, status of the witness (whether a case was witnessed) and cause of cardiac arrest. Logistic regression analyses were also performed to identify the effects of bystander CPR and PAD on 1-month survival and favorable neurological outcome at 1 month. Potential confounding factors included age categories, cause of cardiac arrest, the status of the witness, attempted defibrillation by EMS, and the interval of call to EMS on scene. In this analysis, bystander CPR was defined as performing either chest compression or mouth-to-mouth ventilation or both. Statistical significance was defined as $p < 0.05$. All statistical analyses were conducted using PASW software v. 18 (SPSS, Chicago, IL).

RESULTS

Table 1 shows the baseline characteristics in the five pediatric groups (infants, preschool, elementary school, junior high school, and high school). Cardiac causes accounted for 30.2%

TABLE 1. Baseline Characteristics of the Overall Pediatric Patients by Scholastic Age Category

	Infants ($n = 3{,}049$)	Pre-School ($n = 1{,}632$)	Elementary School ($n = 980$)	Junior High School ($n = 650$)	High School ($n = 1{,}313$)	Total ($n = 7{,}624$)
Male, *n* (%)	1,773 (58.2%)	971 (59.5%)	612 (62.4%)	439 (67.5%)	932 (71.0%)	4,727 (62.0%)
Witnessed, *n* (%)	614 (20.1%)	511 (31.3%)	363 (37.0%)	242 (37.2%)	501 (38.2%)	2,231 (29.3%)
Cardiac cause of arrest, *n* (%)	1,188 (39.0%)	414 (25.4%)	242 (24.7%)	186 (28.6%)	271 (20.6%)	2,301 (30.2%)
Ventricular fibrillation/ pulseless ventricular tachycardia as initial rhythm, *n* (%)	103 (3.4%)	35 (2.1%)	74 (7.6%)	78 (12.0%)	122 (9.3%)	412 (5.4%)
Chest compression, *n* (%)	1,466 (48.1%)	832 (51.2%)	509 (52.0%)	332 (51.5%)	506 (38.8%)	3,645 (48.0%)
Mouth-to-mouth ventilation, *n* (%)	995 (32.7%)	646 (39.8%)	349 (35.8%)	207 (32.1%)	268 (20.6%)	2,465 (32.5%)
Nonfamily bystander, *n* (%)	143 (22.3%)	84 (15.9%)	190 (51.9%)	174 (70.7%)	397 (78.6%)	988 (43.2%)
Time of call						
From 0:00 until 8:00	1,017 (33.4%)	404 (24.8%)	192 (19.6%)	153 (23.5%)	351 (26.7%)	2,117 (27.8%)
From 8:00 until 16:00	1,223 (40.1%)	706 (43.3%)	420 (42.9%)	230 (35.4%)	415 (31.6%)	2,994 (39.3%)
From 16:00 until 24:00	809 (26.5%)	522 (32.0%)	368 (37.6%)	267 (41.1%)	547 (41.7%)	2,513 (33.0%)
Day of call						
Monday to Friday	2,142 (70.3%)	1,098 (67.3%)	666 (68.0%)	476 (73.2%)	949 (72.3%)	5,331 (69.9%)
1 month survival, *n* (%)						
Noncardiac	165 (8.9%)	208 (17.1%)	115 (15.6%)	41 (8.8%)	57 (5.5%)	586 (11.0%)
Cardiac	73 (6.1%)	26 (6.3%)	45 (18.6%)	56 (30.1%)	56 (20.7%)	256 (11.1%)
Favorable cerebral performance categories, *n* (%)						
Noncardiac	47 (2.5%)	100 (8.2%)	61 (8.3%)	20 (4.3%)	26 (2.5%)	254 (4.8%)
Cardiac	24 (2.0%)	9 (2.2%)	26 (10.7%)	40 (21.5%)	39 (14.4%)	138 (6.0%)
Call to emergency medical service on scene, min (SD)	6.80 (3.62)	7.04 (3.56)	7.63 (4.50)	7.17 (4.10)	7.65 (4.58)	7.14 (3.96)

of all pediatric OHCA cases. The overall rates of survival and favorable neurological outcome at 1 month were 11.0% and 5.1%, respectively. The proportion of initial VF/VT was higher in the junior high school group than in the other age groups ($p < 0.01$). The overall rate of attempting PAD use was only 0.7% (50 patients). Noncardiac causes of OHCA included cerebrovascular causes in 1.8% of cases, respiratory causes in 6.9% of cases, and external causes in 37.2% of cases (including trauma, drowning, hanging, and asphyxia); the cause was unknown in the remainder of the cases. The survival rate at 1 month after OHCA was 7.8% in infants, 14.3% in preschool, 16.3% in elementary school, 14.9% in junior high school, and 8.6% in high school. The survival rate of OHCA patients with noncardiac etiology was significantly higher in preschool and elementary school groups than junior high and high school groups ($p < 0.01$). By contrast, the survival rate of OHCA with cardiac etiology was higher in junior high and high school groups ($p < 0.01$). OHCA patients with cardiac etiology in the junior high school group showed the highest rate of 1-month survival and most favorable neurological outcome (CPC 1 and 2) of all the groups. The interval from EMS call to EMS arrival at the scene was significantly shorter in the infant and preschool groups than the elementary school and high school groups ($p < 0.01$).

Table 2 shows the characteristics of witnessed OHCA cases in the five pediatric age groups. The rates of chest compression and mouth-to-mouth ventilation were not higher in witnessed cases than the overall rates in all OHCA cases (witnessed and unwitnessed, shown in Table 1). However, the rates of 1-month survival and favorable neurological outcome were higher in witnessed OHCA cases than the overall rates in all OHCA cases.

Table 3 shows the characteristics of pediatric OHCA by time of call to EMS dispatch center. The number of witnessed OHCA

TABLE 2. Baseline Characteristics of the Witnessed Pediatric Patients by Scholastic Age Category

	Infants (*n* = 614)	Pre-School (*n* = 511)	Elementary School (*n* = 363)	Junior High School (*n* = 242)	High School (*n* = 501)	Total (*n* = 2,231)
Male, *n* (%)	342 (55.7%)	298 (58.3%)	235 (64.7%)	169 (69.8%)	386 (77.0%)	1,430 (64.1%)
Chest compression, *n* (%)	274 (44.8%)	224 (44.4%)	188 (51.9%)	128 (54.0%)	199 (40.4%)	1,013 (45.9%)
Mouth-to-mouth ventilation, *n* (%)	197 (32.3%)	184 (36.5%)	133 (37.2%)	89 (37.6%)	119 (24.2%)	722 (32.8%)
Nonfamily bystander, *n* (%)	141 (23.0%)	79 (15.5%)	188 (51.8%)	172 (71.4%)	396 (79.0%)	976 (43.8%)
1 month survival, *n* (%)						
Noncardiac	62 (17.5%)	97 (24.9%)	48 (18.4%)	21 (15.6%)	31 (8.6%)	259 (17.3%)
Cardiac	42 (16.2%)	15 (12.4%)	28 (27.5%)	51 (47.7%)	47 (33.1%)	183 (25.0%)
Favorable cerebral performance categories, *n* (%)						
Noncardiac	28 (8.0%)	53 (13.6%)	31 (11.9%)	12 (9.0%)	17 (4.8%)	141 (9.4%)
Cardiac	21 (8.1%)	6 (5.0%)	20 (19.6%)	38 (35.5%)	33 (23.2%)	118 (16.1%)

TABLE 3. Characteristics of the Pediatric Patients by Time of Call

	Infants	Pre-School	Elementary School	Junior High School	High School	Total
Time of call from 8:00 until 16:00						
Number of patients	1,223	706	420	230	415	2,994
Witnessed, *n* (%)	227 (18.6%)	227 (32.2%)	176 (41.9%)	114 (49.6%)	188 (45.3%)	932 (31.1%)
Nonfamily bystander	71 (5.8%)	41 (5.8%)	109 (26.0%)	92 (40.0%)	162 (39.0%)	475 (15.9%)
Chest compression	579 (47.3%)	371 (52.5%)	232 (55.2%)	120 (52.2%)	171 (41.2%)	1,473 (49.2%)
Mouth-to-mouth ventilation	394 (32.2%)	304 (43.1%)	165 (39.3%)	86 (37.4%)	106 (25.5%)	1,055 (35.2%)
1 month survival, *n* (%)	100 (8.2%)	132 (18.7%)	94 (22.4%)	60 (26.1%)	59 (14.2%)	445 (14.9%)
Favorable cerebral performance categories, *n* (%)	24 (2.0%)	67 (9.5%)	55 (13.1%)	41 (17.8%)	39 (9.4%)	226 (7.5%)
Time of call from 16:00 to 24:00						
Number of patients	809	522	368	267	547	2,513
Witnessed, *n* (%)	217 (26.8%)	181 (34.7%)	134 (36.4%)	89 (33.3%)	187 (34.2%)	808 (32.2%)
Nonfamily bystander	47 (5.8%)	35 (6.7%)	71 (19.3%)	61 (22.8%)	146 (26.7%)	360 (14.3%)
Chest compression	412 (50.9%)	254 (48.7%)	177 (48.1%)	136 (50.9%)	227 (41.5%)	1,206 (48.0%)
Mouth-to-mouth ventilation	273 (33.7%)	195 (37.4%)	121 (32.9%)	78 (29.2%)	111 (20.3%)	778 (31.0%)
1 month survival, *n* (%)	88 (10.9%)	76 (14.6%)	48 (13.0%)	27 (10.1%)	33 (6.0%)	272 (10.8%)
Favorable cerebral performance categories, *n* (%)	32 (4.0%)	33 (6.3%)	26 (7.1%)	12 (4.5%)	14 (2.6%)	117 (4.7%)

TABLE 4. Logistic Regression Analyses for Outcomes at 1 Month

		Survival at 1 Month			Favorable Cerebral Performance Categories at 1 Month		
		Odds Ratio	95% Confidence Interval	p	Odds Ratio	95% Confidence Interval	p
Age category	Pre-school		Reference			Reference	
	Elementary school	0.95	0.75–1.20	0.65	1.04	0.76–1.43	0.79
	Junior high school	0.71	0.53–0.95	0.02	0.88	0.61–1.29	0.52
	High school	0.43	0.33–0.56	< 0.001	0.53	0.37–0.76	= 0.001
Causes of arrest	Noncardiac		Reference			Reference	
	Cardiac	0.73	0.58–0.91	0.05	0.80	0.60–1.08	0.15
Bystander cardiopulmonary resuscitation	Not performed		Reference			Reference	
	Performed	2.81	2.30–3.44	< 0.001	4.55	3.35–6.18	< 0.001
Status of witness	Not witnessed		Reference			Reference	
	Witnessed	2.49	2.06–3.00	< 0.001	3.51	2.72–4.53	< 0.001
Public access–automated external defibrillator	Not performed		Reference			Reference	
	Performed	3.51	1.81–6.81	< 0.001	5.13	2.64–9.96	< 0.001
Defibrillation by emergency medical service	Not performed		Reference			Reference	
	Performed	4.02	3.03–5.32	< 0.001	3.26	2.30–4.62	< 0.001
Call to emergency medical service on scene interval (1 min increase)		0.95	0.93–0.98	< 0.001	0.98	0.95–1.02	0.35

events by a nonfamily bystander was higher in cases with time of call from 8:00 until 16:00 compared with those from 16:00 until 24:00 ($p = 0.02$). Overall 1-month survival rate was also higher in cases from 8:00 until 16:00 than those from 16:00 until 24:00 ($p < 0.01$).

Logistic regression analyses showed a lower rate of performance of chest compressions in high school patients and a decreasing rate of performance of mouth-to-mouth ventilation with increasing age categories. Cases with a cardiac origin tended to be more likely to receive both chest compressions and mouth-to-mouth ventilation compared with cases of noncardiac origin. Surprisingly, the rate of performance of chest compressions decreased when a witness was present.

Table 4 shows the result of logistic regression analyses for outcomes at 1 month. Bystander CPR significantly increased both 1-month survival (odds ratio 2.81; 95% confidence interval 2.30–3.44) and favorable neurological outcome at 1 month (odds ratio 4.55; 95% confidence interval 3.35–6.18).

DISCUSSION

Our results revealed that the overall rate of bystander-performed chest compression and mouth-to-mouth ventilation was similar to those in witnessed pediatric OHCA cases. Preschool OHCA patients had the highest 1-month survival rate and favorable neurological outcome at 1 month in the noncardiac etiology, and junior high school patients had the highest 1-month outcomes in the cardiac etiology. When PAD was performed, the rate of 1-month survival increased, with a concomitant increase in favorable neurological outcome.

There are many previous reports describing in-hospital cardiac arrest in pediatric patients (17–20). By contrast, only a small number of papers have described the characteristics of pediatric OHCA (4–7). Of these, only a few studies reported the outcomes of pediatric OHCA in a prospective population-based study over a large area (1, 8–11, 21). Atkins et al (1) reported epidemiology outcomes of OHCA in approximately 600 patients of ≤ 20 yr old in a prospective population-based study in a large area of the United States and Canada. They stratified the pediatric patients into three age groups (infants, < 1 yr old; children, 1–11; and adolescents, 12–19). The overall survival rate to hospital discharge was 6.4% and was greater in children and adolescents than in infants. Nitta et al (10) reported outcomes of 950 pediatric OHCA patients in Osaka, Japan stratified into four age groups (infants, < 1 yr; younger children, 1–4 yr; older children, 5–12 yr; and adolescents, 13–17 yr).

In nontrauma cases, the 1-month survival rate was higher in the adolescent group than the other age groups. Herlitz et al (11) reported outcomes of approximately 700 pediatric OHCA patients stratified into four age groups (< 1 yr, 1–4 yr, 5–12 yr, and 13–17 yr) and also reported that adolescents had the highest survival rate.

The results of our study using scholastic age stratification were somewhat different to those of previous studies, with the survival rates of OHCA patients tending to be higher in the preschool and elementary school groups in cases with a noncardiac etiology, and in the junior high and high school groups in cases with a cardiac etiology. These differences might be explained by the different age stratifications, differences in the causes of cardiac arrest (traumatic or nontraumatic), or the much smaller sample sizes of previous studies (which were from one province or prefecture). Because pediatric OHCA cases include infant to adolescent age groups, we think that stratification using several groups, such as our stratification by scholastic age category, is appropriate for describing detailed characteristics and outcomes. The higher VF/VT rate in junior high school patients compared with that in other groups could account for the difference in survival rates of OHCA patients with cardiac etiology. A lower VF/VT rate was observed in infants and preschool age patients compared with other age groups. This is likely to be a result of a lower witness rate because the interval between a call to EMS and their arrival on the scene was shortest in the infant and preschool age categories.

In our previous report, we assessed the outcomes of adult OHCA from the database used in this study and reported that the overall 1-month survival of adult OHCA was approximately 5% (12). Therefore, this study revealed that pediatric patients were more likely to survive after OHCA events compared with adult patients. Recently, several other studies reported that pediatric patients showed better outcomes than adult patients (1, 20), consistent with our results. This study also revealed that infant and high school groups showed poorer outcomes compared with other pediatric groups. The following might explain this observation: infants (< 1 yr old) are in a special age category susceptible to sudden infant death syndrome. Bystander CPR rates were lower in the high school category than the other scholastic age categories, resulting in poor outcomes in the high school category. In addition, the background of patients in the high school group might be more similar to young adult cases, resulting in similar outcomes to adult OHCA. This provides further evidence that age stratification, such as by scholastic age categories from infant to high school as performed here, is necessary for meaningful analysis of the characteristics of pediatric OHCA.

Lotfi et al (22) reported a retrospective study of cardiac arrest in a school setting. Although they included all OHCA events occurring at the school (97; not focused on only pediatric OHCA events), 12 were in students. In this study, involving only pediatric patients 18 yr old and younger, approximately 40% of pediatric OHCA events were called in to the dispatch center between 8:00 and 16:00. Therefore, we suppose that a certain number of pediatric OHCA patients would have been on the school campus when they collapsed. Pediatric OHCA patients who collapse in the daytime may receive bystander CPR more frequently than those in evening and night-time. However, the rate of chest compression performed between 8:00 and 16:00 was at a similar level to that between 16:00 and 24:00, while the rate of mouth-to-mouth ventilation performed increased between 16:00 and 24:00. Furthermore, the rate of chest compression decreased when a witness was present. These findings lead us to think that there is still scope for increasing bystander-performed CPR when pediatric OHCA occurs on a school campus. Possible bystanders of OHCA events between 8:00 and 16:00 might be schoolteachers and schoolmates; therefore, the people who provide the health care policy for a school should prepare measures to increase the rate of bystander-performed CPR for the pediatric OHCA events.

To improve the survival rate with favorable neurological status after a pediatric OHCA event, further effort might be necessary, for example, effective public basic life support (BLS) training programs at school (23). Wide dissemination of PAD devices to schools can also be an effective policy for better outcomes, together with BLS training for all possible bystanders (teachers as well as students) that includes instruction on usage of PAD. It was reported that dissemination of PADs resulted in earlier administration of shocks by laypersons and a higher 1-month survival rate (24). However, PADs were used in only a very small fraction of OHCA events when PADs were placed in the general community (25, 26). The low rate of PAD use by bystanders might be due to a lack of knowledge regarding the use of these devices, which can significantly affect the willingness of bystanders to perform CPR (27).

A previous study reported that although children's ability to perform adequate depth of chest compression depended on their age and weight, children aged 13–14 could effectively perform CPR including chest compression on a manikin as well as adults (28). Therefore, BLS training at schools which includes instruction in PAD use, especially for teachers and students in junior high school, high school and college, can be an effective way to increase bystander BLS skills and CPR attempts in homes and on school campuses. According to an annual report by the Ministry of Education, Culture, Sports, Science and Technology in Japan, there were PADs in approximately 25% of schools in Japan in 2007. The number of schools with PADs has increased over recent years.

Several limitations of our study should be acknowledged. First, we could not specifically analyze the characteristics and outcomes of pediatric OHCA events occurring at schools, because the database used did not include information regarding the sites of the events. Second, the neurological outcome in the database was not defined by pediatric CPC (PCPC) (29), thus we could not compare our results with previous results that used PCPC. Third, the database did not include information about bystanders; thus, we could not assess bystander CPR quality and whether they had participated BLS training before the OHCA events. The database also did not have a subcategory for drowning-associated OHCA, which has previously been found to have a high su rvival rate (30, 31). We could therefore not specifically analyze the outcomes of drowning-associated OHCA. Further study will be needed to clarify these issues. Fourth, outcomes such as survival and neurological outcomes in pediatric OHCA might vary among hospitals, with the medical staff in children's hospitals or certain emergency centers with tertiary care having a greater knowledge and experience of pediatric OHCA patient care compared with staff in general hospitals (32). The database also did not include hospital information such as physician staffing characteristics. As such, we were unable to adjust for these factors in this study.

CONCLUSIONS

Using data from a nationwide population-based database, we demonstrated that bystander-performed CPR and PAD had a significant impact on the outcomes of pediatric OHCA. The improved survival associated with bystander CPR and PAD are clinically important and are of major public health importance for school-aged OHCA patients.

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Monophasic versus biphasic defibrillation for pediatric out-of-hospital cardiac arrest patients: a nationwide population-based study in Japan

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Abstract

Introduction: Conventional monophasic defibrillators for out-of-hospital cardiac-arrest patients have been replaced with biphasic defibrillators. However, the advantage of biphasic over monophasic defibrillation for pediatric out-of-hospital cardiac-arrest patients remains unknown. This study aimed to compare the survival outcomes of pediatric out-of-hospital cardiac-arrest patients who underwent monophasic defibrillation with those who underwent biphasic defibrillation.

Methods: This prospective, nationwide, population-based observational study included pediatric out-of-hospital cardiac-arrest patients from January 1, 2005, to December 31, 2009. The primary outcome measure was survival at 1 month with minimal neurologic impairment. The secondary outcome measures were survival at 1 month and the return of spontaneous circulation before hospital arrival. Multivariable logistic regression analysis was performed to identify the independent association between defibrillator type (monophasic or biphasic) and outcomes.

Results: Among 5,628 pediatric out-of-hospital cardiac-arrest patients (1 through 17 years old), 430 who received defibrillation shock with monophasic or biphasic defibrillator were analyzed. The number of patients who received defibrillation shock with monophasic defibrillator was 127 (30%), and 303 (70%) received defibrillation shock with biphasic defibrillator. The survival rates at 1 month with minimal neurologic impairment were 17.5% and 24.4%, the survival rates at 1 month were 32.3% and 35.6%, and the rates of return of spontaneous circulation before hospital arrival were 24.4% and 27.4% in the monophasic and biphasic defibrillator groups, respectively. Hierarchic logistic regression analyses by using generalized estimation equations found no significant difference between the two groups in terms of 1-month survival with minimal neurologic impairment (odds ratio (OR), 1.57; 95% confidence interval (CI), 0.87 to 2.83; $P = 0.14$) and 1-month survival (OR, 1.38; 95% CI, 0.87 to 2.18; $P = 0.17$).

Conclusions: The present nationwide population-based observational study could not confirm an advantage of biphasic over monophasic defibrillators for pediatric OHCA patients.

Introduction

Ventricular fibrillation (VF) accounts for 5% to 15% of out-of-hospital cardiac arrests (OHCAs) in children [1-4]. In such patients, early defibrillation may improve the outcome [4,5]. Depending on the wave pattern used in the defibrillation shock for VF, two types of defibrillator are used: monophasic and biphasic. It was reported that biphasic waveform defibrillation was more effective and safer compared with monophasic waveform defibrillation in controlled laboratory [6,7], in-hospital [8,9] and out-of-hospital settings [10-12]. In addition, biphasic defibrillators are smaller and lighter than monophasic defibrillators [13]. For these reasons, conventional monophasic defibrillators have been gradually replaced with biphasic defibrillators worldwide.

However, human studies comparing the two types of defibrillators have been performed only with adult patients. Even in a controlled laboratory setting or in-hospital

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setting, to our knowledge, no data compare the outcomes of defibrillation with different waveforms for pediatric OHCA patients. Thus, the advantage of a biphasic over a monophasic defibrillator for pediatric OHCA patients remains unknown.

In the present study, we used the nationwide OHCA registry database in Japan [14] to compare neurologically intact survival outcomes of pediatric OHCA patients who underwent defibrillation with a monophasic or biphasic defibrillator.

Materials and methods

Study design and data source

Our study used the All-Japan Utstein Registry database, which is a prospective, nationwide, population-based registry system of OHCA patients who are transferred to hospital by emergency medical service (EMS) providers [14]. Because only one nationwide emergency transport service system exists in Japan, all OHCA cases in which the patients were transported to hospital are registered in this database. Except for those with decapitation, incineration, decomposition, rigor mortis, or dependent cyanosis, almost all OHCA patients who are treated by EMS personnel are transported to hospital [14]. Therefore, patients in this database are representative of all OHCA patients in Japan.

The present study enrolled all pediatric patients aged 1 to 17 years who were transported to hospital by EMS personnel during 5 consecutive years from January 1, 2005, through December 31, 2009. In this period, because EMS personnel are allowed to perform defibrillation only on patients aged 1 year or older, the subjects in this study were those aged 1 year or older. Given the anonymous nature of the data, informed consent was waived. The study was approved by the Ethics Committee of Nara Medical University.

EMS system in Japan

Japan has approximately 128 million residents (as of 2007) in an area of approximately 378,000 km^2, and residents aged 17 years or younger account for 16% (21 million) of the population. The universal emergency telephone number of 119 directly connects to the regional fire defense headquarters. On acceptance of an emergency call, the nearest available ambulance is dispatched to a scene. All expenses are covered by the local government; the patient does not bear emergency treatment or transportation expenses. Except for limited areas where physician-manned ambulances or helicopters are available, the EMS system is a one-tiered response system [15].

Each ambulance has three EMS staff who can all perform cardiopulmonary resuscitation according to the Japanese guidelines; which, until September 2006, were based on the International Liaison Committee on Resuscitation and the American Heart Association 2000 Guidelines [16]. Since October 2006, resuscitation has been based on the respective 2005 Guidelines [14,17]. In Japan, EMS personnel can give only epinephrine and cannot give amiodarone.

Automated external defibrillator

Each ambulance is equipped with one automated external defibrillator (AED). Either a monophasic or a biphasic defibrillator is applied to OHCA patients, according to the type of defibrillator on the EMS ambulance. The monophasic defibrillator models used in the present study were Heart Start 3000/3000QR (Laerdal Medical, Stavanger, Norway), LIFEPAK 12A (Medtronic), TEC 2202/2203/2212/2213, and AED-9100/9110 (Nihon Kohden). The monophasic defibrillators delivered either monophasic damped sine defibrillation waveforms or monophasic truncated exponential waveforms, according to the type of defibrillator on each EMS ambulance.

Biphasic defibrillator models were Heart Start MRxE/MRx, Heart Start FRx, Heart Start FR2/FR2+, Heart Start 4000, Heart Start HS1, Heart Start XL (Philips Medical Systems, Seattle, WA, USA), AED-9200/9210, AED-9231/9211/9201, AED-1200, AED-2100, TEC-2312/2313, TEC-2503/2513 (Nihon Kohden, Tokyo, Japan), or LIFEPAK 500B, LIFEPAK 1000, LIFEPAK 12B, and LIFEPAK CR-Plus (Medtronic, Minneapolis, MN, USA). All biphasic defibrillators in this study delivered the biphasic truncated exponential waveform.

EMS personnel used the both monophasic and biphasic defibrillators in AED mode, not manual mode. The defibrillation energy dose was set at the level for adults. The recommended adult dose of the monophasic defibrillator was initially 200 J, and thereafter, 360 J. The biphasic defibrillator energy dose was set at the level recommended by the manufacturer. For children aged 1 to 8 years, defibrillation was performed by using self-adhesive pad electrodes with pediatric attenuator systems. For children aged 9 to 17 years, a self-adhesive pad without pediatric attenuator systems was used in the same way as in adults.

Data collection and quality control

All OHCA patient information was input by using an online entry form by EMS personnel, which basically conformed to the Utstein form, with some additions. The data were anonymized at the local fire departments and then transferred to the Fire and Disaster Management Agency (FDMA) and stored [18,19]. The data were checked, and if any were missing, the FDMA informed the corresponding regional fire department, and the data were corrected [18].

The main database items included patient age, sex, bystander-witness status, receipt of bystander CPR, receipt of defibrillation by the EMS, type of defibrillator, and the etiology of the cardiac arrest (cardiac or noncardiac origin). Outcome data included return of spontaneous circulation before arrival at the hospital, survival at 1 month, and neurologic status 1 month after the OHCA [20,21].

The etiology of cardiac arrest was determined by the physician in charge based on physical, laboratory, or radiologic findings, together with scene information obtained from EMS crew [22]. It was presumed to be cardiac in origin unless unequivocal evidence suggested respiratory diseases, cerebrovascular diseases, external causes (trauma, hanging, drowning, drug overdose, asphyxia) or any other noncardiac cause. One-month survival and neurologic- status data were collected by EMS personnel from the hospitals that received the patients, in cooperation with the physicians in charge of the patients through a follow-up interview at 1 month after hospital admission [14,20,23].

Study targets and end points

In this study, we focused on pediatric patients who had confirmed shockable rhythms (ventricular fibrillation or pulseless ventricular tachycardia) and received defibrillation shock by EMS personnel. The primary outcome measure was survival at 1 month with minimal neurologic impairment, which was defined as Glasgow-Pittsburgh Cerebral Performance Category 1 (good cerebral performance) or 2 (moderate cerebral disability) [24,25]. The secondary outcome measures were survival at 1 month and the return of spontaneous circulation (ROSC) before hospital arrival.

Statistical analysis

We compared the outcomes of pediatric OHCA patients receiving defibrillation shock with a monophasic waveform defibrillator with those receiving shock with a biphasic waveform defibrillator. Age was dichotomized into children aged 1 through 11 years (children) and 12 through 17 years (adolescents). The time from emergency call to CPR by EMS was divided into the following three categories: early response (0 to 6 minutes), moderate response (7 to 12 minutes), and late response (13 to 18 minutes). Based on the CPR type, the subjects were categorized into 2000 Guideline-based subgroup and 2005 Guideline-based subgroup. Patient characteristics were evaluated by using unpaired Student *t* tests for numeric variables and χ^2 tests for categoric variables. Outcomes by type of defibrillator were compared by using χ^2 tests.

To identify the association between defibrillator type (monophasic or biphasic) and outcomes, we performed multivariate logistic regression analyses with adjustment for age, sex, bystander-witness status, the type of bystander CPR (no bystander CPR, compression-only CPR or conventional CPR), time from emergency call to CPR by EMS (early, moderate, or late response), cause of arrest (cardiac or noncardiac), the type of guideline-based CPR performed (2000 Guideline based or 2005 Guideline based), and calendar year. We assumed that our data were structured hierarchically into two levels of patients and communities. We accounted for clustering of patients within communities by using a generalized estimation equation (GEE). This method is commonly used instead of a traditional regression analysis because patients in the same community may be correlated, thus violating independence assumptions made by traditional regression procedures [26]. All statistical analyses were conducted by using PASW ver. 17.0J (SPSS, Inc., Chicago, IL, USA). All tests were two-tailed, and a P value < 0.05 was regarded as significant.

Results

The total number of OHCA patients (aged 1 through 17 years) was 5,628 during the study period. Patients who had no attempted resuscitation by EMS (n = 283), patients not shocked by EMS (n = 4848), patients lacking information on whether defibrillation shock was done or not (n = 43; < 0.8%), and patients who underwent defibrillation by a public-access AED by bystanders (n = 24; < 0.4%) were excluded. Consequently, the number of OHCA patients who were shocked for defibrillation by EMS was 430. These 430 patients were eligible for this study. Of the eligible patients, 127 (30%) received shocks with a monophasic defibrillator, and 303 (70%) received shocks with a biphasic defibrillator. Table 1 shows the demographic characteristics of the included pediatric patients. The proportion of patients receiving biphasic waveform defibrillation increased yearly.

Table 2 shows outcomes by type of defibrillator of eligible patients and of subgroups. Neurologic status was not documented for one patient in the monophasic waveform group. Chi-square tests showed no significant differences in any outcome measures between monophasic and biphasic groups in all patients and all subgroups.

Table 3 shows the results of logistic GEE regression analyses. No significant differences were found between the monophasic and biphasic groups in any outcome measures of eligible patients, including ROSC before hospital arrival (odds ratio (OR), 1.46; 95% confidence interval (CI), 0.8 to 2.63; P = 0.20), survival at 1 month (OR, 1.38; 95% CI, 0.87 to 2.18; P = 0.0.17), and survival at 1 month with minimal neurologic impairment (OR, 1.57; 95% CI, 0.87 to 2.83; P = 0.14).

Discussion

Our study showed no significant differences in outcomes between the pediatric OHCA patients who were shocked with a biphasic defibrillator and those who were shocked with a monophasic defibrillator. So far, effective waveform

Table 1 Patient characteristics of the study participants

Number of cases	Total (n = 430)		Monophasic (n = 127)		Biphasic (n = 303)		P
Year							< 0.001
2005, n (%)	89	(20.7)	48	(37.8)	41	(13.5)	
2006, n (%)	74	(17.2)	30	(23.6)	44	(14.5)	
2007, n (%)	90	(20.9)	26	(20.5)	64	(21.1)	
2008, n (%)	92	(21.4)	15	(11.8)	77	(25.4)	
2009, n (%)	85	(19.8)	8	(6.3)	77	(25.4)	
Age, mean (SD)	12.8	(4.2)	13.3	(3.7)	12.6	(4.4)	0.08
Children (1 to 11 years old), n (%)	119	(27.7)	35	(27.6)	84	(27.7)	0.97
Adolescents (12 to 17 years old), n (%)	311	(72.3)	92	(72.4)	219	(72.3)	
Boys, n (%)	293	(68.1)	84	(66.1)	209	(69.0)	0.56
Witnessed by laypersons, n (%)	287	(66.7)	87	(68.5)	200	(66.0)	0.62
Type of bystander-initiated CPR[a]							0.05
No-CPR, n (%)	193	(45.2)	63	(50.0)	130	(43.2)	
Compression-only CPR, n (%)	97	(22.7)	19	(15.1)	78	(25.9)	
Conventional CPR, n (%)	137	(32.1)	44	(34.9)	93	(30.9)	
Call to CPR by EMS, minutes, mean (SD)[b]	8.9	(5.3)	8.8	(5.3)	9.0	(5.4)	0.34
0 to 6 minutes, n (%)	137	(32.0)	46	(36.5)	91	(30.1)	
7 to 12 minutes, n (%)	236	(55.1)	67	(53.2)	169	(56.0)	
13 to 18 min, n (%)	55	(12.8)	13	(10.4)	42	(13.9)	
CPR by EMS to hospital arrival, minutes, mean (SD)	21.3	(10.5)	21.6	(10.6)	21.1	(10.4)	0.66
Type of origin							0.72
Cardiac, n (%)	272	(63.3)	82	(64.6)	190	(62.7)	
Noncardiac, n (%)	158	(36.7)	45	(35.4)	113	(37.3)	
External causes, n (%)	92	(21.4)	24	(18.9)	68	(22.4)	
Respiratory diseases, n (%)	10	(2.3)	4	(3.1)	6	(2.0)	
Cerebrovascular diseases, n (%)	7	(1.6)	2	(1.6)	5	(1.7)	
Others, n (%)	49	(11.4)	15	(11.8)	34	(11.2)	
CPR guidelines							< 0.001
2000 Guideline based, n (%)	146	(34.0)	74	(58.3)	72	(23.8)	
2005 Guideline based, n (%)	284	(66.0)	53	(41.7)	231	(76.2)	
Number of shocks administered to patients who had ROSC before hospital arrival							
Median (25% to 75%)	1	(1-2)	1	(1-2)	1	(1-2)	0.76

CPR, cardiopulmonary resuscitation. [a]Three (0.7%) patients with missing data were excluded. Percentages were calculated based on the total number of events, excluding those missing data. [b]Two (0.5%) patients with missing data were excluded. Percentages were calculated based on the total number of events, excluding those missing data. AHA, American Heart Association; CPR, cardiopulmonary resuscitation; SD, standard deviation; EMS, emergency medical service.

types for defibrillation of pediatric VF have not been well determined. Only studies based on animal models report the potential effectiveness of certain types [27-29]. In an animal model of pediatric defibrillation with "infant" and "child" piglets, biphasic were more effective than monophasic waveforms [29]. Regarding human studies, previous studies with adult patients reported that biphasic waveform shock was superior to monophasic waveform shock in terms of safety under controlled laboratory and in-hospital conditions [6,8,9]. Regarding long-term outcomes, no significant difference was detected between the two types of waveform for defibrillation in any observational studies or in four randomized trials for adults [30-34]. In pediatric patients, no studies compared biphasic and monophasic waveforms, even in controlled laboratory or in-hospital settings. To the best of our knowledge, the present study is the first to verify the association of the outcomes and defibrillation with different defibrillator waveforms in pediatric OHCA.

Owing to the results of adult studies comparing the two defibrillators in laboratory and in-hospital settings, or the greater portability of biphasic defibrillators, most monophasic defibrillators were replaced with biphasic defibrillators in ambulances in Japan. This tendency is common worldwide. Biphasic defibrillators may reduce the physical burden on EMS personnel because of their greater portability. With respect to effectiveness, however, the present study showed no significant advantage of biphasic over monophasic defibrillators on meaningful clinical outcomes for pediatric patients.

Table 2 Outcomes of all patients and subgroups.

	ROSC before hospital arrival			Survival at 1 month			Survival at 1 month with minimal neurologic impairment		
	n	(%)	*P*	*n*	(%)	*P*	*n*	(%)	*P*
All patients (*n* = 430)									
Monophasic (*n* = 127)	31	24.4%	0.52	41	32.3%	0.50	22	17.5%	0.12
Biphasic (*n* = 303)	83	27.4%		108	35.6%		74	24.4%	
Age category									
Children (1 to 11 years)									
Monophasic (*n* = 35)	6	17.1%	0.10	9	25.7%	0.51	3	8.6%	0.72
Biphasic (*n* = 84)	6	7.1%		17	20.2%		9	10.7%	
Adolescents (12 to 17 years)									
Monophasic (*n* = 92)	25	27.2%	0.17	32	34.8%	0.27	19	20.9%	0.11
Biphasic (*n* = 219)	77	35.2%		91	41.6%		65	29.7%	
Time from emergency call to CPR by EMS									
Early response (0 to 6 minutes)									
Monophasic (*n* = 46)	13	28.3%	0.35	19	41.3%	0.65	11	24.4%	0.37
Biphasic (*n* = 91)	33	36.3%		34	37.4%		29	31.9%	
Moderate response (7 to 12 minutes)									
Monophasic (*n* = 67)	17	25.4%	0.93	21	31.3%	0.20	10	14.9%	0.12
Biphasic (*n* = 169)	42	24.9%		68	40.2%		41	24.3%	
Late response (13 to 18 minutes)									
Monophasic (*n* = 13)	1	7.7%	0.33	1	7.7%	0.53	1	7.7%	0.84
Biphasic (*n* = 42)	8	19.0%		6	14.3%		4	9.5%	
Origin of cardiac arrest									
Cardiac									
Monophasic (*n* = 82)	25	30.5%	0.61	32	39.0%	0.53	19	23.2%	0.059
Biphasic (*n* = 190)	64	33.7%		82	43.2%		66	34.7%	
Noncardiac									
Monophasic (*n* = 45)	6	13.3%	0.59	9	20.0%	0.68	3	6.8%	0.95
Biphasic (*n* = 113)	19	16.8%		26	23.0%		8	7.1%	
CPR Guidelines									
2000 Guideline based									
Monophasic (*n* = 74)	17	23.0%	0.12	24	32.4%	0.64	12	16.4%	0.50
Biphasic (*n* = 72)	25	34.7%		26	36.1%		15	20.8%	
2005 Guideline based									
Monophasic (*n* = 53)	14	26.4%	0.84	17	32.1%	0.64	10	18.9%	0.31
Biphasic (*n* = 231)	58	25.1%		82	35.5%		59	25.5%	

CPR, cardiopulmonary resuscitation; ROSC, return of spontaneous circulation.

Study limitations

Several limitations of this study should be considered. First, because of the relatively small sample size (n = 430), the present study may have been too underpowered to detect true differences in outcomes between the groups. For example, to detect the true difference in 1-month survival with minimal neurologic impairment (17.5% versus 24.4%), the necessary sample size was estimated to be 1,321 on the basis of a two-sided α value of 0.05 and a β error of 0.20 [35].

Second, the inherent bias in an observational study is a potential limitation. For example, the monophasic EMS users were possibly less well supported by public funds, and received a lower frequency of training and retraining. If true, this could have influenced the results.

Third, data on whether VF was terminated by defibrillation were not collected, so our study could not directly compare the probability of terminating VF after defibrillation. However, 1-month survival with minimal neurologic impairment is considered to be a better outcome measure than the probability of terminating VF.

Fourth, the neurologic outcome in the database was not defined by pediatric Cerebral Performance Category [36].

However, despite these limitations, we believe that our study is valid, given the use of uniform data collection

Table 3 Odds ratios of outcomes for biphasic vs. monophasic defibrillators in the logistic regression models

	ROSC before hospital arrival			Survival at 1 month			Survival at 1 month with minimal neurologic impairment		
	OR	(95% CI)	*P*	OR	(95% CI)	*P*	OR	(95% CI)	*P*
Age (1-year increase)	1.13	1.06 to 1.21	0.009	1.05	0.98 to 1.11	0.17	1.11	1.03 to 1.20	0.01
Sex									
Boys	Ref.			Ref.			Ref.		
Girls	1.19	0.71 to 1.98	0.51	1.58	1.05 to 2.36	0.03	1.50	0.89 to 2.51	0.13
Witness status									
Witness	Ref.			Ref.			Ref.		
No witness	0.75	0.48 to to 1.17	0.20	0.55	0.34 to 0.89	0.02	0.40	0.23 to 0.71	0.002
Type of bystander-initiated CPR									
No CPR	Ref.			Ref.			Ref.		
Compression-only CPR	0.81	0.50 to 1.31	0.40	0.85	0.50 to 1.45	0.56	1.32	0.72 to 2.41	0.37
Conventional CPR	1.34	0.87 to 2.06	0.18	1.38	0.91 to 2.08	0.13	1.54	0.87 to 2.73	0.14
Call to CPR by EMS									
0 to 6 minutes	Ref.			Ref.			Ref.		
7 to 12 minutes	0.68	0.44 to 1.06	0.09	1.00	0.65 to 1.53	0.99	0.67	0.36 to 1.27	0.22
13 to 18 minutes	0.46	0.21 to 1.01	0.05	0.26	0.12 to 0.58	0.001 >	0.35	0.12 to 0.97	0.04
Cause of arrest									
Cardiac origin	Ref.			Ref.			Ref.		
Noncardiac origin	0.48	0.28 to 0.83	0.01	0.51	0.31 to 0.85	0.01	0.23	0.11 to 0.49	0.001 >
Type of guideline-based CPR performed									
2000 Guideline based	Ref.			Ref.			Ref.		
2005 Guideline based	0.58	0.17 to 1.95	0.37	1.09	0.41 to 2.89	0.86	1.24	0.34 to 4.47	0.74
Year									
2005	Ref.			Ref.			Ref.		
2006	1.24	0.71 to 2.16	0.45	1.09	0.59 to 2.02	0.78	0.90	0.38 to 2.12	0.81
2007	1.65	0.36 to 7.45	0.52	0.84	0.30 to 2.34	0.74	1.13	0.27 to 4.75	0.86
2008	1.63	0.42 to 6.31	0.48	1.08	0.36 to 3.22	0.89	1.42	0.34 to 5.85	0.63
2009	1.98	0.55 to 7.12	0.29	0.92	0.29 to 2.86	0.88	1.32	0.33 to 5.22	0.70
Defibrillator									
Monophasic	Ref.			Ref.			Ref.		
Biphasic	1.46	0.81 to 2.63	0.20	1.38	0.87 to 2.18	0.17	1.57	0.87 to 2.83	0.14

All models included age, sex, whether the collapse was witnessed by a bystander, the type of bystander CPR performed (no bystander CPR, compression-only CPR, or conventional CPR), time from emergency call to CPR by the EMS (early response, moderate response, or late response), cause of arrest, the type of guideline-based CPR performed (2000 AHA Guideline based or 2005 AHA Guideline based), calendar year and the type of defibrillator (monophasic or biphasic). Regression analyses did not include patients with missing data. OR, odds ratio; CI, confidence interval.

and consistent definitions based on the Utstein guidelines [24,25] and the relatively large sample size as an observational study of pediatric OHCA in a nationwide population-based setting.

Conclusions

Our nationwide population-based observational study did not confirm an advantage of biphasic defibrillator over a monophasic defibrillator for 1-month survival with minimal neurologic impairment of pediatric OHCA patients.

Key messages

- No significant differences in neurologic outcomes was found between the pediatric OHCA patients who were shocked with a biphasic defibrillator and those who were shocked with a monophasic defibrillator.
- Biphasic defibrillators may reduce the physical burden on EMS personnel because of their greater portability. With respect to effectiveness, however, the present study showed no significant advantage of biphasic over monophasic defibrillators on meaningful clinical outcomes for pediatric patients.

Abbreviations

AED: automated external defibrillator; CPC: cerebral performance category; CPR: cardiopulmonary resuscitation; EMS: emergency medical service; FDMA: Fire and Disaster Management Agency of Japan; GEE: generalized estimation equation; OHCA: out-of-hospital cardiac arrest; OR: odds ratio; ROSC: return of spontaneous circulation; VF: ventricular fibrillation.

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Authors' contributions

ST and TI designed the study. TO and ST conducted data cleaning. HY, HH, and TH provided statistical advice on the study design and analyzed the data. ST drafted the manuscript, and ST, HY, TH, HY, TO, MA, and SK contributed substantially to its revision. ST takes responsibility for the article as a whole. All authors approved the manuscript before submission.

Competing interests

The authors declare that they have no competing interests.

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Elderly out-of-hospital cardiac arrest has worse outcomes with a family bystander than a non-family bystander

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Abstract

Background: A growing elderly population along with advances in equipment and approaches for pre-hospital resuscitation necessitates up-to-date information when developing policies to improve elderly out-of-hospital cardiac arrest (OHCA) outcomes. We examined the effects of bystander type (family or non-family) intervention on 1-month outcomes of witnessed elderly OHCA patients.

Methods: Data from a total of 85,588 witnessed OHCA events in patients aged ≥65 years, which occurred from 2005 to 2008, were obtained from a nationwide population-based database. Patients were stratified into three age categories (65–74, 75–84, ≥85 years), and the effects of bystander type (family or non-family) on initial cardiac rhythm, rate of bystander cardiopulmonary resuscitation (CPR), and 1-month outcomes were assessed.

Results: The overall survival rate was 6.9% (65–74 years: 9.8%, 75–84 years: 6.9%, ≥85 years: 4.6%). Initial VF/VT was recorded in 11.1% of cases with a family bystander and 12.9% of cases with a non-family bystander. The rate of bystander CPR was constant across the age categories in patients with a family bystander and increased with advancing age categories in patients with a non-family bystander. Patients having a non-family bystander were associated with significantly higher 1-month rates of survival (OR: 1.26; 95% CI: 1.19–1.33) and favorable neurological status (OR: 1.47; 95% CI: 1.34–1.60).

Conclusions: Elderly patient OHCA events witnessed by a family bystander were associated with worse 1-month outcomes than those witnessed by a non-family bystander. Healthcare providers should consider targeting potential family bystanders for CPR education to increase the rate and quality of bystander CPR.

Keywords: Out-of-hospital cardiac arrest, Elderly, Bystander cardiopulmonary resuscitation, Bystander type, Survival rate

Background

Out-of-hospital cardiac arrest (OHCA) is one of the most common causes of death in middle and old age, and it is an important public health concern. OHCA is associated with a high mortality rate [1], even when patients receive appropriate treatment in accordance with the links in the "chain of survival" concept, consisting of rapid access to emergency medical services (EMS), cardiopulmonary resuscitation (CPR), defibrillation including public-access automated external defibrillation (PAD), and advanced cardiovascular life support (ACLS) [2-6].

Early bystander CPR can be critical in improving the survival rate and neurological outcome after OHCA [2,3,5-7]. The outcome of cardiopulmonary arrest, as measured by survival rate and cerebral performance category (CPC), is worse when the quality of CPR is suboptimal in some way, such as insufficient depth of chest compression or an excessive number of ventilations. Poor OHCA outcomes may therefore be partly due to delay in starting CPR or suboptimal CPR quality [7]. A better understanding of the reasons why bystander CPR is not performed in some elderly OHCA patients may

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assist in finding ways to increase the rate of bystander CPR and thereby improve the outcome.

A patient receiving high-quality, early CPR has a better chance of survival with intact neurological status, indicating that the quality and timing of bystander CPR can have a significant impact on outcome. The quality and the timing of bystander CPR might be affected by bystander characteristics such as age, gender, and bystander type (family or non-family). Approximately 70% of OHCA events occur at home [8-10]. In elderly OHCA patients, a family member such the patient's spouse may be the bystander performing CPR, and the spouse may be an elderly person with physical limitations, which may affect the quality of CPR performed and the speed of calling the EMS or starting bystander CPR.

In this study, we describe the characteristics and outcomes of elderly OHCA cases using a nationwide, population-based database and evaluate the impact of bystander type (family or non-family) on outcomes. The age of the OHCA patient may affect the response, such as affecting ACLS administration by EMS in the ambulance and treatment by physicians after arrival at the hospital. This study can provide important information to support developing policies to increase the rate of bystander CPR and improve outcomes when resuscitating elderly OHCA patients.

Methods

Study design and data sources

This is an observational study using a database of all recorded OHCA patients transported to the hospital in Japan from January 2005 to December 2008. The Fire and Disaster Management Agency (FDMA) administers the EMS in Japan and provides the only ambulance service, which is available to all citizens. Japan has 807 local fire departments with dispatch centers, and all OHCA patients transported to the hospital by EMS were recorded in a national OHCA database by the FDMA. EMS personnel gathered the data, and the database was maintained by the local fire departments. All data were verified and anonymized at the local fire department; they were then transferred to and stored in the national-level OHCA database developed by the FDMA for public use. With permission from the FDMA, we extracted data from the national database to perform a nationwide, population-based study using all recorded cases of OHCA in Japan over a 4-year period. The Ethics Committee of Nara Medical University approved the study design (authorization code: 260).

Patient details and outcomes

The OHCA data entry form was largely based on the Utstein form [11] and was extended to include details of all OHCA cases, including those due to non-cardiac causes such as stroke, asphyxia, and trauma, as well as unwitnessed cases [12-15]. Patient data collected included age, sex, initial cardiac rhythm, whether the OHCA was witnessed by a bystander or not, whether bystander CPR was performed or not, bystander category (family, layperson other than family, or EMS personnel), the time of collapse, call to EMS, start of bystander CPR, whether or not EMS attempted defibrillation, and the outcome in terms of survival and CPC at 1 month after OHCA. Nursing home staff members were classified as laypersons other than family in this study. Initial cardiac rhythm was categorized by EMS as ventricular fibrillation (VF), pulseless ventricular tachycardia (VT), pulseless electrical activity, or asystole.

EMS personnel collected data regarding survival and neurological status at 1 month from the hospitals that had received the patients, in cooperation with the physicians who had treated the patients. Neurological status at 1 month was determined by assessing CPC by follow-up interview.

Subjects

During the 4-year study period, data from 431,950 OHCA patients were included in the national database. To determine differences due to bystander type in witnessed elderly OHCAs, we selected witnessed OHCA patients aged ≥65 years with a time interval from the call to EMS to EMS arrival at the scene of ≤60 min and excluded cases with an EMS personnel bystander. We stratified cases into three age categories as follows: 65–74 years, 75–84 years, and ≥85 years. In total, data from 85,588 cases of witnessed elderly OHCA events were analyzed.

Data analysis

To assess whether bystander type affected outcomes in witnessed elderly OHCAs, we divided cases into two groups based on bystander type (family or non-family) and analyzed whether bystander CPR was performed, whether there was initial VF/VT, and whether PAD was performed. We also determined the time intervals (minutes) from the call to EMS to EMS arrival at the scene, from collapse to the start of bystander CPR, and from collapse to the call to EMS. Analyses of the time intervals from collapse to the start of bystander CPR and from collapse to the call to EMS were limited to those with an interval of ≤60 min. We measured outcomes in terms of 1-month survival and favorable neurological status at 1 month in the three age categories. A favorable neurological status was defined as CPC category 1 (good cerebral performance) or 2 (moderate cerebral disability) [16].

Data were examined by bystander type and age category. Statistical analyses were conducted to examine differences between groups in terms of the factors mentioned above using a *t*-test or chi-square test as appropriate. Logistic regression analyses were performed to identify the effects of bystander type on 1-month outcomes (survival and favorable neurological status), using family bystander as a reference. Potential confounding factors included age category, sex, bystander type, bystander CPR, attempted defibrillation by EMS, use of PAD, and interval from the call to EMS to EMS arrival at the scene. In this analysis, bystander CPR included chest compression only, mouth-to-mouth ventilation only, and chest compression with mouth-to-mouth ventilation (conventional CPR).

Results

Males accounted for 56.6% of elderly OHCA patients. The mean age of males (78.5 years) was significantly younger than that of females (83.0 years) ($P < 0.001$). The overall 1-month survival rate was 6.9% and of favorable neurological status was 2.8%. Table 1 shows the 1-month outcomes by initial cardiac rhythm, bystander CPR type, whether or not PAD was performed, age category, and bystander type. The 1-month outcomes of OHCA with chest compression only and with conventional CPR were very similar. The 1-month rates of survival and favorable neurological status decreased with increasing age categories.

Table 2 shows basic demographic characteristics by bystander type. Bystander CPR rate was 43.6% overall, 35.5% in cases with a family bystander, and 60.2% in cases with a non-family bystander. Cases with a non-family bystander had a significantly higher rate of bystander CPR, including both chest compression only (26.4% vs. 22.4% with a family bystander) and conventional CPR (32.5% vs. 11.8% with a family bystander). The rates of PAD and initial VF/VT were higher among patients with a non-family bystander than those with a family bystander. The 1-month outcomes were also significantly better in the non-family bystander group. The intervals from collapse to start of bystander CPR and from collapse to the call to EMS were significantly shorter among cases with a non-family bystander than those with a family bystander.

Figure 1 shows the rates of bystander CPR and 1-month outcomes by bystander type and age category. Interestingly, the rate of bystander CPR was constant among age categories in cases with a family bystander (white column in Figure 1), but increased with advancing age categories among patients with a non-family

Table 1 Overall 1-month outcomes for witnessed elderly OHCA patients

	n	1-month outcomes			
		Survival		Favorable CPC	
		n	%	*n*	%
Initial cardiac rhythm					
VF/VT	9,977	1,972	19.8	1,066	10.7
PEA	29,652	1,855	6.3	493	1.7
Asystole	43,319	1,177	2.7	186	0.4
Bystander CPR					
Non	48,263	2,981	6.2	1,024	2.1
Chest compression only	20,283	1,569	7.7	746	3.7
M-to-M ventilation only	1,160	84	7.2	38	3.3
Conventional CPR	15,880	1,291	8.1	594	3.8
PAD					
Not performed	82,614	5,639	6.8	2,245	2.7
Performed	480	118	24.6	94	19.6
Age category					
65–74 years	23,338	2,291	9.8	1,117	4.8
75–84 years	33,832	2,327	6.9	845	2.5
85 years and over	28,416	1,307	4.6	440	1.6
Bystander type					
Family	57,563	3,548	6.2	1,292	2.2
Non-family	28,023	2,377	8.5	1,110	4.0

OHCA: out-of-hospital cardiac arrest, CPC: cerebral performance categories, CPR: cardiopulmonary resuscitation, VF: ventricular fibrillation, VT: pulseless ventricular tachycardia, PEA: pulseless electrical activity, M-to-M: mouth-to-mouth, PAD: public access automated external defibrillator.

Table 2 Demographic characteristics and outcomes by bystander type

	Bystander type				*P* value
	Family (*n* = 57,565)		Non-family (*n* = 28,023)		
	n	%	*n*	%	
Age category					
65–74 years	15,854	27.5	7,485	26.7%	0.011
75–84 years	24,032	41.7	9,800	35.0%	<0.001
85 years and over	17,679	30.7	10,738	38.3%	<0.001
Initial cardiac rhythm					
VF/VT	6,361	11.1	3,616	12.9%	<0.001
PAD performed	72	0.1	408	1.5%	<0.001
Bystander performed CPR					
Non	37,112	64.5	11,152	39.8%	<0.001
Chest compression only	12,881	22.4	7,402	26.4%	<0.001
M-to-M ventilation only	792	1.4	368	1.3%	0.468
Conventional CPR	6,780	11.8	9,101	32.5%	<0.001
1-Month outcomes					
Survival	3,548	6.2	2,377	8.5%	<0.001
Favorable CPC	1,292	2.2	1,110	4.0%	<0.001
Interval	Min	SD	Min	SD	
Call–arrival of EMS	7.5	3.9	7.1	3.7	<0.001
Collapse–bystander CPR	4.8	6.9	2.0	4.2	<0.001
Collapse–call	5.6	7.8	4.9	6.6	<0.001

EMS: emergency medical service; other abbreviations as for Table 1.

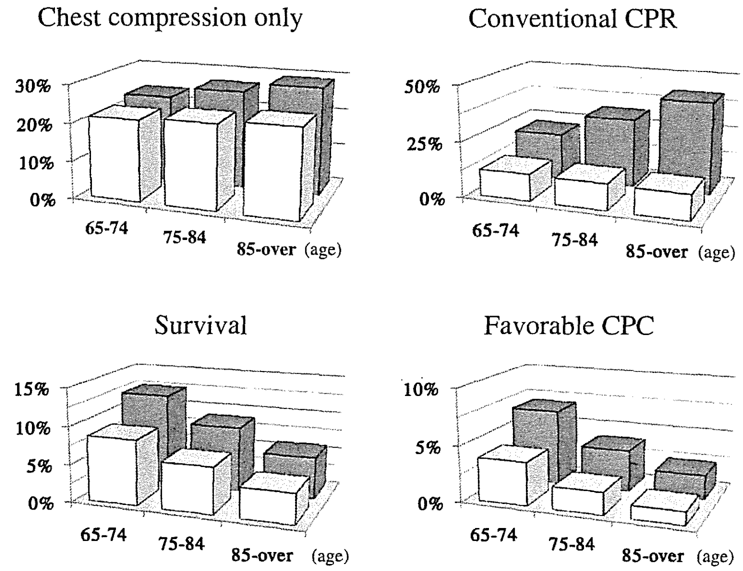

Figure 1 Rates of bystander cardiopulmonary resuscitation (CPR) and 1-month outcomes by bystander type and age category. White columns indicate cases with a family bystander, and gray columns indicate cases with a non-family bystander. Numbers on the horizontal axes indicate age categories.

bystander (gray column). The rate of conventional CPR was markedly higher among patients with a non-family bystander.

Table 3 shows the results of logistic regression analyses for outcomes at 1 month. Cases with a non-family bystander had significantly higher rates of 1-month survival (OR: 1.26; 95% CI: 1.19–1.33) and favorable neurological status (OR: 1.47; 95% CI: 1.34–1.60). CPR consisting of either chest compression only or conventional CPR was associated with higher rates of 1-month survival and favorable neurological status. PAD was also associated with a significantly higher 1-month rate of survival and of favorable neurological status.

Discussion

In this study we assessed the effect of bystander type on 1-month outcomes (survival and favorable neurological status) among elderly OHCA patients. Our results revealed that OHCA patients with a non-family bystander were more likely to survive compared than those with a family bystander. The rate of bystander CPR increased with advancing age categories among patients with a non-family bystander, but seemed to be the same across all age categories in cases with a family bystander. Bystander chest compression only and conventional CPR had significant impacts and similar 1-month outcomes, and PAD also had a significant impact on 1-month outcomes.

Many previous reports have described outcomes among elderly patients with cardiopulmonary arrest [17-21]. However, most studies were published in the 1980s and 1990s and had relatively small data sets. Over the past few decades, countries with increased life expectancies are having larger numbers of elderly people. The resuscitation techniques and equipment used by prehospital EMS and hospital physicians are advancing, and it is therefore important for these care providers to have up-to-date information about the characteristics and outcomes of OHCA cases among the elderly. Since some characteristics of OHCA patients such as their age may affect the decisions made by EMS regarding the provision of ACLS and the treatment decisions made by physicians after hospital arrival, the present study provides important information to support correct decision-making by EMS and physicians. Up-to-date information is an important consideration when developing effective policies to increase bystander CPR rates and improve outcomes.

Previous studies have reported that approximately half of OHCA patients did not receive bystander CPR before EMS arrival at the scene [9,22]. Hauff *et al.* [22] reported that the physical limitations of bystanders were the major reason for lack of bystander CPR, even when a dispatcher provided CPR instructions via telephone. Lack of bystander CPR often appeared to be due to a combination of the bystander's physical limitations and the position of the OHCA patient. Patient emesis and bystander concerns about disease transmission also appeared to impede bystander CPR.

Recently, several papers have reported on the outcomes of elderly OHCA patients [23,24]. Deasy *et al.* [23] studied 30,006 OHCA patients attended by paramedics, of whom

Table 3 Results of logistic regression analyses for 1-month outcomes

	1-Month outcomes					
	Survival			Favorable CPC		
	OR	95% CI	*P* value	OR	95% CI	*P* value
Bystander type						
Family	Reference			Reference		
Non-family	1.26	1.19-1.33	<0.001	1.47	1.34-1.60	<0.001
Sex						
Male	Reference			Reference		
Female	0.95	0.89-1.01	0.076	0.96	0.88-1.05	0.373
Age category						
65–74 years	Reference			Reference		
75–84 years	0.79	0.75-0.85	<0.001	0.63	0.58-0.70	<0.001
85 years and over	0.54	0.50-0.58	<0.001	0.40	0.36-0.46	<0.001
Bystander CPR						
Non	Reference			Reference		
Chest compression only	1.34	1.25-1.43	<0.001	1.84	1.67-2.04	<0.001
M-to-M ventilation only	1.21	0.97-1.53	0.098	1.62	1.16-2.27	0.005
Conventional CPR	1.39	1.29-1.50	<0.001	1.78	1.59-2.00	<0.001
PAD						
Not performed	Reference			Reference		
Performed	2.87	2.29-3.60	<0.001	4.55	3.53-5.86	<0.001
Defibrillation by EMS						
Not performed	Reference			Reference		
Performed	2.91	2.74-3.09	<0.001	3.88	3.55-4.23	<0.001
Call–arrival of EMS interval (1-min increase)	0.89	0.88-0.90	<0.001	0.86	0.85-0.88	<0.001

OR: odds ratio, CI: confidence interval; other abbreviations as for Table 2.

32% were aged 65–79 years, 21% were 80–89 years, 5% were 90–99 years, and 0.1% were ≥100 years. The rate of attempted resuscitation decreased with advancing age, with overall survival rates to hospital discharge of patients aged 65–79 years, 80–89 years, and 90–99 years of 8%, 4%, and 2%, respectively. They also assessed information about the location of collapse and reported that the proportion of OHCA events occurring at nursing homes increased with advancing age. By comparison, the present study indicated a slightly higher survival rate, with an overall bystander CPR rate of <50% and an increasing bystander CPR rate with advancing age categories among non-family-witnessed OHCA patients. Surprisingly, the rate of bystander CPR was only 35.5% among cases with a family bystander, indicating that OHCA patients with family bystanders were less likely to receive bystander CPR than those with a non-family bystander, especially in the older age categories.

The relatively good 1-month outcomes in the present study could be explained by the selection of only witnessed OHCA cases. Most OHCA cases with a family bystander may occur at the patient's home, whereas patients in the more advanced age groups may be more likely to be in a nursing home where OHCA could be witnessed by nursing home staff, which would increase the proportions of cases with a non-family bystander. Nursing home staff classified as non-family bystanders may have basic life support (BLS) training and may be accustomed to dealing with OHCA, resulting in a higher bystander CPR rate and earlier performance of bystander CPR, which could achieve a higher initial VF/VT rate and better outcomes. It is known that immediate bystander CPR maintains VF longer in OHCA patients, which is a strong predictor of survival [25]. Our results also indicate a shorter interval from the call to EMS to EMS arrival at the scene and from collapse to the call to EMS in the non-family bystander group compared to the family bystander group, which could also affect the rate of initial VF/VT and 1-month outcomes. As the difference in the interval from collapse to bystander CPR was more marked than the differences in intervals from the call to EMS to EMS arrival or from collapse to the call to EMS between the family and non-family groups, the interval from collapse to bystander CPR seemed to have the most impact on initial VF/VT rates and 1-month outcomes. Family bystanders may be elderly people such as the spouse of the OHCA patient and may have physical limitations that make it difficult to perform bystander CPR compared to a younger non-family bystander such as a colleague, passer-by, or facility staff member.

It has been reported that patients with known heart disease received bystander CPR in only 16% of cases [26] and that older people are not very willing to learn CPR even when they have a family member with known heart disease [27]. Generally, a large proportion of OHCA events occurs at the patient's home, and these have a poor prognosis [9,28]. Herlitz *et al.* [9] reported the characteristics and outcomes of OHCA patients who collapsed at home compared with those who collapsed in other places. Those who collapsed at home were witnessed less often, received bystander CPR less often, were found to have VF less often, and had a longer interval between collapse and call to EMS, start of CPR, and first defibrillation. Furthermore, conventional bystander CPR (chest compression with ventilation) was performed less frequently when the collapse was in the patient's home. While they concluded that OHCA occurring at home was a strong independent predictor of adverse outcome, they did not give reasons for this. Even though they identified the bystander as layperson, ambulance personnel, medical personnel, or police, they did not distinguish if a layperson was a family or non-family bystander. Jackson *et al.* [8] reported that OHCA occurring outside the home was associated with improved outcomes. Patients with witnessed OHCA outside the home were more likely to receive bystander CPR and to survive. Our results showed a lower bystander CPR rate and a higher rate of adverse outcomes in cases with a family bystander compared to a non-family bystander.

It has been suggested that simplifying the CPR technique to include chest compression only may increase the rate of bystander CPR in elderly OHCA patients when a dispatcher provides telephone CPR instruction [29]. In the present study, both bystander chest compression only and bystander conventional CPR were associated with improved outcomes, with both having a similar level of impact on the rates of 1-month survival and favorable neurological status. The simpler procedure of chest compression only might therefore be appropriate for dispatcher-assisted telephone CPR for elderly OHCA patients when the bystander is an elderly person with physical limitations or emotional distress.

Limitations

Several limitations of our study should be acknowledged. First, the database did not include detailed information about bystanders such as age and gender, the quality of bystander CPR, and whether the bystander had BLS or ACLS training. Therefore, we could not assess the influence of these factors on outcome. Second, PAD was implemented because early defibrillation using PAD has a significant impact on survival and favorable neurological outcome. Therefore, the accessibility of PAD in OHCA patients with family versus non-family bystanders should be evaluated. However, we could not assess the effects of OHCA location because the database did not include this information. The type of family bystander may be different depending on whether the OHCA occurs at home or elsewhere. Third, we did not have data regarding the medical histories or comorbidities of OHCA patients. Fourth, there is a possibility that family members may have been aware of patient preferences not to attempt resuscitation in the event of OHCA. However, the database did not include detailed information about this point.

Conclusion

Elderly OHCA patients had worse 1-month outcomes when witnessed by a family bystander compared with a non-family bystander. Healthcare providers should consider targeting potential bystanders for CPR education to increase the rate and quality of bystander CPR and to improve the rates of survival and favorable neurological outcome among elderly OHCA patients. In elderly OHCA patients, there may be a need to change scripted instructions from the emergency telephone service to direct the bystander to start chest compressions immediately without ventilation.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

The contribution of each author was as follows: MA and TI designed this study and conducted data analysis. TO conducted data cleaning. TO, SK, ST, HH, and HY jointly interpreted the results. All authors read and approved the final manuscript.

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