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Public-Access Defibrillation and Survival of Out-of-Hospital Cardiac Arrest in Public vs. Residential Locations in Japan

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Background: This study assessed whether the dissemination of public-access defibrillation (PAD) at the population level is associated with an increase in neurologically favorable outcomes among patients experiencing ventricular fibrillation (VF) in public vs. residential locations in Japan.

Methods and Results: We enrolled adult patients with bystander-witnessed VF between 2013 and 2015. The primary outcome measure was 1-month neurologically favorable outcome defined by cerebral performance category 1 or 2. The number of survivors with neurologically favorable outcome attributed to PAD after VF arrest was estimated by location of arrest. A total of 16,252 adult patients with bystander-witnessed VF arrest were analyzed. In public locations, 29.3% (2,334/7,973) of out-of-hospital cardiac arrest (OHCA) patients received PAD, whereas 1.1% (89/8,279) of OHCA patients received PAD in residential locations. OHCA patients with PAD had significantly better neurological outcomes compared with those without PAD in public locations (51.8% vs. 25.5%, P<0.001), whereas there were no significant differences in neurologically favorable outcome between patients with or without PAD in residential locations (22.5% vs. 18.6%, P=0.357). The total number of patients with neurologically favorable outcomes attributed to PAD was estimated at 615 in public locations, but only 3 in residential locations.

Conclusions: In Japan, when compared with residential locations, PAD works more successfully in public locations for adults with bystander-witnessed VF arrest.

Key Words: Automated external defibrillator; Cardiopulmonary resuscitation; Out-of-hospital cardiac arrest; Public-access defibrillation; Ventricular fibrillation

Because of reinforcement of the chain of survival,[1–3] as well as revisions to cardiopulmonary resuscitation (CPR) guidelines,[4,5] survival from out-of-hospital cardiac arrest (OHCA) in industrialized countries has been increasing.[2,3] However, the proportion of survival still remains low.

Earlier defibrillation plays a key role in improving survival from out-of-hospital ventricular fibrillation (VF) arrest.[4,5] Many reports have demonstrated that public-access defibrillation (PAD) by laypersons can contribute to improved patient outcomes after OHCA and the introduction of public-access automated external defibrillators (AEDs) has been widely welcomed in industrialized countries.[5,6] However, the effectiveness of PAD in relation to the location of an OHCA has not been sufficiently investigated at the population level. In Japan, public-access AED use for the general public was legally permitted in July 2004.[7] The Fire and Disaster Management Agency (FDMA) has merged the All-Japan Utstein Registry,[8,9] a prospective, nationwide, population-based OHCA registry, with location data from ambulance records since 2013[7] and has since captured data from over 15,000 events of bystander-witnessed VF arrest between 2013 and 2015. The aim of our study was to assess whether nationwide dissemination of PAD at the population level has been associated with an increase in survivors with a neurologically favorable outcome after VF arrest in a public vs. residential location.

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Methods

Study Design, Population, and Settings

Details of the All-Japan Utstein Registry of the FDMA have been reported previously.[8] Briefly, the registry is a prospective population-based OHCA registry based on the international Utstein-style[10,11] that covers a population of approximately 127 million people in Japan within a geographic area of approximately 378,000 km^2. Cardiac arrest was defined as cessation of cardiac mechanical activity and confirmed by the absence of circulation by attending emergency medical service (EMS) personnel. All OHCA survivors were followed up for up to 1 month after the event by the relevant EMS providers in order to assess patient outcomes. The data capture forms were filled by EMS personnel, in cooperation with the physician(s) in charge of the patient. The data were transferred and integrated into the registration system of the FDMA database. The data were then checked at data terminals and confirmed by the FDMA. If incomplete data forms were found, the EMS personnel in charge were asked to complete them. In addition to the previous data items obtained using the international Utstein-style,[10,11] the FDMA started merging the All-Japan Utstein Registry with detailed information on the location of OHCA occurrence from ambulance records since January 2013.[7] According to the current international Utstein standardized template, locations of arrest were classified as home/residence, industrial/workplace, sports/recreation event, street/highway, public building, assisted living/nursing home, educational institution, other, and unknown/not recorded.[12] The study protocol was approved by the Ethics Committee of Kyoto University and Osaka University. Personal identifiers were removed from the FDMA database. The requirement for informed consent of patients was waived.

EMS System in Japan

EMS in Japan is provided by regional governments, and, as previously described,[8] there were 750 fire departments with dispatch centers throughout Japan in 2015.[7] Emergency life-saving technicians (ELSTs), who are highly-trained emergency care providers, are allowed to insert an intravenous line, an airway adjunct, and to use semi-AEDs for OHCA patients. Specially trained ELSTs are further allowed to intubate and administer adrenaline. Each ambulance has a crew of 3 emergency providers, including at least 1 ELST. Treatment for cardiac arrest was conducted based on the Japanese CPR guidelines.[13] Generally, prehospital termination of resuscitation by EMS personnel is not allowed as do-not-resuscitate orders (or living wills) are essentially not permitted in Japan. Therefore, excluding cases of decapitation, incineration, decomposition, rigor mortis, or dependent cyanosis, most OHCA patients treated by EMS personnel were transported to a hospital, and the relevant data were recorded in the registry.

Study Subjects

This study included adult OHCA patients aged ≥18 years old, who had VF rhythm, whose OHCA was witnessed by bystanders, had had CPR attempted by bystanders or EMS personnel, and were subsequently transported to a medical institution by the EMS.[12,14] The etiology of cardiac arrest was presumed to be medical in origin unless it was caused by trauma, drug overdose, drowning, electrocution, or asphyxia.[12] When bystanders provided defibrillation using a public-access AED, the victim's first documented rhythm was regarded as VF. We excluded OHCA patients with unknown age, unknown witness status, unknown first documented rhythm, unknown origin, unknown outcome, unknown location of arrest, and those occurring in healthcare facilities (i.e., assisted living/nursing home).

Data Collection and Quality Control

We obtained the following data from the All-Japan Utstein Registry as well as ambulance records between January 1, 2013 and December 31, 2015:[7] location of arrest, origin of arrest, age, sex, witness of cardiac arrest, first documented rhythm, dispatcher instruction of CPR, initiation of PAD, initiation of bystander CPR, time course of resuscitation (i.e., time of collapse, contact with patient by EMS, initiation of PAD, initiation of AED defibrillation by EMS, and hospital arrival), and outcomes after OHCA. The times of collapse and initiation of PAD were obtained by EMS interview with the bystander or from the public-access AED records before leaving the scene. In ambulance records in Japan, public location is defined as an area such as public-access point (e.g., healthcare facility, hotel, market, and restaurant) or street/highway, and residential location consists of living room, bath room, entrance/corridor, toilet, kitchen, and other.[7]

Dissemination of Public-Access AED in Japan

In Japan, the use of AED by bystanders for OHCA patients has been legal since July 2004.[7] The cumulative sales of public-access AEDs rapidly increased thereafter, and had reached 602,382 in 2015 (excluding those used in medical facilities and EMS institutions).[15] Public-access AEDs have been deployed mainly in public spaces such as schools, nursing facilities, sports facilities, cultural facilities, workplaces, and transportation facilities. This has been driven by both private and public initiatives. CPR training programs have been conducted primarily by local fire departments based on the Japanese CPR guidelines.[13] The number of people in the Japanese general population who had received any CPR training increased to 4,402,343 in 2015.[16]

Endpoints

The primary endpoint of this study was 1-month survival with neurologically favorable outcome. The 1-month neurological status was scored by the physician in charge, using the Glasgow-Pittsburgh cerebral performance category (CPC) scale: category 1, good performance; category 2, moderate disability; category 3, severe cerebral disability; category 4, coma/vegetative state; and category 5, death/brain death. A 1-month survival with favorable neurological outcome was defined as CPC 1 or 2.[10,11] The secondary endpoints were prehospital return of spontaneous circulation and 1-month survival after OHCA.

Statistical Analysis

In this study, all analyses were performed separately by location of cardiac arrest (i.e., "public location" and "residential location"), based on methods used in previous studies.[7,17,18] In this study, we defined a "public location" as either industrial/workplace, sports/recreation event, street/highway, public building, educational institution, and other public places; we defined a "residential location" as home/residence as defined in the Utstein template.[12] Patients' characteristics and outcomes with or without PAD were assessed using t-test for numeric variables and chi-square test for

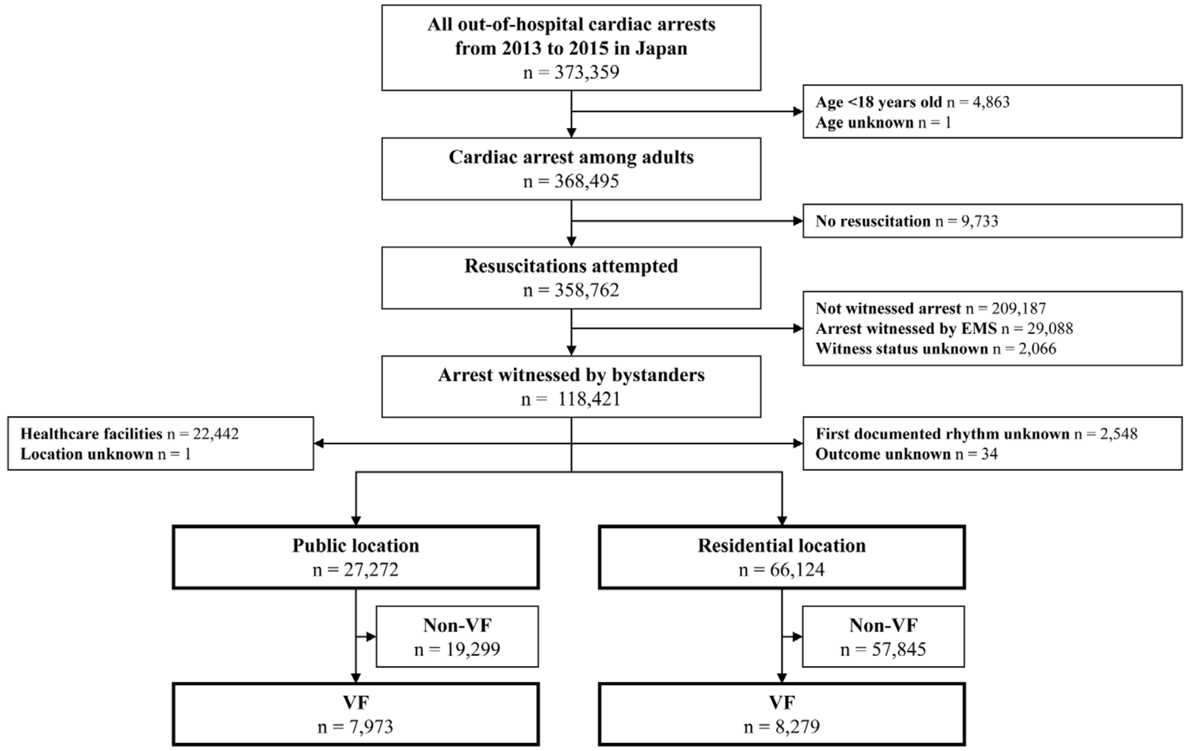

Figure 1. Study flowchart of patients with out-of-hospital cardiac arrest in Japan between 2013 and 2015. EMS, emergency medical service; VF, ventricular fibrillation.

categorical variables. The yearly trends in the proportion of patients receiving PAD and the proportion of patients having 1-month survival with neurologically favorable outcome after OHCA during the study period were assessed using the Mantel-Haenszel chi-square test of linear association. In addition, to assess the effect of dissemination of PAD for VF arrest at the population level, the number of survivors with neurologically favorable outcome attributed to PAD was estimated annually as follows: the number of VF patients receiving PAD×(the proportion of patients with neurologically favorable outcome among VF patients receiving PAD−the proportion among those without PAD). These trends were also tested with linear regression models. All tests were 2-tailed, and P<0.05 was considered statistically significant. Statistical analyses were conducted using SPSS, version 25.0 J.

Results

Figure 1 shows the flowchart for selection of eligible OHCA patients. During the study period, a total of 373,359 OHCA cases were registered in the All-Japan Utstein Registry. Of these, 16,252 adult patients with bystander-witnessed VF arrest were analyzed (7,973 in public locations, 8,279 in residential locations). Among 7,973 VF arrests in public locations, 2,200 (27.6%) occurred in public buildings, 1,651 (20.7%) on a street/highway, 1,209 (15.2%) at industrial/workplaces, 1,067 (13.4%) at a sports/recreation event, 178 (2.2%) in educational institutions, and 1,668 (20.9%) in other public places.

Table 1 shows the characteristics of eligible patients with or without PAD according to their location of arrest. Overall, the proportion of OHCA patients receiving PAD was 14.9% (2,423/16,252). In public locations, the proportion of patients receiving PAD was 29.3% (2,334/7,973); in residential locations this proportion was 1.1% (89/8,279). OHCA patients with PAD were significantly more likely to receive bystander CPR than those without PAD, in both locations (99.5% of patients with PAD vs. 56.0% of patients without PAD in public locations [P<0.001], and 98.9% of patients with PAD vs. 53.3% of patients without PAD in residential locations [P<0.001]). OHCA patients who received PAD in public locations were relatively younger than those who received PAD in residential locations (mean age: 60 years in public locations; 72 years in residential locations). The time interval from collapse to first shock by bystanders or EMS personnel was 6 min in public locations and 8 min in residential locations.

Figure 2 shows the yearly trends in the proportion of patients receiving PAD by location of arrest. During the study period, the proportion of patients who received PAD significantly increased in public locations (from 25.0% in 2013 to 32.1% in 2015, P for trend <0.001). The proportion of patients who received PAD in residential locations did not increase over the study period.

Table 2 shows the outcomes of eligible patients who did or did not receive PAD, subdivided by the location of their arrest. OHCA patients in public locations who received PAD showed significantly better outcomes after OHCA compared with those who did not receive PAD (P<0.001

Table 1. Characteristics of Bystander-Witnessed VF Arrest With or Without PAD in Public vs. Residential Locations

	Total		P value	Public location		P value	Residential location		P value
	PAD (n=2,423)	No PAD (n=13,829)		PAD (n=2,334)	No PAD (n=5,639)		PAD (n=89)	No PAD (n=8,190)	
Year, n (%)			<0.001			<0.001			0.462
2013	704 (29.1)	4,806 (34.8)		669 (28.7)	2,055 (36.4)		35 (39.3)	2,751 (33.6)	
2014	824 (34.0)	4,568 (33.0)		794 (34.0)	1,739 (30.8)		30 (33.7)	2,829 (34.5)	
2015	895 (36.9)	4,455 (32.2)		871 (37.3)	1,845 (32.7)		24 (27.0)	2,610 (31.9)	
Time of collapse, n (%)			<0.001			<0.001			0.014
0:00–5:59	60.0 (2.5)	1,971.0 (14.3)		49.0 (2.1)	354.0 (6.3)		11.0 (12.4)	1,617.0 (19.7)	
6:00–11:59	956.0 (39.5)	4,370.0 (31.6)		931.0 (39.9)	2,088.0 (37.0)		25.0 (28.1)	2,282.0 (27.9)	
12:00–17:59	1,004.0 (41.4)	3,957.0 (28.6)		972.0 (41.6)	2,112.0 (37.5)		32.0 (36.0)	1,845.0 (22.5)	
18:00–23:59	403.0 (16.6)	3,531.0 (25.5)		382.0 (16.4)	1,085.0 (19.2)		21.0 (23.6)	2,446.0 (29.9)	
Weekday, n (%)	1,700 (70.2)	9,585 (69.3)	0.402	1,633 (70.0)	3,967 (70.3)	0.733	67 (75.3)	5,618 (68.6)	0.176
Age, mean (SD)	60 (15.2)	66 (15.5)	<0.001	60 (15.0)	63 (15.3)	<0.001	72 (16.2)	67 (15.4)	0.036
Age group, n (%)			<0.001			<0.001			0.073
Adults aged 18–74 years	2,015 (83.2)	9,461 (68.4)		1,966 (84.2)	4,290 (76.1)		49 (55.1)	5,171 (63.1%)	
Elderly aged ≥75 years	408 (16.8)	4,368 (31.6)		368 (15.8)	1,349 (23.9)		40 (44.9)	3,019 (36.9%)	
Men, n (%)	2,126 (87.7)	10,963 (79.3)	<0.001	2,065 (88.5)	4,687 (83.1)	<0.001	61 (68.5)	6,276 (76.6)	0.051
Medical origin, n (%)	2,381 (98.3)	13,575 (98.2)	0.726	2,295 (98.3)	5,446 (96.6)	<0.001	86 (96.6)	8,129 (99.3)	0.005
Witnessed by family members, n (%)	243 (10.0)	8,950 (64.7)	<0.001	196 (8.4)	1,428 (25.3)	<0.001	47 (52.8)	7,522 (91.8)	<0.001
Dispatcher instruction, n (%)	1,109 (45.8)	7,435 (53.8)	<0.001	1,054 (45.2)	2,494 (44.2)	0.447	55 (61.8)	4,941 (60.3)	0.778
Bystander CPR, n (%)	2,411 (99.5)	7,522 (54.4)	<0.001	2,323 (99.5)	3,157 (56.0)	<0.001	88 (98.9)	4,365 (53.3)	<0.001
Chest compression-only CPR	1,659 (68.5)	6,652 (48.1)		1,598 (68.5)	2,736 (48.5)		61 (68.5)	3,916 (47.8)	
Conventional CPR with rescue breathing	694 (28.6)	869 (6.3)		672 (28.8)	420 (7.4)		22 (24.7)	449 (5.5)	
CPR type unknown	58 (2.4)	1 (0.0)		53 (2.3)	1 (0.0)		5 (5.6)	0 (0.0)	
No CPR	12 (0.5)	6,307 (45.6)		11 (0.5)	2,482 (44.0)		1 (1.1)	3,825 (46.7)	
Time from collapse to contact with the patient by EMS personnel, min, mean (SD)	12 (6.2)	11 (5.7)	<0.001	12 (6.1)	10 (5.8)	<0.001	14 (6.3)	11 (5.6)	<0.001
Time from collapse to first shock by bystanders or EMS personnel, min, mean (SD)	6 (4.8)	13 (6.1)	<0.001	6 (4.8)	12 (6.0)	<0.001	8 (6.0)	13 (6.2)	<0.001
Time from collapse to hospital arrival, min, mean (SD)	36 (14.2)	35 (13.4)	<0.001	36 (14.3)	33 (13.7)	<0.001	40 (13.0)	36 (13.1)	<0.001

The times from contact with the patient, first shock by bystander or EMS personnel, and hospital arrival were calculated for 16,193 (missing n=59), 15,170 (missing n=1,082), and 16,159 (missing n=93) patients, respectively. CPR, cardiopulmonary resuscitation; EMS, emergency medical service; PAD, public-access defibrillation; SD, standard deviation; VF, ventricular fibrillation.

for all outcomes). No significant differences in outcomes were identified for OHCA patients in residential locations.

Table 3 shows the trends in 1-month survival with neurologically favorable outcome during the study period. The total number of patients with a neurologically favorable outcome attributed to PAD was estimated to be 615 in public locations during the 3-year study period. In residential locations, however, we estimated that only 3 patients had favorable neurological outcomes that were associated with the administration of PAD. These numbers did not significantly increase during the 3-year period.

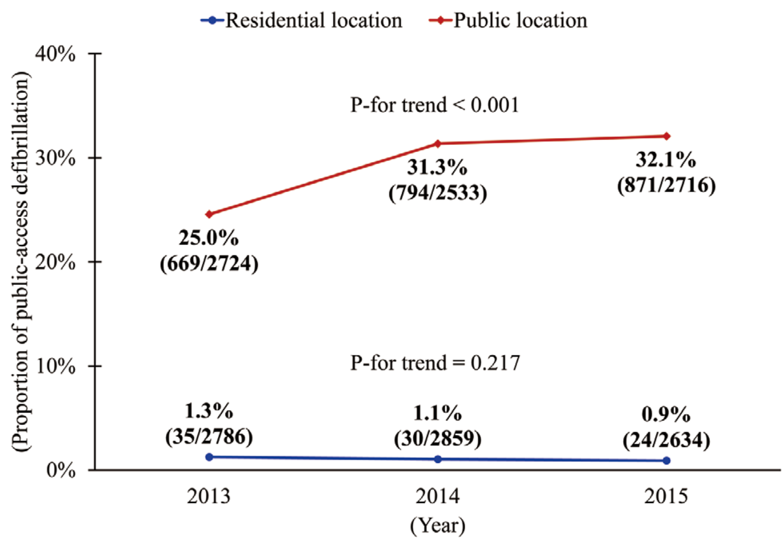

Figure 2. Trends in the proportion of patients with out-of-hospital ventricular fibrillation who received public-access defibrillation in public vs. residential locations between 2013 and 2015.

Table 2. Outcomes of Bystander-Witnessed VF Arrest With or Without PAD in Public vs. Residential Locations

	Total			Public location			Residential location		
	PAD (n=2,423)	No PAD (n=13,829)	P value	PAD (n=2,334)	No PAD (n=5,639)	P value	PAD (n=89)	No PAD (n=8,190)	P value
Outcome, n (%)									
Prehospital ROSC	1,428 (58.9)	4,629 (33.5)	<0.001	1,398 (59.9)	1,985 (35.2)	<0.001	30 (33.7)	2,644 (32.3)	0.775
One-month survival	1,399 (57.7)	4,374 (31.6)	<0.001	1,373 (58.8)	1,999 (35.4)	<0.001	26 (29.2)	2,375 (29.0)	0.965
CPC 1 or 2	1,230 (50.8)	2,965 (21.4)	<0.001	1,210 (51.8)	1,438 (25.5)	<0.001	20 (22.5)	1,527 (18.6)	0.357

CPC, cerebral performance category; ROSC, return of spontaneous resuscitation. Other abbreviations as in Table 1.

Table 3. Trends in Neurologically Favorable Outcome of Patients With Bystander-Witnessed VF Arrest With or Without PAD in Public vs. Residential Locations

	Total	2013	2014	2015	P value for trend
Public location, % (n/N)					
PAD	51.8 (1,210/2,334)	51.1 (342/669)	50.6 (402/794)	53.5 (466/871)	0.323
Non-PAD	25.5 (1,438/5,639)	22.0 (452/2,055)	27.8 (484/1,739)	27.2 (502/1,845)	<0.001
Estimated number of patients with neurologically favorable outcome attributed to PAD after VF	615	195	181	223	0.333
Residential location, % (n/N)					
PAD	22.5 (20/89)	14.3 (5/35)	26.7 (8/30)	29.2 (7/24)	0.161
Non-PAD	18.6 (1,527/8,190)	18.0 (495/2,751)	17.5 (496/2,829)	20.5 (536/2,610)	0.018
Estimated number of patients with neurologically favorable outcome attributed to PAD after VF	3	–1	3	2	0.432

Estimated number of survivors with favorable neurological outcome attributed to PAD was estimated annually as follows: number of VF patients receiving PAD×(the proportion of favorable neurological outcome among VF patients receiving PAD–the proportion among those without PAD). Abbreviations as in Table 1.

Discussion

By analysis of a nationwide, continuous, population-based OHCA registry, we were able to clearly demonstrate that the effectiveness of PAD was influenced by location: either public or residential. During the study period, the total number of survivors with a neurologically favorable outcome attributed to PAD after bystander-witnessed VF was estimated to be 615 in public locations, but only 3 in residential locations. Importantly, the large-scale dissemination of public-access AEDs, as well as a nationwide population-based registry with location data, has enabled us to evaluate the effect of PAD dissemination in real-world settings. Our study proving the effectiveness of PAD for OHCA patients in public locations reinforces the importance of deploying public-access AEDs in prehospital settings.

A previous study using the All-Japan Utstein Registry reported that the increased PAD by bystanders was associated with an increase in the number of survivors with neurologically favorable outcomes after out-of-hospital VF.[9] However, information on the location of arrest was not included in that analysis. In this study, we were able to obtain information on the location of arrest and could perform all analyses separately based on OHCA location; this has been previously performed in other studies in the USA and Denmark.[17,19] Among bystander-witnessed VF patients receiving PAD in public locations, the proportion of patients with a neurologically favorable outcome at 1 month after OHCA was 51.8%, similar to the rates identified in previous reports.[17,20] Importantly, public-access AEDs have been extensively introduced and deployed in public locations, and so they are no longer rare in Japan. However, despite more than 600,000 AEDs being installed in prehospital settings throughout Japan,[15] only 615 patients were estimated to have had a favorable neurological outcome attributed to PAD after bystander-witnessed VF arrest in a public location during the 3-year period. We believe there is significant room for improvement of these numbers and therefore it is critical that we develop a strategy to increase the use of public-access AEDs.

Among bystander-witnessed VF patients receiving PAD in a residential location, the proportion of patients with a neurologically favorable outcome at 1 month after OHCA was 22.5%; this proportion was lower than for patients in public locations. There could be several reasons for the smaller number of patients who benefitted from PAD in a residential location. Hansen and colleagues in Denmark reported some AEDs might have been inaccessible to bystanders at the point of a nearby cardiac arrest when in a residential location.[17,21] As mentioned in **Table 1**, the time interval from collapse to first shock by bystanders or EMS personnel was around 2 min longer in residential locations than in public locations, which suggests inaccessible public-access AEDs nearby the cardiac arrest. It is also possible that OHCA patients tended to be older in the residential locations than in the public locations, and so the outcomes were reflective of this.[17,21] Indeed, in our study, patients in residential locations were 10 years older, on average, than those in public locations. Optimizing AED deployment to maximize the availability of bystander use is critical. For instance, increasing the number of AED devices in high-rise buildings may improve OHCA outcomes in residential locations,[22,23] as the number of people living in high-rise buildings is currently increasing across Japan.[22]

If AED dissemination is associated with an increase in the number of VF survivors with a neurologically favorable outcome after OHCA, our AED deployment strategy should also consider economics. However, discussion concerning the cost-effectiveness of the PAD program is often controversial. Investigators in the PAD trial estimated that the cost-effectiveness of PAD was similar to that of other medical interventions,[24] whereas other reports have suggested that a nationwide PAD program (including dissemination of public-access AEDs) is less likely to have a cost benefit.[25,26] The cost-effectiveness of PAD would be influenced by various factors such as OHCA frequency, the rate of AED use, population density, population characteristics, and EMS infrastructure. Further research on the cost-effectiveness of PAD, based on the All-Japan Utstein Registry, will be addressed in the near future.

In this study, the estimated number of patients who experienced a neurologically favorable outcome that was attributed to PAD after VF did not significantly increase during the 3-year period. Our findings suggest that even though the number of public-access AEDs has been increasing in Japan, we need to use public-access AEDs more effectively.[15] Recently, systems that transport AEDs using social networks or drone technology have been developed. Studies in Sweden have reported that a smartphone-based application activated by emergency dispatch centers can be used to locate and then alert laypersons to nearby suspected OHCAs.[27] In addition, a study in Canada suggested that an optimized drone network designed with the aid of a novel mathematical model could substantially reduce the AED delivery time directly to an OHCA event.[28] However, many regulatory and technical challenges must be addressed before drone-delivered AED systems can be utilized in real-world scenarios.[28] In the near future, such efforts could lead to an increased and optimized placement of public-access AED for use by laypersons, followed by an concomitant increase in the number of survivors with a neurologically favorable outcome after OHCA.

Study Limitations

This study has some inherent limitations. First, we considered only OHCA patients to whom shocks were administrated by public-access AEDs and the study lacks information on those for whom unsuccessful attempts were made to use a public-access AED. Second, we did not obtain information on the actual deployment of public-access AEDs. Third, this study did not assess the factor as to whom witnessed an OHCA, although this would affect the implementation of PAD.[29] Fourth, there may be unmeasured confounding factors that might have influenced the association between location and outcome. Finally, as with all epidemiological studies, the integrity and validity of the data, as well as ascertainment bias, are potential limitations. However, the use of uniform data collection based on the Utstein-style guidelines for reporting cardiac arrest, the large sample size, and the population-based design should minimize these potential sources of bias.

Conclusions

In Japan, the dissemination of PAD was more effective (for neurologically favorable outcomes) for adults with bystander-witnessed VF arrest in public rather residential locations. However, the total estimated number of bystander-witnessed VF patients with a neurologically favorable outcome that could be attributed to PAD was 615. Therefore, we need to continue to make efforts to further increase the number of OHCA survivors who can benefit from the use of public-access AEDs with a neurologically favorable outcome.

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Disclosure

None.

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