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## ORIGINAL ARTICLE

# Nationwide Public-Access Defibrillation in Japan

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## ABSTRACT

**BACKGROUND**

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It is unclear whether dissemination of automated external defibrillators (AEDs) in public places can improve the rate of survival among patients who have had an out-of-hospital cardiac arrest.

**METHODS**

From January 1, 2005, through December 31, 2007, we conducted a prospective, population-based, observational study involving consecutive patients across Japan who had an out-of-hospital cardiac arrest and in whom resuscitation was attempted by emergency responders. We evaluated the effect of nationwide dissemination of public-access AEDs on the rate of survival after an out-of-hospital cardiac arrest. The primary outcome measure was the 1-month rate of survival with minimal neurologic impairment. A multivariate logistic-regression analysis was performed to assess factors associated with a good neurologic outcome.

**RESULTS**

A total of 312,319 adults who had an out-of-hospital cardiac arrest were included in the study; 12,631 of these patients had ventricular fibrillation and had an arrest that was of cardiac origin and that was witnessed by bystanders. In 462 of these patients (3.7%), shocks were administered by laypersons with the use of public-access AEDs, and the proportion increased, from 1.2% to 6.2%, as the number of public-access AEDs increased ( $P < 0.001$  for trend). Among all patients who had a bystander-witnessed arrest of cardiac origin and who had ventricular fibrillation, 14.4% were alive at 1 month with minimal neurologic impairment; among patients who received shocks from public-access AEDs, 31.6% were alive at 1 month with minimal neurologic impairment. Early defibrillation, regardless of the type of provider (bystander or emergency-medical-services personnel), was associated with a good neurologic outcome after a cardiac arrest with ventricular fibrillation (adjusted odds ratio per 1-minute increase in the time to administration of shock, 0.91; 95% confidence interval, 0.89 to 0.92;  $P < 0.001$ ). The mean time to shock was reduced from 3.7 to 2.2 minutes, and the annual number of patients per 10 million population who survived with minimal neurologic impairment increased from 2.4 to 8.9 as the number of public-access AEDs increased from fewer than 1 per square kilometer of inhabited area to 4 or more.

**CONCLUSIONS**

Nationwide dissemination of public-access AEDs in Japan resulted in earlier administration of shocks by laypersons and in an increase in the 1-month rate of survival with minimal neurologic impairment after an out-of-hospital cardiac arrest.

\*The investigators and coordinators participating in the Implementation Working Group for the All-Japan Utstein Registry of the Fire and Disaster Management Agency of Japan are listed in the Appendix.

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**S**UDDEN DEATH FROM CARDIAC ARREST IS a major public health problem in the industrialized world.<sup>1</sup> The rate of survival after an out-of-hospital cardiac arrest has been increasing as improvements are made in connecting the links in the “chain of survival,” but it is still low.<sup>1-3</sup> Although early defibrillation plays a key role in the chain of survival,<sup>1,4</sup> it is difficult to reduce the time from a patient’s collapse to defibrillation by emergency medical service personnel.

One way to improve the rate of survival after an out-of-hospital cardiac arrest is to have laypersons administer defibrillation to the patient immediately, with the use of an automated external defibrillator (AED). Many studies, including a large, randomized trial,<sup>5-10</sup> have shown that a public-access–defibrillation program improves the rate of survival among patients with an out-of-hospital cardiac arrest, and as a result of these findings, public-access–defibrillation programs have been introduced in many areas. However, these studies were conducted in limited geographic areas or situations,<sup>1,5-12</sup> and whether the nationwide dissemination of public-access AEDs would actually increase the rate of survival among people who have had an out-of-hospital cardiac arrest remains to be determined.

Since July 2004, it has been legal for any citizen in Japan to use an AED, and public-access AEDs have become increasingly available.<sup>13</sup> In January 2005, the Fire and Disaster Management Agency (FDMA) of Japan launched a prospective, nationwide, population-based, cohort study involving persons who had an out-of-hospital cardiac arrest. The purpose of the study is to evaluate the effect of the nationwide dissemination of public-access AEDs on the rate of survival among patients who have had an out-of-hospital cardiac arrest of cardiac origin.

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## METHODS

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### STUDY DESIGN

The All-Japan Utstein Registry of the FDMA is a prospective, nationwide, population-based registry of out-of-hospital cardiac arrests that is based on the standardized Utstein style.<sup>14,15</sup> We enrolled in this observational study all patients 18 years of age or older who, between January 1, 2005, and December 31, 2007, had an out-of-hospital cardiac arrest of cardiac origin before the arrival of emergency medical services (EMS) personnel, were treated by EMS personnel, and were then

transported to medical institutions. The ethics committee at Kyoto University Graduate School of Medicine approved the study. The requirement of written informed consent was waived.

Cardiac arrest was defined as the cessation of cardiac mechanical activity, as confirmed by the absence of signs of circulation.<sup>14,15</sup> The arrest was presumed to be of cardiac origin unless it was caused by cerebrovascular disease; respiratory disease; malignant tumors; external factors, including trauma, hanging, drowning, drug overdose, and asphyxia; or any other noncardiac factor. The cardiac or noncardiac origin was determined clinically by the physician in charge, in collaboration with the EMS personnel, and was confirmed by a staff member at the FDMA.

### EMS SYSTEM IN JAPAN

Japan has an area of approximately 378,000 km<sup>2</sup> and an inhabited area of 121,000 km<sup>2</sup> (defined in Japan as areas in which people can live, excluding forests, fields, marshes, and lakes),<sup>16</sup> and its population was approximately 127 million in 2005.<sup>17</sup> There were 807 fire stations with dispatch centers in 2007; EMS at these fire stations is provided by municipal governments. In most cases, an ambulance has a crew of three emergency providers, including at least one emergency lifesaving technician, a person who has undergone extensive training in the provision of emergency care before a patient’s arrival at the hospital. Emergency lifesaving technicians are allowed to insert an intravenous line and an adjunct airway and to use semiautomated external defibrillators to treat patients who are having an out-of-hospital cardiac arrest. Since July 2004, specially trained emergency lifesaving technicians have been permitted to insert tracheal tubes, and since April 2006, they have been permitted to administer intravenous epinephrine. All EMS providers perform cardiopulmonary resuscitation (CPR) according to the Japanese CPR guidelines, which until September 2006 were based on the 2000 American Heart Association (AHA) guidelines and since October 2006 have been based on the 2005 AHA guidelines.<sup>18</sup> EMS providers are not permitted to terminate resuscitation in the field. Therefore, most patients with an out-of-hospital cardiac arrest who are treated by EMS personnel are transported to hospitals. Training in conventional CPR, which includes chest compressions and rescue breathing, as outlined in the Japanese CPR guidelines, has been offered to approximately 1.4 mil-

**Table 1. Temporal Trends in the Cumulative Number of Public-Access Automated External Defibrillators (AEDs) and in the Incidence of Out-of-Hospital Cardiac Arrests in Japan.\***

Variable	Total	2005	2006	2007
Public-access AEDs (no.)				
Total	88,265	9906	43,212	88,265
Per square kilometer of inhabited area	0.97	0.11	0.48	0.97
Per 100,000 population	69.0	7.8	33.8	69.0
Out-of-hospital cardiac arrests per 100,000 population (%)†				
Total	54.1	52.8	54.2	55.3
Of presumed cardiac origin	28.0	27.8	27.9	28.4
Of presumed cardiac origin and witnessed by bystanders	9.6	9.2	9.5	9.8
Of presumed cardiac origin, with ventricular fibrillation, and witnessed by bystanders	2.6	2.5	2.7	2.8

\* Data are from Marukawa.<sup>13</sup>

† The incidence of out-of-hospital cardiac arrests was adjusted for age.

lion Japanese citizens per year, mainly by members of local fire departments.<sup>19</sup>

#### DISSEMINATION OF AEDs IN JAPAN

Since July 2004, it has been legal for any citizen in Japan to use an AED. Placement of AEDs in public areas, including schools, medical and nursing facilities, work places, sports and cultural facilities, and transportation facilities, depends on both public and private initiatives.<sup>20,21</sup> The cumulative number of public-access AEDs, excluding those in medical facilities and EMS institutions, as estimated from sales of AEDs, increased from 9906 to 88,265 during the 3-year study period (Table 1).<sup>13</sup>

#### DATA COLLECTION AND QUALITY CONTROL

Data were collected prospectively with the use of a data form that was based on the Utstein-style guidelines for reporting out-of-hospital cardiac arrests<sup>14,15</sup>; the data that were collected included the sex and age of the patient, the initial cardiac rhythm, and the time course of resuscitation, as well as information on whether the arrest was witnessed by a bystander, whether a bystander initiated CPR, whether the patient was intubated, whether epinephrine was administered, and whether spontaneous circulation was restored before the patient's arrival at the hospital. In addition, information was collected on survival and

neurologic status 1 month after the event. The times of the receipt of an emergency call by the EMS, the arrival of a vehicle at the scene, the initial contact with the patient, the initiation of CPR, defibrillation by EMS personnel, and arrival at the hospital were recorded according to the times on the clock used by the EMS system that responded to the call. An AED analyzes a patient's rhythm automatically and delivers a shock only when it detects ventricular fibrillation. Therefore, when laypersons delivered shocks with the use of a public-access AED, the patient's first recorded rhythm was regarded as ventricular fibrillation, which included ventricular tachycardia in the absence of a pulse. In cases in which bystanders initiated CPR, chest compression alone and conventional CPR with rescue breathing were recorded as "CPR by bystander." The times of collapse, administration of the first shock from a public-access AED, and initiation of CPR by a bystander were determined through an interview that EMS personnel conducted with the bystander before the EMS personnel left the scene. If the time of administration of the first shock from the public-access AED was not ascertained, the interval from the patient's collapse to administration of a shock from the AED was replaced with the interval from the patient's collapse to the time CPR was administered by the bystander. The time of the initiation of CPR was defined as the time CPR was initiated by bystanders or by EMS personnel, whichever was earlier. Similarly, the time of the administration of the first shock was defined as the time of the administration of the shock by laypersons or by EMS personnel, whichever was earlier.

All patients who survived the cardiac arrest were followed for up to 1 month after the event by the EMS providers in charge. Neurologic outcome was determined by means of a follow-up interview 1 month after successful resuscitation, with the use of the Cerebral Performance Category (CPC) scale, on which category 1 represents good cerebral performance; category 2, moderate cerebral disability; category 3, severe cerebral disability; category 4, coma or vegetative state; and category 5, death.<sup>14,15</sup>

The data form was completed by the EMS personnel in cooperation with the physicians in charge of the patients and was transferred to their fire stations; the data were then integrated into the registry system on the FDMA database

server. The data were checked for consistency by the computer system and were confirmed by the study investigators. If the data form was incomplete, the FDMA returned it to the fire station, and the form was completed.

#### END POINTS

The primary end point was survival at 1 month with minimal neurologic impairment, which was defined as a CPC category of 1 or 2.<sup>14,15</sup> Secondary end points were the return of spontaneous circulation before arrival at the hospital and survival at 1 month.

#### STATISTICAL ANALYSIS

Data on cardiac arrests that were of cardiac origin, involved patients who were in ventricular fibrillation, and were witnessed by a bystander were included in the analyses. The age-adjusted annual incidence of out-of-hospital cardiac arrests was calculated with the use of 2005 census data and data from a 1985 Japanese population model.<sup>17,22</sup> Trends in categorical and continuous variables were analyzed with the use of univariate regression models and linear tests. A multivariate analysis was used to assess the factors associated with a good neurologic outcome, and odds ratios and their 95% confidence intervals were calculated. Potential confounding factors that were adjusted for in the multivariate analysis included the sex and age of the patient, the relation of the bystander to the patient (family member or other), the type of CPR initiated by a bystander (compression-only or conventional CPR), the use or non-use of a public-access AED to administer a first shock, the time from the patient's collapse to the initiation of CPR, and the time from the patient's collapse to the first shock. The interaction between the provider of the shock (bystander using a public-access AED or EMS personnel) and the time to the first shock was also incorporated in the multivariate analysis. The mean time from collapse to shock, the annual incidence of the administration of a shock with the use of a public-access AED, and the subsequent rate of survival with minimal neurologic impairment per 10 million daytime population were compared among prefectures according to the number of public-access AEDs per square kilometer of inhabited area (<1, 1 to <4, or 4 or more). All statistical analyses were performed with the use of the SPSS statistical package, version 16.0J (SPSS). All tests were two-

tailed, and P values of less than 0.05 were considered to indicate statistical significance.

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## RESULTS

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#### CARDIAC ARRESTS AND AVAILABILITY OF PUBLIC-ACCESS AEDS

During the 3 years of the study, 312,319 out-of-hospital cardiac arrests in adults were documented (Fig. 1), of which 168,827 were presumed to be of cardiac origin; 55,271 of these were witnessed by bystanders. A total of 12,631 adults with a cardiac arrest of cardiac origin witnessed by a bystander had an initial ventricular fibrillation. Of these, 462 received a first shock from a public-access AED before the arrival of EMS personnel, 11,697 received a first shock from EMS personnel, and 472 received no shocks.

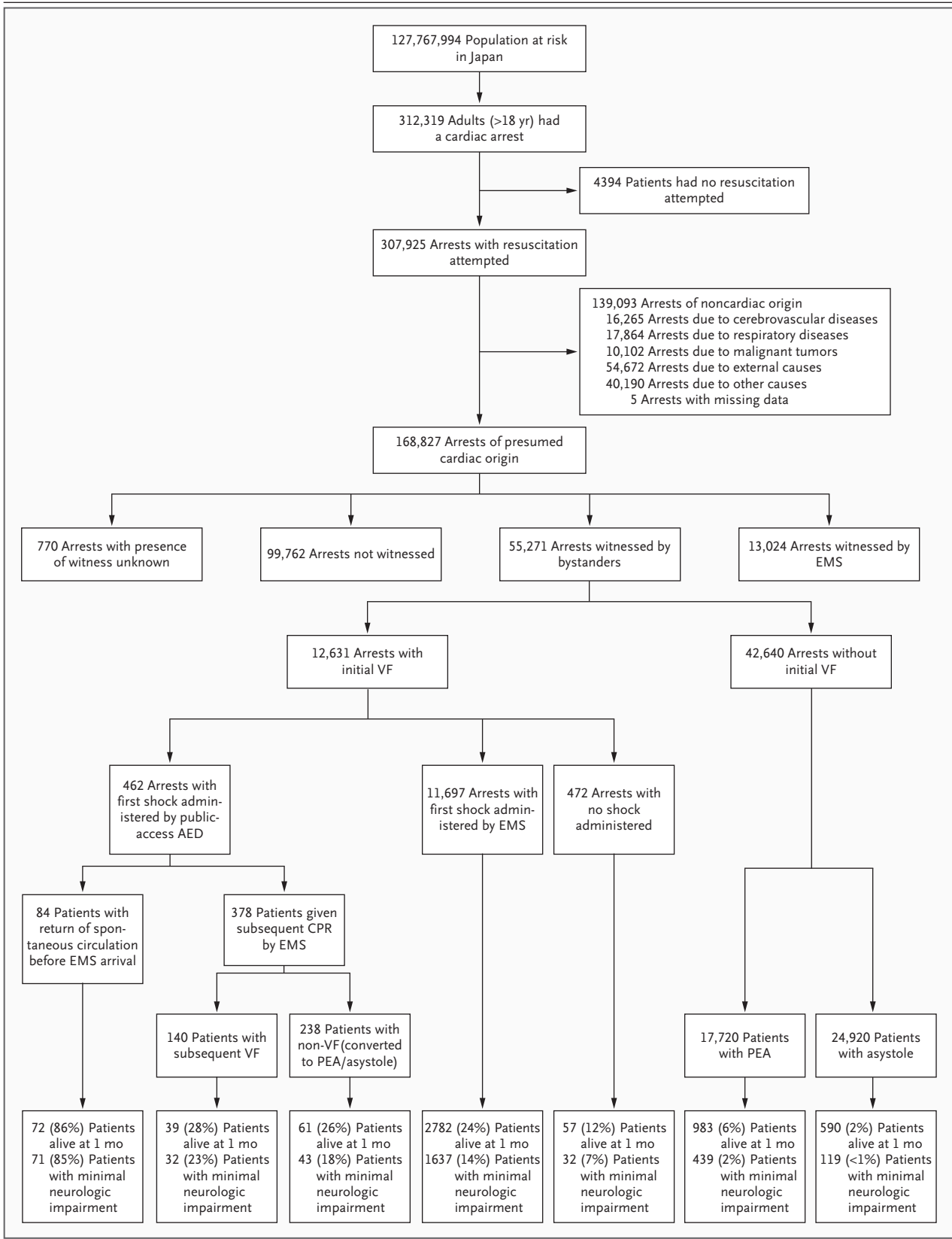
Over the course of the 3-year study period, the number of public-access AEDs increased from 0.11 to 0.97 per square kilometer of inhabited area (Table 1). The age-adjusted annual incidence of out-of-hospital cardiac arrests among adults during the study period was 54.1 per 100,000 person-years, and the incidence of out-of-hospital cardiac arrests of cardiac origin was 28.0 per 100,000 person-years. Of these arrests, 9.6 per 100,000 person-years were witnessed by a bystander and 2.6 per 100,000 person-years also involved patients who were in ventricular fibrillation. Incidences gradually increased year by year.

#### SURVIVAL WITH MINIMAL NEUROLOGIC IMPAIRMENT

Among the people who received a first shock from a public-access AED, the rate of survival with minimal neurologic impairment at 1 month was 84.5% for patients in whom spontaneous circulation was restored before the arrival of EMS personnel (71 of 84 patients), as compared with 22.9% for those who continued to have ventricular fibrillation (32 of 140) and 18.1% for those who did not have ventricular fibrillation but had pulseless electrical activity or asystole at the time that EMS personnel administered CPR (43 of 238). Data on neurologic outcome 1 month after the event were not available for 55 of the 12,631 patients who had bystander-witnessed arrests and ventricular fibrillation.

#### TEMPORAL TRENDS

Table 2 shows temporal trends in the characteristics of the patients and in the outcomes of



**Figure 1 (facing page). Study Population and Outcomes.**

AED denotes automated external defibrillator, CPR cardiopulmonary resuscitation, EMS emergency medical service, PEA pulseless electrical activity, and VF ventricular fibrillation.

bystander-witnessed arrests among patients who had ventricular fibrillation and arrests for which public-access AEDs were used to administer the first shock. Among bystander-witnessed arrests

in patients who had ventricular fibrillation, no significant temporal trend was found in either the mean age of the patients or the ratio of male to female patients. Over the course of the 3 years, the prevalence of bystander-initiated CPR increased from 43.3% to 53.6% ( $P<0.001$ ). Compression-only CPR accounted for more than 50% of cardiac arrests involving bystander-initiated CPR. The time from the patient's collapse to the initiation of CPR decreased from 6.5 minutes to 5.7 minutes ( $P<0.001$ ), whereas the time to ad-

**Table 2. Temporal Trends in Characteristics and Outcomes of Bystander-Witnessed Arrests among Patients with Ventricular Fibrillation and in the Use of a Public-Access Automated External Defibrillator (AED) to Administer a First Shock.\***

Variable	Total	2005	2006	2007	P Value for Trend
Bystander-witnessed arrests with ventricular fibrillation					
No. of events	12,631	3841	4388	4402	
Patient's age — yr	64.4±15.1	64.4±14.8	64.6±15.0	64.1±15.4	0.33
Male sex — no. of patients (%)	10,055 (79.6)	3066 (79.8)	3488 (79.5)	3501 (79.5)	0.75
Relationship of bystander to patient — no. (%)					<0.001
Family member	7376 (58.4)	2324 (60.5)	2577 (58.7)	2475 (56.2)	
Other	5255 (41.6)	1517 (39.5)	1811 (41.3)	1927 (43.8)	
CPR initiated by bystander — no. of events (%)†	6127 (48.5)	1662 (43.3)	2106 (48.0)	2359 (53.6)	<0.001
Chest compression only	3148 (24.9)	744 (19.4)	1037 (23.6)	1367 (31.1)	
Conventional CPR‡	2979 (23.6)	918 (23.9)	1069 (24.4)	992 (22.5)	
Time from collapse to initiation of CPR — min	6.0±5.8	6.5±6.0	6.0±5.6	5.7±5.8	<0.001
Time from collapse to first shock — min§	11.6±6.3	12.0±6.2	11.4±6.2	11.6±6.5	0.36
Restoration of spontaneous circulation before arrival at hospital — no. of patients (%)	3118 (24.7)	821 (21.4)	1049 (23.9)	1248 (28.4)	<0.001
Survival at 1 mo — no. of patients (%)	3011 (23.8)	745 (19.4)	1019 (23.2)	1247 (28.3)	<0.001
Survival at 1 mo with minimal neurologic impairment — no. of patients (%)¶	1815 (14.4)	406 (10.6)	566 (12.9)	843 (19.2)	<0.001
First shock with the use of a public-access AED					
No. of patients receiving shock	462	45	143	274	
Patient's age — yr	62.1±16.5	66.6±13.2	63.6±15.4	60.6±17.4	<0.001
Male sex — no. of patients (%)	361 (78.1)	34 (75.6)	108 (75.5)	219 (79.9)	0.31
Relationship of bystander to patient — no. (%)					0.01
Family member	61 (13.2)	8 (17.8)	27 (18.9)	26 (9.5)	
Other	401 (86.8)	37 (82.2)	116 (81.1)	248 (90.5)	
Time from collapse to first shock or initiation of CPR — min	3.2±4.4	3.6±5.1	3.5±5.1	2.9±3.8	0.03
Restoration of spontaneous circulation before arrival at hospital — no. of patients (%)	185 (40.0)	12 (26.7)	47 (32.9)	126 (46.0)	0.002
Survival at 1 mo — no. of patients (%)	172 (37.2)	11 (24.4)	47 (32.9)	114 (41.6)	0.01
Survival at 1 mo with minimal neurologic impairment — no. of patients (%)	146 (31.6)	11 (24.4)	41 (28.7)	94 (34.3)	0.11

\* Plus-minus values are means ±SD. CPR denotes cardiopulmonary resuscitation.

† Data on CPR initiated by bystander were missing for 63 events (19 in 2005, 27 in 2006, and 17 in 2007). Percentages were calculated on the basis of the total number of events, including those with missing data.

‡ Conventional CPR included chest compressions and rescue breathing.

§ Only patients who received a shock were considered in the calculation of time from collapse to first shock.

¶ Data on survival at 1 month with minimal neurologic impairment were missing for 55 patients (29 in 2005, 21 in 2006, and 5 in 2007). Percentages were calculated on the basis of the total number of patients, including those with missing data.

**Table 3. Factors Contributing to 1-Month Survival with Minimal Neurologic Impairment among Patients with Bystander-Witnessed Cardiac Arrests and Ventricular Fibrillation.\***

Factor	Adjusted Odds Ratio for Survival (95% CI)	P Value
Male sex	0.90 (0.79–1.04)	0.15
Age $\geq$ 75 yr	0.41 (0.35–0.48)	<0.001
Relationship of bystander to patient		
Family member	Reference	
Other	1.32 (1.10–1.59)	0.002
Type of bystander-initiated CPR		
No CPR	Reference	
Chest compression only	1.65 (1.40–1.96)	<0.001
Conventional CPR†	1.67 (1.40–2.00)	<0.001
Time from collapse to initiation of CPR (per 1-minute increase)	0.98 (0.96–0.99)	0.02
Use of AED	1.21 (0.81–1.82)	0.35
Interaction between provider of AED shock and time to first shock	1.02 (0.96–1.09)	0.50
Time from collapse to first shock (per 1-minute increase)	0.91 (0.89–0.92)	<0.001

\* AED denotes automated external defibrillator, CI confidence interval, and CPR cardiopulmonary resuscitation.

† Conventional CPR included chest compressions and rescue breathing.

ministration of the first shock did not change significantly ( $P=0.36$ ). Consequently, the percentage of persons who survived and had minimal neurologic impairment at 1 month increased from 10.6% in 2005 (406 of 3841 persons) to 19.2% in 2007 (843 of 4402) ( $P<0.001$ ). The percentage of patients who received a shock from a public-access AED increased from 1.2% in 2005 (45 of 3841 patients) to 6.2% in 2007 (274 of 4402) ( $P<0.001$  for trend). The mean age of these patients decreased over the course of the 3-year study period from 66.6 years to 60.6 years ( $P<0.001$ ), and the mean time from collapse to the administration of the first shock or initiation of CPR decreased from 3.6 minutes to 2.9 minutes ( $P=0.03$ ). The proportion of arrests witnessed by family members was only 13.2%. The frequency of a good neurologic outcome among patients who received a shock from a public-access AED increased from 24.4% in 2005 (11 of 45 patients) to 34.3% in 2007 (94 of 274), although the difference was not significant ( $P=0.11$ ). Among patients who had a good neurologic outcome after ventric-

ular fibrillation, the proportion who had received AED shocks administered by a bystander increased markedly, from 2.7% (11 of 406 patients) to 11.2% (94 of 843 patients) ( $P<0.001$  for trend).

#### FACTORS ASSOCIATED WITH A GOOD NEUROLOGIC OUTCOME

In a multivariate analysis (Table 3), earlier administration of shock and earlier initiation of CPR were associated with a good neurologic outcome, but the provider of the shock (bystander or EMS personnel) was not (adjusted odds ratio per 1-minute increase in the time to administration of shock, 0.91; 95% confidence interval [CI], 0.89 to 0.92; adjusted odds ratio per 1-minute increase in the time to initiation of CPR, 0.98; 95% CI, 0.96 to 0.99; adjusted odds ratio for shock administered by a bystander with the use of an AED, 1.21; 95% CI, 0.81 to 1.82). Both compression-only CPR and conventional CPR administered by a bystander were associated with a good neurologic outcome (adjusted odds ratio for compression-only CPR, 1.65; 95% CI, 1.40 to 1.96; adjusted odds ratio for conventional CPR, 1.67; 95% CI, 1.40 to 2.00).

#### FACTORS ASSOCIATED WITH AVAILABILITY OF PUBLIC-ACCESS AEDs

Table 4 shows the interval from a patient's collapse to the first administration of a shock from a public-access AED, the annual incidence of shocks administered with the use of a public-access AED, and the rate of survival with minimal neurologic impairment after the administration of shocks from a public-access AED, according to the number of public-access AEDs per square kilometer of inhabited area. The mean ( $\pm$ SD) interval from a patient's collapse to defibrillation decreased as the number of public-access AEDs per inhabited area increased (3.7 $\pm$ 4.8 minutes when there was <1 public-access AED per square kilometer, 3.2 $\pm$ 5.3 minutes when there were 1 to less than 4, and 2.2 $\pm$ 3.7 minutes when there were 4 or more;  $P<0.001$ ). The annual number of patients per 10 million population who had minimal neurologic impairment after a shock from a public-access AED increased as the number of public-access AEDs per square kilometer of inhabited area increased (2.4 $\pm$ 4.1 patients per 10 million population when there was <1 public-access AED per square kilometer, 7.6 $\pm$ 5.1 when there were 1 to less than 4, and 8.9 $\pm$ 5.8 when there were 4 or more) ( $P=0.01$ ).



**Table 4. Variables Associated with the Administration of a Shock with the Use of a Public-Access Automated External Defibrillator (AED), According to the Number of Public-Access AEDs per Square Kilometer of Inhabited Area.\***

Variable	No. of Public-Access AEDs/km <sup>2</sup> of Inhabited Area			P Value for Trend
	<1	1 to <4	≥4	
Prefectures (no.)†				
2005	46	1	0	
2006	43	3	1	
2007	37	8	2	
Time from collapse to shock (min)	3.7±4.8	3.2±5.3	2.2±3.7	<0.001
Annual incidence of shock with AED, per 10 million daytime population	7.7±8.1	19.2±11.2	29.6±14.8	<0.001
Annual incidence of good neurologic outcome after shock with AED, per 10 million daytime population	2.4±4.1	7.6±5.1	8.9±5.8	0.01

\* Plus–minus values are means ±SD.

† In Japan there are 47 prefectures, which are the largest local administrative units.

## DISCUSSION

An analysis of data from a nationwide registry of patients with out-of-hospital cardiac arrests showed that the number of patients who received shocks from public-access AEDs and who survived increased as the number of public-access AEDs increased year by year. Thus, our study shows the actual effect of the greater dissemination of public-access AEDs throughout Japan.

Our study shows that the reduction in time to the administration of a first shock that resulted from the nationwide dissemination of public-access AEDs increased the rate of survival after an out-of-hospital cardiac arrest. Previous studies have shown mixed results of public-access–defibrillation programs, but all these studies were conducted in limited areas or situations.<sup>1,5–12</sup> Even the Public Access Defibrillation trial (PAD; ClinicalTrials.gov number, NCT00004560), which was a large, community-based intervention trial involving 19,000 volunteers,<sup>5</sup> did not show whether the nationwide dissemination of public-access AEDs would actually increase the rate of survival after cardiac arrests, because an intervention trial itself is a special situation. Our study, which shows the success of nationwide dissemination of public-access AEDs, provides support for the concept of public-access defibrillation and should encourage other countries or communities to promote public-access–defibrillation programs.

We also found that increasing the number of

public-access AEDs per square kilometer of inhabited area was strongly associated with shortening the time to the administration of a first shock and in increasing the number of patients who survived with minimal neurologic impairment after receiving a shock. On the basis of our data, we can extrapolate that if the number of public-access AEDs increased from 1 per square kilometer (i.e., a unit placed every 1000 linear meters) to more than 4 per square kilometer (i.e., a unit placed every 500 linear meters), the rate of survival with minimal neurologic impairment in the area could increase about four times. These data support the recommendation that public-access AEDs be made available within a 1.0-minute to 1.5-minute brisk walk from any location.<sup>23</sup> Although the number of public-access AEDs per square kilometer of inhabited area increased during the 3 years of the study, their availability is still not sufficient in most areas.

In Japan, the placement of public-access AEDs is not controlled and depends on both public and private initiatives.<sup>20</sup> A total of 25% of public-access AEDs are located in schools, 19% in medical or nursing facilities, 16% in workplaces, 4% in sports facilities, 3% in cultural facilities, and 3% in public transportation facilities.<sup>21</sup> Depending on the location, AEDs have been shown to be either very effective in reducing mortality after out-of-hospital arrests among patients with ventricular fibrillation (e.g., in airports or casinos)<sup>5–9</sup> or of minimal effectiveness (e.g., in homes).<sup>12</sup> The

association between the locations of public-access AEDs and their effectiveness requires further investigation.

In this study, we observed a significant improvement in the rate of survival in the brief span of 3 years. There may be various factors other than the dissemination of public-access AEDs that would improve the outcome of out-of-hospital cardiac arrest. The improvement in survival that occurred during the study period could be explained in part by the changes to the 2005 CPR guidelines.<sup>24</sup> Advanced life-support treatments administered before arrival at the hospital, as well as special treatments administered in the hospital, such as hypothermia, might result in improved survival after an out-of-hospital cardiac arrest.<sup>25,26</sup> However, the notable increase in the proportion of patients who received AED shocks administered by bystanders among patients who had a good neurologic outcome after ventricular fibrillation suggests the effect of the dissemination of public-access AEDs on improving survival.

This study underscores the importance not only of shocks administered early after a cardiac arrest but also of bystander-initiated CPR, irrespective of the type of CPR. The time from a patient's collapse to the initiation of CPR was reduced because of the increase in bystander-initiated CPR, and both early shock and early initiation of CPR contributed to a better outcome. Familiarity with the use of an AED, along with increased dissemination of public-access AEDs, might promote both a willingness to use an AED and a positive attitude toward CPR.<sup>27</sup> A previous study showed that dissemination of public-access AEDs without an emphasis on CPR did not improve the rate of survival after an out-of-hospital cardiac arrest.<sup>28</sup> The present study reinforces the importance of the combination of early initiation of CPR and early defibrillation.<sup>1</sup>

Although public-access AEDs are becoming increasingly available, among patients with out-of-hospital cardiac arrests who have ventricular fibrillation, the frequencies of shock administration and CPR initiation by bystanders are still only 7% and 50%, respectively, and the rate of survival is still low. Even in the intensive intervention trial of public-access defibrillation, CPR was attempted by a bystander in only half the cases of out-of-hospital cardiac arrests that were

witnessed by bystanders, and a public-access AED was used in only one third of the cases.<sup>5</sup> Using an AED and performing CPR are known to be difficult for laypersons.<sup>23</sup> To overcome this problem, the use of CPR that involves chest compression only, a skill that is simpler and easier to learn and perform, should be encouraged.<sup>29,30</sup> Further efforts are warranted to strengthen the four elements in public-access–defibrillation programs — planning the program, training laypersons, establishing a link with the EMS system, and setting up a system for maintaining the device and for monitoring quality improvement.<sup>23</sup>

This study has some limitations. First, we did not obtain detailed information on the place of collapse or on the location of the public-access AED. Second, we had data only on cases in which public-access AEDs were used and the shock was delivered; we did not have data on cases in which an attempt was made to use an AED but the shock was not delivered. Therefore, we could not evaluate how many cases there were in which an attempt was made to use an AED in patients who did not have ventricular fibrillation or how many cases there were in which a patient with ventricular fibrillation did not receive a shock because of human or mechanical error. Since AEDs have a high sensitivity for detecting ventricular fibrillation, however, one can assume that they would rarely miss ventricular fibrillation.<sup>31</sup> Third, information is lacking on the bystanders who used AEDs, including the conditions under which they witnessed the out-of-hospital cardiac arrest and administered shocks. Fourth, as with all epidemiologic studies, the integrity and validity of the data, as well as ascertainment bias, are potential limitations of our study. The use of uniform data collection based on Utstein-style guidelines for reporting cardiac arrest, the large sample size, and the population-based design should minimize these potential sources of bias. If the rate of survival is improved by the dissemination of public-access AEDs, it is also essential to perform an economic analysis. Investigators in the PAD trial estimated that the cost-effectiveness of public-access defibrillation was similar to that of other medical interventions.<sup>32</sup>

In conclusion, this large, population-based, observational study showed that nationwide dissemination of public-access AEDs increased the frequency of the administration of shocks with

the use of public-access AEDs and contributed to improved outcomes after out-of-hospital ventricular-fibrillation arrests of cardiac origin that were witnessed by bystanders. This finding reinforces the importance of the public-access-defibrillation concept for increasing survival after out-of-hospital cardiac arrests.

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#### APPENDIX

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