

Original Article

Impact of type of emergency department on the outcome of out-of-hospital cardiac arrest: a prospective cohort study

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Aim: To assess whether the outcomes of out-of-hospital cardiac arrest (OHCA) differ between patients treated at tertiary or secondary emergency medical facilities.

Methods: Data from the Japanese Association for Acute Medicine Out-of-Hospital Cardiac Arrest (JAAM-OHCA) registry between June 2014 and December 2015 were analyzed and compared between patients treated at tertiary (tertiary group) and secondary (secondary group) emergency medical facilities. The primary outcome of this study was a favorable neurological outcome at 1 and 3 months after OHCA, defined as a Glasgow–Pittsburgh cerebral performance category of 1 or 2.

Results: Between June 2014 and December 2015, a total of 13,491 patients with OHCA were registered in the JAAM-OHCA registry. Of these, 12,836 were eligible in the present analysis, with 11,583 in the tertiary group and 1,253 in the secondary group. The proportions of patients with favorable neurological outcomes in the tertiary group were significantly higher than those in the secondary group at 1 (4.7% versus 2.0%, $P < 0.001$) and 3 (3.5% versus 1.6%, $P < 0.001$) months after OHCA. Even after adjusting for baseline characteristics of patients, treatment at a tertiary emergency medical facility was independently associated with favorable neurological outcomes at 1 (odds ratio, 2.856, 95% confidence interval, 1.429–5.710; $P = 0.003$) and 3 (odds ratio, 2.462, 95% confidence interval, 1.203–5.042; $P = 0.014$) months after OHCA.

Conclusion: The neurological outcomes of patients with OHCA treated at tertiary emergency medical facilities were better than those of patients treated at secondary emergency medical facilities.

Key words: Japanese Association for Acute Medicine, outcome, out-of-hospital cardiac arrest, registry, type of emergency department

INTRODUCTION

OUT-OF-HOSPITAL CARDIAC ARREST (OHCA) is a leading cause of death, and few patients survive with mild or no neurologic deficits.¹ To improve the outcomes of OHCA, the American Heart Association (AHA) guidelines recommend post-cardiac arrest care.² However, high-quality

post-cardiac arrest care requires abundant medical resources and extensive clinical experience, so it can be difficult for some facilities to meet these guidelines for care.

In Japan, a three-phase emergency medical system is established. Tertiary emergency medical facilities (tertiary facilities) provide medical treatment for severe patients who need intensive care. Some tertiary facilities are certified as critical care medical centers by the Japanese Ministry of Health, Labour and Welfare and can accept emergency and severely ill patients, including those with OHCA. However, many patients are transported to secondary facilities by the emergency medical service (EMS) for a variety of reasons, including hospital location.³ Currently, however, there is limited information on the differences, if any, of the outcomes of OHCA between patients treated at tertiary or secondary facilities.

Accordingly, our primary objective was to investigate the differences in the outcome of OHCA between patients treated at tertiary and secondary facilities using data from a nationwide registry of patients who experienced OHCA.

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METHODS

Patients

WE ANALYZED DATA from the Japanese Association for Acute Medicine Out-of-Hospital Cardiac Arrest (JAAM-OHCA) registry, a prospective, multicenter cohort study, for patients registered between June 2014 and December 2015. The design of the JAAM-OHCA registry has been reported in more detail elsewhere.⁴ Briefly, the JAAM-OHCA registry enrolls 73 hospitals in Japan that have an emergency department (Fig. 1). The registry includes all patients who sustained cardiac arrest in a prehospital setting, for whom resuscitation was attempted, and who were transported to a participating institution. The registry excluded OHCA patients who did not receive cardiopulmonary resuscitation (CPR) by a physician, those with in-hospital cardiac arrest, and those who refused to participate in our registry, either personally or by family members. Patients who were transported to a participating institution after undergoing any procedures at another hospital were excluded from the registry. For this analysis, we analyzed data for patients aged ≥ 18 years if CPR was attempted by a physician after hospital arrival, and who were treated at a tertiary (tertiary group) or secondary (secondary group) emergency medical facility.

Data collection

Prehospital resuscitation data were collected from the All-Japan Utstein registry of the Fire and Disaster Management Agency of Japan. The JAAM-OHCA registry collected additional information on patients after hospital arrival, including baseline characteristics of patients and treatments carried out. The following outcomes were also prospectively collected: return of spontaneous circulation (ROSC) status, condition after hospital arrival, 1- and 3-month survival, and neurological status at 1 and 3 months after OHCA using the Glasgow–Pittsburgh cerebral performance category (CPC) scale. The CPC scale is a five-category scale in which categories are defined as: 1, good cerebral performance; 2, moderate cerebral disability; 3, severe cerebral disability; 4, coma or vegetative state; and 5, death or brain death. The neurological status of survivors was evaluated at 1 and 3 months after the event by medical staff at each institution. For the purpose of this study, a favorable neurological outcome was defined as a CPC score of 1 or 2. The primary outcomes of the present study were the proportion of patients with favorable neurological outcomes at 1 and 3 months after OHCA. Secondary outcomes included ROSC status, condition after hospital arrival, and 1- and 3-month survival.

Statistical analysis

Assuming that the proportions of patients with favorable neurological outcomes in the tertiary and secondary groups would be 3.0% and 1.0%, respectively,⁵ and the ratio of registered patients is 10:1, we calculated that at least 6,427 and 643 patients, respectively, are needed to detect a difference between the two groups with a power of $>90\%$.

Data are shown as the median and interquartile range for continuous values, and as percentages for categorical values. Missing data were not imputed. Continuous variables were compared between the two groups using Mann–Whitney *U*-tests and categorical variables were compared using Fisher's exact tests. Multivariable logistic regression analysis was undertaken to investigate the association between the type of emergency department and favorable neurological outcomes at 1 and 3 months after OHCA with adjustment for covariates. Baseline variables and the type of emergency department were included in the logistic regression model to predict the outcome variables (favorable neurological outcomes at 1 and 3 months after OHCA). The threshold of significance was set at $P < 0.05$. Statistical analyses were carried out using spss software version 22.0 (SPSS, Chicago, IL, USA).

RESULTS

A TOTAL OF 13,491 patients with OHCA were registered in the JAAM-OHCA registry between June 2014 and December 2015 (Fig. 2). Excluding 319 patients aged < 18 years, 307 patients who were not resuscitated by physicians after hospital arrival, and 29 patients who were transferred to another type of emergency medical facility, 12,836 patients (11,583 in the tertiary group and 1,253 in the secondary group) were eligible for this analysis.

Table 1 shows the characteristics of the participating facilities, which comprised 55 tertiary and 16 secondary facilities. The total bed capacity, intensive care unit bed capacity, and annual expected number of OHCA cases were significantly greater for tertiary than secondary facilities. The numbers of physicians and nurses who treat OHCA patients were similar between the two groups, except for the number of nurses available in the daytime, which was significantly lower at tertiary facilities. Regarding the specialism of physicians involved in the treatment of OHCA patients, acute care physicians and intensive care physicians were more frequently involved in treatment at tertiary facilities than at secondary facilities. Extracorporeal cardiopulmonary resuscitation (ECPR) and targeted temperature management for OHCA were available at significantly more tertiary hospitals than at secondary facilities.

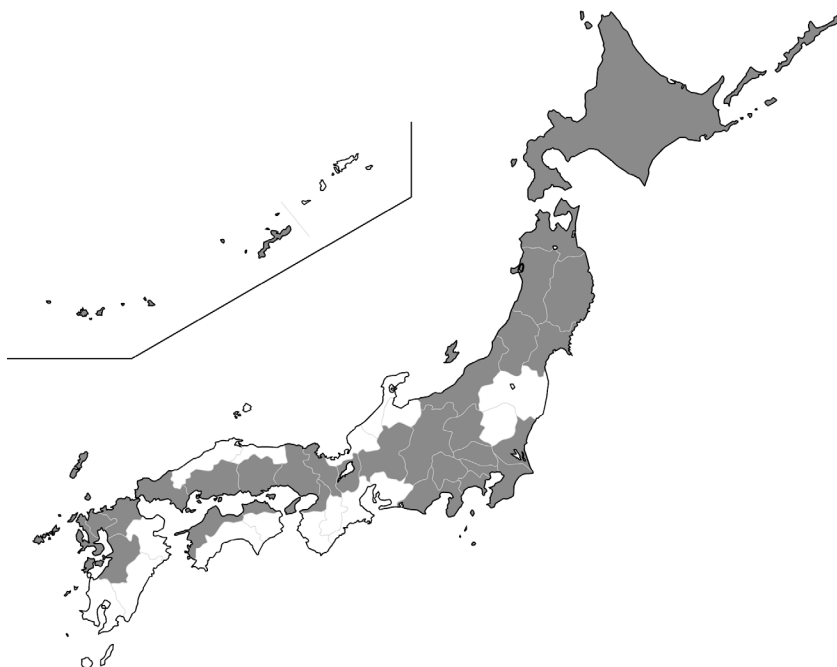


Fig. 1. Geographic distribution (gray areas) of the 73 hospitals participating in the Japanese Association for Acute Medicine Out-of-Hospital Cardiac Arrest registry.

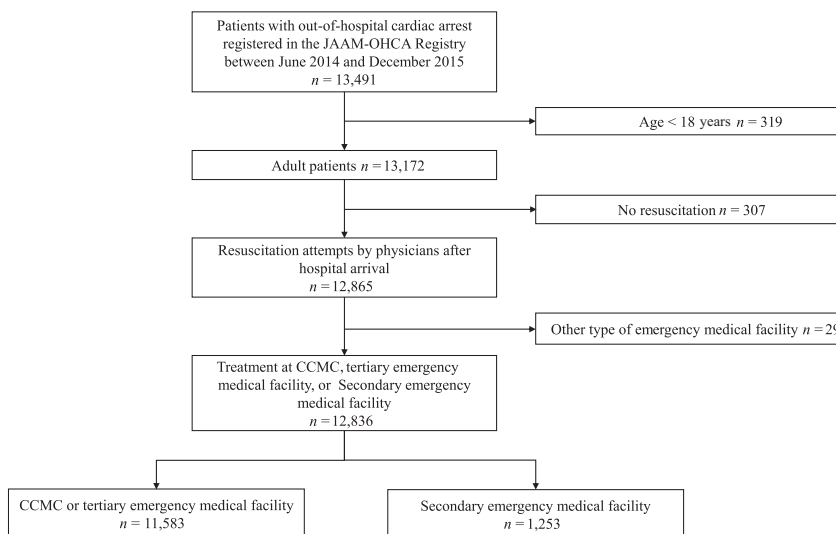


Fig. 2. Selection of patients with out-of-hospital cardiac arrest (OHCA) included in this study. CCMC, critical care medical center; JAAM, Japanese Association for Acute Medicine.

Table 2 shows the baseline characteristics, advanced treatments provided in hospital, and the outcomes of patients treated at both types of facility. The median age of patients and proportion of patients with cardiac causes were significantly lower in the tertiary group compared with the

secondary group. The proportion of male patients was significantly greater in the tertiary group compared with the secondary group. In the tertiary group, the proportion of patients with witnessed OHCA and those who underwent shock with a public-access automated external defibrillator

Table 1. Characteristics of the participating Japanese emergency medical facilities

	Tertiary emergency medical facilities	Secondary emergency medical facilities	P-value
No. of participating facilities	55	16	
Bed capacity, median (IQR)			
Total	634 (506–801)	398 (262–524)	0.002
Intensive care unit	12 (8–20)	6 (2–10)	<0.001
Expected number of OHCA cases per year, median (IQR)	150 (100–250)	61 (27–90)	<0.001
Number of physicians or nurses available for treatment of OHCA cases, <i>n</i> (%) [†]			
≥3 Physicians during daytime shifts	47 (85.5)	12 (75.0)	0.448
≥3 Physicians during night-time shifts	32 (58.2)	8 (50.0)	0.580
≥3 Nurses during daytime shifts	16 (29.1)	16 (100)	<0.001
≥3 Nurses during night-time shifts	12 (21.8)	7 (43.8)	0.110
Facilities with specialists available for the treatment of OHCA, <i>n</i> (%) [†]			
Acute care physicians	55 (100.0)	13 (81.3)	0.010
Intensive care physicians	50 (90.9)	8 (50.0)	0.001
Anesthesiologists	44 (80.0)	14 (87.5)	0.718
Cardiologists	50 (90.9)	14 (87.5)	0.651
ECPR available for OHCA (anytime or daytime), <i>n</i> (%) [†]	54 (98.2)	13 (81.3)	0.032
Targeted temperature management available for OHCA, <i>n</i> (%) [†]	55 (100)	14 (87.5)	0.048

[†]Values are given as number (%) of hospitals.

ECPR, extracorporeal cardiopulmonary resuscitation; IQR, interquartile range; OHCA, out-of-hospital cardiac arrest.

were significantly higher than in the secondary group. Regarding first-documented rhythm, the proportion of patients with ventricular fibrillation/pulseless ventricular tachycardia at EMS arrival was significantly greater in the tertiary group, as was the proportion of patients with a detectable pulse on hospital arrival. The proportion of patients who departed from the scene of onset by ambulance or helicopter with a physician was also significantly greater in the tertiary group. The time from call to EMS arrival was similar in both groups, but the time from call to hospital arrival was longer in the tertiary group than in the secondary group.

Regarding advanced treatments provided in hospital, we found that tracheal intubation, extracorporeal life support, intra-aortic balloon pumping, coronary angiography, percutaneous coronary intervention, and target temperature management were carried out in significantly more patients in the tertiary group than in the secondary group, but the rate of defibrillation was similar in both groups. Regarding drug treatment during cardiac arrest, adrenaline and atropine were given to significantly more patients in the secondary group than in the tertiary group.

Regarding the outcomes of patients, the 1-month survival rate was significantly greater in the tertiary group than in the secondary group (9.2% versus 6.1%, $P < 0.001$). The proportions of patients with a favorable neurological outcome at 1

(4.7% versus 2.0%, $P < 0.001$) and 3 (3.5% versus 1.6%, $P < 0.001$) months after OHCA were both significantly greater in the tertiary group than in the secondary group.

Table 3 shows the results of the multivariable logistic regression analysis for favorable neurological outcomes at 1 and 3 months after OHCA. Even after adjustment for the baseline characteristics of patients, admission to a tertiary facility was independently associated with favorable neurological outcomes at 1 (odds ratio, 2.856; 95% confidence interval, 1.429–5.710; $P = 0.003$) and 3 (odds ratio, 2.462; 95% confidence interval, 1.203–5.042; $P = 0.014$) months after OHCA.

DISCUSSION

IN THIS ANALYSIS of a nationwide, multicenter, prospective registry of OHCA patients who were transported by EMS personnel to participating hospitals, patients transported to a tertiary facility showed significantly better neurological outcomes at 1 and 3 months after OHCA as compared with patients transported to secondary facilities. Admission to a tertiary facility was independently associated with favorable neurological outcomes at 1 and 3 months after OHCA; this association remained after adjusting for the patients' baseline characteristics. Consistent with a previous report,³ our results indicate that the type of emergency

Table 2. Baseline characteristics, advanced treatments provided in hospital, and outcomes of patients with out-of-hospital cardiac arrest

	Tertiary group <i>n</i> = 11,583	Secondary group <i>n</i> = 1,253	<i>P</i> -value
Baseline characteristics			
Age, years	74 (60–83)	80 (68–87)	<0.001
Male gender	7,162 (61.8)	708 (56.5)	<0.001
Cause			
Cardiac	5,899 (50.9)	712 (56.8)	<0.001
Non-cardiac	5,683 (49.1)	541 (43.2)	
Witnessed	4,901 (46.1)	463 (42.5)	0.022
Bystander-initiated CPR			
CPR with rescue breaths	522 (4.5)	73 (5.8)	<0.001
Chest-compression-only CPR	3,692 (31.9)	466 (37.2)	
Shock by a public-access AED	194 (1.7)	9 (0.7)	
No bystander interventions	6,213 (53.6)	542 (43.3)	
First documented rhythm at EMS arrival			
VF/pulseless VT	1,006 (9.5)	67 (6.1)	<0.001
PEA/asystole	9,067 (85.4)	998 (91.6)	
Other	548 (5.2)	25 (2.3)	
Departure by ambulance or helicopter with a physician	1,549 (13.4)	78 (6.2)	<0.001
First documented rhythm at hospital arrival			
VF/pulseless VT	509 (4.4)	54 (4.3)	<0.001
PEA/asystole	9,819 (84.8)	1,118 (89.2)	
Presence of pulse	1,254 (10.8)	81 (6.5)	
Time from call to EMS arrival, min	8 (7–10)	8 (7–10)	0.518
Time from call to hospital arrival, min	33 (27–40)	30 (24–38)	<0.001
Advanced treatments provided in hospital			
Defibrillation	1,145 (9.9)	110 (8.8)	0.230
Tracheal intubation after hospital arrival	8,170 (70.5)	668 (53.3)	<0.001
Extracorporeal life support	468 (4.0)	25 (2.0)	<0.001
Intra-aortic balloon pumping	398 (3.4)	27 (2.1)	0.018
Coronary angiography	851 (7.3)	62 (4.9)	0.002
Percutaneous coronary intervention	407 (3.5)	26 (2.1)	0.008
Targeted temperature management	852 (7.4)	69 (5.5)	0.017
Drug treatment during cardiac arrest [†]			
Adrenaline	9,199 (79.4)	1,068 (85.2)	<0.001
Amiodarone	515 (4.4)	41 (3.3)	0.060
Nifekalant	63 (0.5)	4 (0.3)	0.407
Lidocaine	74 (0.6)	13 (1.0)	0.101
Atropine	167 (1.4)	54 (4.3)	<0.001
Magnesium	129 (1.1)	12 (1.0)	0.774
Vasopressin	51 (0.4)	10 (0.8)	0.083
Patient outcomes			
Condition after hospital arrival			
Admitted to ICU/ward	3,210 (27.7)	298 (23.8)	0.003
Death at the ED	8,372 (72.3)	955 (76.2)	
1-month survival	1,068 (9.2)	77 (6.1)	<0.001
CPC 1 month after OHCA			
CPC 1	420 (3.6)	19 (1.5)	<0.001
CPC 2	130 (1.1)	6 (0.5)	
CPC 3	187 (1.6)	17 (1.4)	
CPC 4	331 (2.9)	35 (2.8)	
CPC 5	10,513 (90.8)	1,176 (93.9)	

Table 2. (Continued)

	Tertiary group <i>n</i> = 11,583	Secondary group <i>n</i> = 1,253	<i>P</i> -value
Favorable neurological outcome 1 month after OHCA	550 (4.7)	25 (2.0)	<0.001
3-month survival	662 (5.7)	39 (3.1)	<0.001
CPC 3 months after OHCA			
CPC 1	334 (2.9)	15 (1.2)	0.001
CPC 2	70 (0.6)	5 (0.4)	
CPC 3	90 (0.8)	10 (0.8)	
CPC 4	167 (1.4)	8 (0.6)	
CPC 5	8,057 (69.6)	889 (70.9)	
Favorable neurological outcome 3 months after OHCA	404 (3.5)	20 (1.6)	<0.001

Data are shown as the median (interquartile range) for continuous values, and as *n* (%) for categorical values.

†Some patients received multiple drugs.

AED, automated external defibrillator; CPC, cerebral performance category; CPR, cardiopulmonary resuscitation; ED, emergency department; EMS, emergency medical service; ICU, intensive care unit; OHCA, out-of-hospital cardiac arrest; PEA, pulseless electrical activity; VF, ventricular fibrillation; VT, ventricular tachycardia.

Table 3. Multivariable analysis of favorable neurological outcomes at 1 and 3 months after out-of-hospital cardiac arrest (OHCA)

Variable	Favorable neurological outcome 1 month after OHCA			Favorable neurological outcome 3 months after OHCA		
	aOR	95% CI	<i>P</i> -value	aOR	95% CI	<i>P</i> -value
Age (per year)	0.962	0.954–0.970	<0.001	0.966	0.957–0.976	<0.001
Male gender	0.748	0.543–1.031	0.077	0.969	0.671–1.400	0.867
Cardiac cause	3.391	2.331–4.932	<0.001	2.539	1.675–3.850	<0.001
Witnessed	2.338	1.653–3.307	<0.001	2.313	1.558–3.432	<0.001
Bystander-initiated CPR (ref: no bystander interventions)						
CPR with rescue breaths	0.859	0.484–1.524	<0.001	0.596	0.296–1.201	0.001
Chest-compression-only CPR	0.825	0.604–1.126		0.683	0.478–0.976	
Shock by a public-access AED	2.601	1.585–4.268		2.313	1.301–4.110	
First documented rhythm at EMS arrival (ref: other)						
VF/pulseless VT	0.745	0.487–1.139	<0.001	1.272	0.772–2.095	<0.001
PEA/asystole	0.104	0.069–0.159		0.139	0.085–0.228	
Departure by ambulance or helicopter with a physician	1.545	1.104–2.162	0.011	1.435	0.985–2.093	0.060
First documented rhythm at hospital arrival (ref: presence of pulse)						
VF/pulseless VT	0.084	0.058–0.122	<0.001	0.075	0.048–0.116	<0.001
PEA/asystole	0.014	0.009–0.021		0.018	0.012–0.027	
Time from call to EMS arrival (per min)	0.985	0.935–1.037	0.555	1.021	0.966–1.078	0.464
Time from call to hospital arrival (per min)	0.973	0.960–0.986	<0.001	0.970	0.955–0.984	<0.001
Tertiary medical facility	2.856	1.429–5.710	0.003	2.462	1.203–5.042	0.014

AED, automated external defibrillator; aOR, adjusted odds ratio; CI, confidence interval; CPR, cardiopulmonary resuscitation; EMS, emergency medical service; PEA, pulseless electrical activity; VF, ventricular fibrillation; VT, ventricular tachycardia.

department to which a patient is admitted after OHCA influences their prognosis.

The 2010 AHA guidelines included post-cardiac arrest care in their chain of survival concept in order to improve the outcomes of OHCA because of the increasing

importance of systematic care and advances in the multispecialty management of patients following ROSC that can affect neurologically intact survival.⁶ The importance of post-cardiac arrest care was further emphasized in the 2015 AHA guidelines.² Recommended post-cardiac arrest care

includes acute cardiovascular interventions, hemodynamic stabilization, targeted temperature management, seizure management, respiratory care and glucose control. These critical care interventions require extensive medical resources. As shown in Tables 1 and 2, the tertiary facilities had greater medical resources than secondary facilities, and greater proportions of patients treated in tertiary facilities underwent critical care interventions than patients treated in secondary facilities. These features of tertiary facilities might contribute to the improved neurological outcomes of patients treated in such facilities.

Several observational studies have shown that high-volume centers are associated with more favorable outcomes.^{7,8} For example, in an Austrian, prospective, multicenter registry study, hospitals that treated more than 100 OHCA patients/year were associated with better neurological outcomes than lower-volume hospitals.⁷ Similarly, a Korean nationwide, population-based surveillance study showed that high-volume emergency departments that treated more than 69 OHCA patients per 2 years was associated with better survival to discharge than lower-volume emergency departments.⁸ High-volume centers have the advantage of greater staff experience and could have established protocols for post-resuscitation care. As shown in Table 1, the tertiary facilities included in the JAAM-OHCA registry treated a greater volume of OHCA patients compared with the secondary facilities, and this might contribute to the improved outcome in the present study.

To develop a strategy for optimizing the management of patients with OHCA, it is important to investigate whether the outcomes of OHCA differ according to the type of medical facility. Several reports showed better outcomes after implementation of EMS bypass of non-cardiac arrest-receiving centers.^{9,10} However, there is a limited number of tertiary facilities and accessibility could be a problem, depending on where the OHCA occurs. The safe transportation time, distance, and optimal mode of transportation for patients with OHCA are not known.¹¹ Bypassing hospitals might also have a negative impact on the skills and morale of staff as well as their reputation. In addition, longer delays for EMS to arrive and longer transportation times are becoming problematic in Japan due to increasing demand,¹² and bypassing the closest hospital could exacerbate this situation.

Despite these issues, Tagami *et al.*⁵ reported that the neurological outcomes of patients improved after implementation of the fifth link of the “chain of survival” concept (i.e., advanced life support and post-cardiac arrest care). After implementing this link, all patients were directly transported to a tertiary facility, or indirectly transported to a tertiary facility by way of a local secondary hospital after ROSC.

Their results are consistent with our findings in term of the improved outcomes of patients treated at tertiary facilities, and their strategy could be feasible in other regions of Japan. Therefore, a two-sided strategy consisting of direct transportation of the patient to a tertiary facility after OHCA or indirect transportation to a tertiary facility by way of a local secondary facility after ROSC could be reasonable.

There are some limitations of this study. First, the participating facilities represent a small proportion of facilities in Japan. During the study period, approximately 180,000 patients experienced OHCA in Japan,¹² but the JAAM-OHCA registry contained only approximately 7% of patients in the All-Japan Utstein registry. In particular, the registry includes a very small number of secondary facilities, and the total number of secondary facilities is much larger than that of tertiary facilities in Japan. However, because only institutions with JAAM members participate in the registry, the secondary facilities in this study are likely to provide more advanced medical care than general secondary facilities. Therefore, it is somewhat surprising that we observed such a profound difference in patient outcomes between the secondary and tertiary facilities included in the present study. Second, hospital selection bias might exist. Patients expected to have favorable neurological outcomes are perhaps more likely to be transported to a tertiary facility. Although we adjusted for the baseline characteristics of patients, other unmeasured and unadjusted confounding factors might exist because this study was not a randomized controlled trial. Finally, because the participating facilities are located in Japan, our findings cannot be applied to the management and outcomes of OHCA in other countries. However, the results of observational studies carried out in various countries support the use of specialized cardiac resuscitation centers for treatment of OHCA patients.^{2,13}

CONCLUSIONS

THIS ANALYSIS OF JAAM-OHCA registry data collected between 2014 and 2015 revealed that the neurological outcomes of patients treated at a tertiary facility after OHCA were better than those of patients treated at a secondary facility. We believe these findings should be helpful in the future development of strategies for responding to OHCA patients in order to improve their outcomes.

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DISCLOSURE

Approval of the research protocol: The protocol was approved by the Ethics Committee of Kyoto University as the corresponding institution. All participating hospitals, including our hospital, approved the JAAM-OHCA registry protocol.

Informed consent: The requirement for informed consent of patients was waived.

Registry and the registration no. of the study/trial: This study was not registered.

Animal studies: N/A.

Conflict of interest: None declared.

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