

Impact of the number of on-scene emergency life-saving technicians and outcomes from out-of-hospital cardiac arrest in Osaka City[☆]



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ABSTRACT

Backgrounds: In Japan, ambulance staffing for cardiac arrest responses consists of a 3-person unit with at least one emergency life-saving technician (ELST). Recently, the number of ELSTs on ambulances has increased since it is believed that this improves the quality of on-scene care leading to better outcomes from out-of-hospital cardiac arrest (OHCA). The objective of this study was to evaluate the association between the number of on-scene ELSTs and OHCA outcome.

Methods: This was a prospective cohort study of all bystander-witnessed OHCA patients aged ≥ 18 years in Osaka City from January 2005 to December 2007 using an on Utstein-style database. The primary outcome measure was one-month survival with favorable neurological outcome defined as a cerebral performance category ≤ 2 . Multivariable logistic regression model were used to assess the contribution of the number of on-scene ELSTs to the outcome after adjusting for confounders.

Results: Of the 2408 bystander-witnessed OHCA patients, one ELST group was present in 639 (26.5%), two ELST were present in 1357 (56.4%), and three ELST group in 412 (17.1%). The three ELST group had a significantly higher rate of one-month survival with favorable neurological outcome compared with the one ELST group (8.0% versus 4.5%, adjusted OR 2.26, 95% CI 1.27–4.04), while the two ELST group did not (5.4% versus 4.5%, adjusted OR 1.34, 95% CI 0.82–2.19).

Conclusions: Compared with the one on-scene ELST group, the three on-scene ELST group was associated with the improved one-month survival with favorable neurological outcome from OHCA in Osaka City.

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1. Introduction

Sudden cardiac arrest (SCA) is one of the leading causes of death and an important public health problem in the industrialized world.^{1,2} In Japan, approximately 60,000 out-of-hospital cardiac arrests (OHCAs) of cardiac origin occur every year, and this number has been steadily increasing.³ Despite continuous improvements

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in the “chain of survival,” survival from OHCA remains low.^{1–4}

In Japan, the Emergency Medical Service (EMS) system response mostly consists of a single tiered ambulance system that is dispatched to the scene of all OHCA. Each ambulance is staffed with a 3-person unit including at least one emergency life-saving technician (ELST). ELST are trained to perform advanced airway management and may also administer adrenaline under on-line medical command.⁵ The number of trained ESLTs has been steadily increasing in Japan,⁵ which might improve the quality of care delivered on scene and lead to improved outcomes from OHCA. However, the benefits of having multiple higher trained providers on critical EMS calls for OHCA patients remain controversial.^{6,7}

In 1998, the Osaka Municipal Fire Department launched a population-based registry of OHCA in Osaka City, a large urban community with approximately 2.7 million inhabitants. Using this database, we collected approximately 2400 bystander-witnessed OHCA from January 1st, 2005 to December 31st, 2007. The aim of this study was to evaluate the association between the number of ELSTs on scene and outcomes from OHCA.

2. Methods

2.1. Study design, population, and setting

The present study was carried out within the Utstein Osaka Project, a prospective, population-based cohort study of all persons with OHCA treated by EMS personnel in Osaka prefecture, Japan. This study included all OHCA patients in Osaka City aged 18 years or older who were presumed to be of cardiac and non-cardiac origin, witnessed by bystanders, and transported to medical institutions from January 1, 2005 through December 31, 2007. Osaka City is the third largest city in Japan with a population of 2.7 million residents (2005) in an area of 222 km².⁸ Cardiac arrest was defined as the cessation of cardiac mechanical activities as confirmed by the absence of signs of circulation.^{9,10} An arrest was presumed to be of cardiac etiology unless it was caused by trauma, drowning, drug overdose, asphyxia, exsanguination, or by any other non-cardiac causes determined clinically by a physician in charge, working in collaboration with the EMS.

This study was approved by the Ethics Committees of the Kyoto University Graduate School of Medicine. The requirement to obtain individual informed consent for the review of patient outcome was waived by the Personal Information Protection Law and the National Research Ethics Guidelines of Japan.

2.2. The EMS system in Osaka City

The municipal EMS system is the same as in other areas of Osaka Prefecture, and has been described previously.^{4,11,12} The EMS system is operated by the Osaka Municipal Fire Department and is activated by dialing 119 on the telephone. During the study period, there were 25 fire stations (60 ambulances) and a single dispatch center in Osaka City.¹³ Life support is available there 24 h every day.

Each fire ambulance has three EMS personnel with at least one ELST, a highly-trained prehospital emergency care provider. ELSTs are authorized to use an automated external defibrillator, to insert an intravenous line, and to place advanced airway management devices for OHCA patients under on-line medical control direction. Specially trained ELSTs have been permitted to insert tracheal tubes since July 2004 and to administer intravenous epinephrine since July 2006. In Japan, EMS personnel are not permitted to terminate resuscitation in the field and all patients on whom resuscitation is attempted are transported to the hospital. Until September 2006, all EMS providers performed CPR according to the Japanese Guidelines

based on the American Heart Association, European Resuscitation Council, and the International Liaison Committee on Resuscitation 2000 Guidelines using a 15:2 compression-to-ventilation ratio. After September 2006, they switched to a ratio of 30:2 based on the 2005 Guidelines.¹⁴ Public-access defibrillation programs have been promoted in Japan since July 2004.¹⁴

2.3. ELST certification

There are two options to becoming certified as an ELST in Japan.¹¹ The first is through the educational system within the fire department itself. To become an Emergency Medical Technician (EMT), all fire department personnel are required to have received fundamental medical education in emergency care for 250 h through a training academy. After being actively engaged in pre-hospital setting as an EMT for more than 5 years or 2000 h, EMTs must pass the national examination of ELST after having received at least one additional year of medical education and training at the fire academy. The second way is through the education system in an accredited EMT school or college. To become an ELST, candidates must pass the national examination of ELST after receiving medical education and training in emergency care at the certified EMT school or college for at least two years. The cumulative number of ELSTs has increased gradually in Osaka City and reached to 508 in 2007 since the ELST system started in 1991.¹³

2.4. Data collection and processing

Data were prospectively collected using a data collection tool designed by the project steering committee. Included were all core data elements recommended in the Utstein style for OHCA,^{9,10} including age, sex, etiology, first documented rhythm, resuscitation time-course, bystander-initiated CPR, location of arrest, advanced airway placement, adrenaline administration, year, field return of spontaneous circulation (ROSC), total ROSC, hospital admission, and one-month survival and neurological status at one month after the event as well as the number of on-scene ELSTs. Resuscitation time-course included a series of EMS-related times such as call, the initiation of CPR, departure at the scene, and hospital arrival. ROSC was defined as the restoration of a sustained spontaneous perfusing rhythm.^{9,10} The data sheet was filled out by the EMS personnel in cooperation with the physicians in charge of the patient. It was then transferred to the Information Center for Emergency Medical Services of Osaka and reviewed by the investigators. If the information provided on the data sheet was unclear or incomplete, it was returned to the appropriate EMS personnel for completion.

2.5. Methods of measurement

All survivors were followed for up to one month after the event, and the neurological outcomes were determined by the physician responsible for the care of the patient. Neurological status was determined using the Cerebral Performance Category (CPC) scale: category 1, good cerebral performance; category 2, moderate cerebral disability; category 3, severe cerebral disability; category 4, coma or vegetative state; and category 5, death.^{9,10} Neurologically favorable survival was defined as a CPC category 1 or 2.^{9,10} The primary outcome measure was one-month survival with favorable neurological outcome. Secondary outcomes included field ROSC, total ROSC, hospital admission, and one-month survival.

2.6. Primary data analysis

Patient characteristics, EMS characteristics, and outcomes among bystander-witnessed OHCA patients were evaluated after grouping the EMS scene personnel based on the number of ELSTs

(One ELST plus two EMTs, two ELSTs and one EMT, or three ELSTs [no EMT]). Patient characteristics were compared using chi-square test for categorical variables and one-way analysis of variance for numerical variables. EMS characteristics such as procedures and care time intervals by EMS were tested with univariable regression models for categorical variables and linear tests for numerical variables. Multivariable logistic regression models were used to assess the contribution of the number of on-scene ELSTs to the outcomes referring to one ELST. Odds ratios (ORs) and their 95% confidence intervals (CIs) were calculated after adjusting for potential confounding factors that were biologically essential and considered to be associated with outcomes were included in the multivariable analysis. Those factors included age (for one year old increase), sex (male or female), etiology (presumed cardiac or non-cardiac), first documented rhythms (VF or others), location of arrest (public or not), bystander CPR (yes or no), advanced airway management (yes or no), epinephrine administration (yes or no), and the time interval from call to CPR by EMS (for one minute increase), and year (for one year increase). All statistical analyses were performed using SPSS statistical package ver16.0J (SPSS, Inc., Chicago, IL). All tests were 2-tailed, and P values of <0.05 were considered statistically significant.

3. Results

3.1. Overview of OHCA patients in Osaka City

During these 3 years, a total of 6942 OHCA patients were registered (Fig. 1). Of them, 6849 were adults aged ≥ 18 years old,

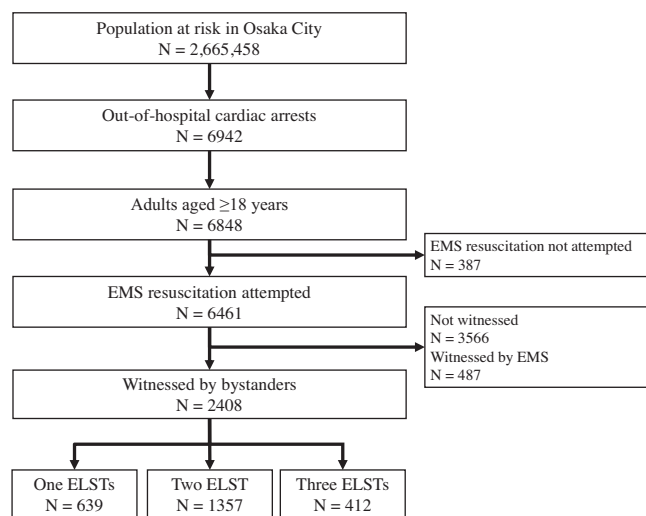


Fig. 1. Overview of out-of-hospital cardiac arrests with an abridged Utstein template from January 1, 2005 through December 31, 2007. EMS, emergency medical service; ELST, emergency life-saving technician.

Table 1

Patient characteristics of bystander-witnessed out-of-hospital cardiac arrest by the number of ELSTs.

	The number of on-scene ELSTs			P value
	One ELST (N = 639)	Two ELSTs (N = 1357)	Three ELSTs (N = 412)	
Age, year, mean (SD)	68.9 (17.4)	69.8 (16.8)	68.7 (17.2)	0.950
Men, n (%)	423 (66.2)	840 (61.9)	272 (66.0)	0.101
Cardiac etiology, n (%)	414 (64.8)	927 (68.3)	284 (68.9)	0.231
VF as first documented rhythm, n (%) ^a	109 (17.1)	227 (16.8)	70 (17.1)	0.981
Public location, n (%)	138 (21.6)	288 (21.2)	82 (19.9)	0.794
Bystander CPR, n (%)	214 (33.5)	428 (31.5)	158 (38.3)	0.036

ELST denotes emergency life-saving technician; VF, ventricular fibrillation; CPR, cardiopulmonary resuscitation; SD, standard deviation.

^a Data on VF were missing for 14 (0.6%) patients.

and 6461 were attempted resuscitation by EMS. A total of 2408 bystander-witnessed OHCA patients were eligible for our analyses excluding 487 patients witnessed by EMS and 3566 patients without witness. Among these patients, 639 (26.5%) received basic life support (BLS) or advanced life support (ALS) procedures by one ELST on the scene, 1357 (56.4%) two ELSTs, and 412 (17.1%) three ELSTs, respectively. The proportion of on-scene three ELSTs did not significantly increase during the study period.

3.2. Patient characteristics by the number of on-scene ELSTs

Table 1 shows the patient characteristics of bystander-witnessed OHCA by the number of on-scene ELSTs. Mean age and the proportion of male, public places, VF as first documented rhythm, and presumed cardiac etiology were similar between the three groups. The proportion of patients with bystander CPR was significantly different between the groups ($P=0.036$).

3.3. EMS characteristics by the number of on-scene ELSTs

EMS advanced interventions and activity times of bystander-witnessed OHCA by the number of on-scene ELSTs are noted in Table 2. The proportion of adrenaline administration (from 4.7% in the one ELST group to 14.1% in the three ELST group, P for trend <0.001) and advanced airway management (from 78.2% in the one ELST group to 83.5% in the three ELST group, P for trend = 0.003) was significantly higher as the number of on-scene ELSTs increased. The EMS scene time also increased with the presence of more ELSTs (from 12.4 minutes in the one ELST group to 13.5 minutes in the three ELST group, P for trend = 0.001) whereas the time interval from 119 call to CPR initiation by EMS remained the same.

3.4. Outcomes by the number of ELSTs

Table 3 shows the outcomes from bystander-witnessed OHCA by the number of on-scene ELSTs. The three ELST group had a significantly higher rate of one-month survival with favorable neurological outcome compared with the one ELST group (8.0% versus 4.5%, adjusted OR 2.26, 95% CI 1.27–4.04). However, the two ELST group did not (5.4% versus 4.5%, adjusted OR 1.34, 95% CI 0.82–2.19). However, increasing the number of on-scene ELSTs did not significantly improve field ROSC, total ROSC, hospital admission, and one month survival after OHCA.

3.5. Factors associated with favorable neurological outcome

In the multivariable analysis, factors associated with one-month survival with favorable neurological outcome are shown as a forest plot in Fig. 2. Younger age (adjusted OR for one year old increase 0.99, 95% CI 0.97–0.99), presumed cardiac etiology (adjusted OR 2.24, 95% CI 1.25–4.02), VF as first documented rhythm (adjusted

Table 2
EMS characteristics of bystander-witnessed out-of-hospital cardiac arrest by the number of ELSTs.

	The number of on-scene ELSTs			P for trend
	One ELST (N = 639)	Two ELSTs (N = 1357)	Three ELSTs (N = 412)	
Adrenaline, n (%)	30 (4.7)	136 (10.0)	58 (14.1)	<0.001
Advanced airway, n (%)	500 (78.2)	1099 (81.0)	44 (83.5)	0.003
EMS care interval, min, mean (SD)				
Call to EMS CPR start	8.3 (3.4)	8.0 (3.0)	8.1 (3.4)	0.171
EMS scene time	12.4 (5.1)	12.9 (5.2)	13.5 (5.5)	0.001

ELST denotes emergency life-saving technician; EMS, emergency medical service; CPR, cardiopulmonary resuscitation; SD, standard deviation.

Table 3
Outcomes from bystander-witnessed out-of-hospital cardiac arrest by the number of ELSTs.

	Total (N = 2408)	The number of on-scene ELSTs		
		One ELST (N = 639)	Two ELSTs (N = 1357)	Three ELSTs (N = 412)
Field ROSC, n (%)	318 (13.2)	75 (11.7)	175 (12.9)	68 (16.5)
Adjusted OR (95% CI)		Reference	1.07 (0.78–1.45)	1.41 (0.96–2.07)
Total ROSC, n (%)	1030 (42.8)	265 (41.5)	77 (42.5)	188 (45.6)
Adjusted OR (95% CI)		Reference	1.03 (0.84–1.25)	1.17 (0.90–1.51)
Hospital admission, n (%)	57 (35.6)	212 (33.2)	488 (36.0)	157 (38.1)
Adjusted OR (95% CI)		Reference	1.14 (0.93–1.40)	1.24 (0.95–1.62)
One-month survival, n (%)	281 (11.7)	69 (10.8)	160 (11.8)	52 (12.6)
Adjusted OR (95% CI)		Reference	1.15 (0.84–1.59)	1.24 (0.82–1.87)
CPC 1 or 2, n (%)	135 (5.6)	29 (4.5)	73 (5.4)	33 (8.0)
Adjusted OR (95% CI)		Reference	1.34 (0.82–2.19)	2.26 (1.27–4.04)

ELST, denotes emergency life-saving technician; ROSC, return of spontaneous circulation; CPC, cerebral performance category; OR, odds ratio; CI, confidence interval. ORs were calculated after adjusting for age, gender, etiology, first documented rhythm, location, bystander CPR, advanced airway management, epinephrine administration, call to CPR time by EMS, and year.

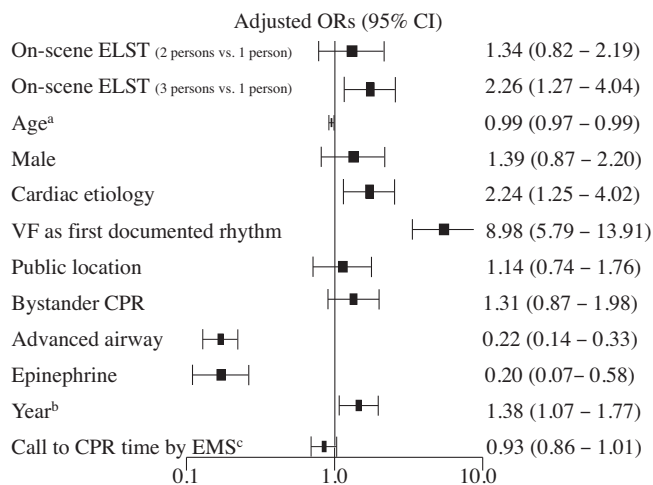


Fig. 2. Multivariable-adjusted odds ratios for one-month neurologically favorable survival. OR, odds ratio; CI, confidence interval; VF, ventricular fibrillation; CPR, cardiopulmonary resuscitation; ELST, emergency life-saving technician; EMS, emergency medical service. ^aOR for one year old increase, ^bOR for one year increase, ^cOR for one minute increase.

OR 8.98, 95% CI 5.79–13.91), and year (adjusted OR for one year increase 1.38, 95% CI 1.07–1.77) were also associated with a better neurological outcome. Advanced airway management (adjusted OR 0.22, 95% CI 0.14–0.33) and epinephrine administration (adjusted OR 0.20, 95% CI 0.07–0.58) were associated with a worse outcome.

4. Discussion

From this large, prospective registry in Osaka City, we demonstrated that the three on-scene ELST group was associated with the improved one-month survival with favorable neurological outcome from OHCA compared with the one on-scene ELST group.

Since ELST program started in 1991, the Fire and Disaster Management Agency of Japan has recommended that each ambulance be staffed with a 3-person unit including at least one ELST. The cumulative number of certified ELSTs in Japan was reported to be 21,268 in 2010.⁵ However, the impact of increasing the number of on-scene ELSTs has been insufficiently investigated to date. The results from this study will provide additional useful information on the design and structure of EMS systems in Japan and elsewhere.

Why did on-scene participation of three ELSTs contribute to improving favorable neurological outcome from OHCA? Although the proportion of advanced airway management and adrenaline administration increased with increasing the number of on-scene ELSTs in this target area, these treatment factors did not contribute to improving one-month survival with favorable neurological outcome from OHCA in the multivariable analysis. Far from it, they seemed to be associated with a worse outcome like some previous observational studies suggested.^{15,16} However, we consider that there should be an inversion phenomenon of cause-and-effect and it would be difficult to assess the effect of ALS measures in this observational study, because EMS personnel in Japan could provide advanced life support measures only for OHCA patients who did not get ROSC by basic life support such as chest compressions and defibrillations. The adjustment in the multivariable analysis for epinephrine administration and use of advanced airways procedures which were used more extensively when there were more trained EMS personnel might be questioned, but the analysis without these variables also produced the same conclusions. Previous observational studies showed that the procedural experience of paramedics was associated with the improved outcome after pre-hospital cardiac arrests.^{17–19} Of note, that paper also showed no effect of the years of treatment decision making on outcomes from cardiac arrest.¹⁹ Because ELSTs in Japan are well-trained and have accumulated their on-scene experience to obtain the certification as described in the Methods, on-scene participation of the multiple ELSTs with more clinical experience might lead to better CPR quality and improve team dynamics and crew resource management, and resulted in better outcomes from OHCA.

While favorable neurological outcome significantly differed by the number of ELSTs, there were no significant associations between the ELST groups and other outcomes, although all adjusted ORs were greater than one. Our previous report suggesting the effectiveness of CPR by bystanders also showed significant difference only in neurological outcome while there were no difference in other outcomes.²⁰ Different from advanced treatments like epinephrine administration,^{12,15} the effectiveness of CPR or the CPR quality might tend to be greater in neurological function rather than other outcomes, and this discrepancy also might suggest that on-scene participation of the multiple ELSTs contribute better neurological outcomes by improving CPR quality. In addition, the improvement in favorable neurological outcome during the study period could be partially explained by the changes of the CPR guideline,²¹ which might contribute to improve the CPR quality by EMS. Unfortunately, we did not have detailed information on CPR quality measures or team dynamics between ELSTs. We are now prospectively collecting these data in the designated target area and hope to address this issue in a future study.

Other published observational studies have not been able to demonstrate the benefits from having additional advanced trained providers such as paramedics on scene on survival or resuscitation process measures.^{6,7} One study demonstrated decreased survival rates as the number of on-scene paramedics increased,⁶ and suggested that the CPR quality was more important than the number of paramedics themselves. If so, both this study and our study, which look like different results, might suggest the same thing (i.e., importance of improving the CPR quality). In addition, there are several reasons why these findings are different from ours. This study used an OHCA data registry from a two tiered EMS system. Osaka has a single tier EMS system and is one of the most advanced areas of prehospital cares and has a considerable high rate of favorable neurological outcome.⁴ These differences in EMS system might affect the effect of the number of EMS personnel. Although a previous report showed that two tiered system are more effective than single tiered systems with regards to improved survival from OHCA,²² such systems might reduce the effectiveness of the having a higher number of trained personnel on scene.

Furthermore, differences in the prehospital emergency systems between Japan and western countries might also have affected the differences in the effects seen from having a higher number of more trained providers on scene. Unlike paramedics from western countries, highly-trained ELSTs in Japan are only permitted to perform ALS procedures during resuscitation efforts.^{11,23} In addition, EMS providers were not permitted to terminate resuscitation in the field.^{3,24} These differences in the training levels of ELST vs. paramedics from western countries require further study.

Importantly, the number of ELSTs needed within EMS in Japan deserves discussion, even if the increased number of on-scene ELSTs contributed to improving the outcome from OHCA in this study. Potential disadvantages of having more ELSTs on the scene include decreased procedural experience per ELST. It is also very expensive to train and maintain the skills of EMS personnel¹¹ and the cost-effectiveness of any EMS system structure changes should be considered as well. Clearly, more studies are needed to assess the association between the increased number of on-scene ELSTs, the skills performed and the OHCA outcome to better understand how to best deploy the most efficient and cost-effective emergency medical system.

This study has some inherent limitations, however. First, we did not obtain data on the ELST certification basis (college training vs. practice pathway) or experience level, both of which could have an influence on the outcomes. In addition, we were not able to classify the exact ELST level (additional certification is required for endotracheal intubation or/and adrenaline administration). Secondly, CPR quality measures which have been associated with outcomes from

OHCA (compression rate, compression depth, CPR fraction, per-shock pauses and ventilation rate) were not available for analysis in this study.^{25,26} Third, our data does not address potential impact of post-resuscitation care within hospitals (hemodynamic support, induced hypothermia, and coronary interventional therapies).²⁷ Fourth, CPC scores might be biased due to physician's invested interest in the patient's outcome. Finally, this was not a randomized controlled trial and although we adjusted for Utstein confounding variables in the multivariable analysis, other unknown confounding factors might exist which may have affected our findings.

5. Conclusions

Compared with the one on-scene ELST group, the three on-scene ELST group was associated with the improved one-month survival with favorable neurological outcome from OHCA in Osaka City. Additional studies are required to further understand these findings.

Conflict of interest

There are no conflicts of interest to declare.

Role of funding source

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