International Journal of Cardiovascular Diseases & Diagnosis

Research Article

70% of OHCA Receiving PAD Has Cardiac Arrest EGC Waveform - An Analysis of the Initial Electrocardiogram upon EMS Arrivals -

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Submitted: 11 September 2017; **Approved:** 14 September 2017; **Published:** 17 September 2017

Citation this article: Furukawa S, Tanaka H, Shirakawa T, Sagisaka R, Tanaka S, et al. 70% of OHCA Receiving PAD Has Cardiac Arrest EGC Waveform - An Analysis of the Initial Electrocardiogram upon EMS Arrivals. Int J Cardiovasc Dis Diagn. 2017;2(2): 036-042.

ABSTRACT

Background: Importance of bystander Cardiopulmonary Resuscitation (CPR) and Automated External Defibrillator (AED) has been illuminated and over decays. But, it is little known about Electrocardiogram (ECG) change after Public Access Defibrillation (PAD) by citizens.

Aim: We evaluated the relationship between the initial Electrocardiography (ECG) rhythm on the EMS arrival and outcomes who received PAD.

Methods: In this retrospective nationwide observational study, a total of 61,838 witnessed cardiogenic OHCA with bystander CPR between 2005 and 2012 were used. Patients were divided into two groups and compared as follows: PAD group (n=2,643) and No-PAD group (n=59,195). The primary outcomes were return of spontaneous circulation (ROSC) on the field and favorable neurological outcomes (CPC1or2) at one month sorted by ECG waveform on the EMS arrivals. Odds ratio and multiple logistic regression were used for multivariate analysis.

Results: We found that 31.2% of the PAD group reached field ROSC and remained 68.8 % manifested cardiac arrest ECG waveform (Ventricular Fibrillation, pulseless Ventricular Tachycardia, Pulseless Electrical Activity, and Asystole) upon EMS arrival. Therefore, the delivery of PAD was strongly related to increased rates of favorable neurological outcomes at one month (PAD group: AOR, 6.01; 95% CI, 5.55 to 6.51: No-PAD group: AOR, 8.10; 95% CI, 7.44 to 8.81).

Conclusion: The delivery of PAD positively affects field ROSC and favorable neurological outcome, though 68.8 % of patients are still in cardiac arrest on the arrival of EMS. Not only continuous bystander CPR and AED, but also prompt EMS arrival and ALS treatment are extremely important for improve the chances of survival.

Keywords: PAD; Initial ECG; Favorable neurological outcom

BACKGROUND

Demand for ambulance transportation rapidly increases due to progressive aging population in recent Japan, and it led to delay response times [1]. Furthermore, the Japanese population has been adopting a more Westernized lifestyle and diet in recent times, leading to an increase in cardiogenic sudden deaths and stroke incidents. In order to increase resuscitation rates in cases of cardiogenic events, treatment by bystanders is of great importance, as well as the pre-hospital treatment delivered by Emergency Medical Service (EMS) crews[2].

Increasing the use of Public Access Defibrillation (PAD) delivered at the scene of cardiac arrest is one strong weapon for improving survival rates in cases of Out-Of-Hospital Cardiac Arrest (OHCA). In Japan, PAD has been permitted since 2014, and there have been more than 200 cases of PAD use reported since then [3,4]. This report revealed that one month post-arrest survival with favorable neurological outcomes has also been reported in around 45 % of OHCA cases in which PAD was used [4]. Kiyohara et al. analyzed the PAD delivered cases, and the increasing the number of AEDs positively affects to increasing favorable neurological outcomes [5].

However, not all PAD cases lead to favorable neurological outcomes; Return of Spontaneous Circulation (ROSC) would not be present in PAD cases. Many Japanese Utstein studies have focused on the favorable neurological outcomes of PAD use [3-5], but none have focused on patient condition after PAD use, or on the initial ECG and prognosis upon contact with the EMS. It is suggested that the initial ECG upon arrival of the EMS is directly linked to the effectiveness of the pre-hospital care, in particular bystander CPR and PAD delivered cases. In this study, we therefore examined the initial ECG upon arrival of the EMS after delivery of PAD in cases of OHCA, ROSC and favorable neurological outcomes at one month post-cardiac arrest.

METHOD

Study design

This was a nationwide retrospective observational study. The Utstein data collected for this study were corrected for various input errors in terms of numbers and timing, according to the statistical committee policy of the Fire and Disaster Management Agency (FDMA). We deleted all personal information, and applied for access to anonymous public domain data. This study was approved by the Institutional Review Board at Kokushikan University.

Setting

Japan has an area of 378 000 km^2, including both urban and rural communities, and the population was 127.5 million inhabitants in 2014

EMS systems

The EMS systems in Japan were composed fire departments operate EMS services, covered by a nationwide, single-tier, fire-based EMS system.

A single EMS number “119” is known as EMS call during nationwide. EMS dispatch, which is operated by local fire departments, which also gives CPR instructions via phone with hands-only CPR before EMS arrival (as T-CPR). Nationwide, the overall dispatcher-assisted T-CPR rate was 46% among all OHCA cases in 2012.

Lay rescuers bystander treatment

Bystander CPR and PAD for lay rescuers are recommended by the national 2010 resuscitation guidelines. In Japan, 3.5 million citizens per year participate in the CPR training programs offered by local fire departments, Japan Red Cross, driver’s license school, schools, nonprofit organizations and medical societies. Public Access Defibrillation (PAD) applied if AED is available near by the scene.

EMT Field protocol

All EMT field Basic Life Support (BLS) and ELST Advanced Life Support (ALS) protocols followed the 2005 and 2010. After an initial assessment and ECG rhythm is obtained by EMS provider, EMS defibrillation is applied. Advanced airways, for example Laryngeal Mask Airway (LMA), Combi-tube, King Airway, Esophageal Gastric Tube Airway (EGTA) and Endotracheal Tube (ET), are applied

if patients manifest difficulty with ventilation. Continuous BVM is selected when initial ventilation is successful. If patients do not have Return of Spontaneous Circulation (ROSC) after initial EMS defibrillation, an ELST can selected administered epinephrine administration for patients age more than 8-year-old with PEA, witnessed asystole (asystole without witnessed were excluded) and/or refractory VF/VT rhythms after shock. Thus, All of the ELSTs, they must follow EMS field protocol. After ELST procedure was done, post-verification process in all ALS and BLS protocol cases, as off-line medical control to be confirmed properly of these decisions.

Study population

A Total of 925,288 cases of witnessed cardiogenic OHCA with bystander CPR between in Jan 1 2005 and Dec 31 2012 were used in this study (Figure 1).

The following exclusion criteria were applied: age over the 115 and/or ECG unknown (n=15); physician on board or Advanced Life Support (ALS) provided by physician (n=193,201); non-cardiogenic cardiac arrest (n=322,992); unwitnessed cases (n=1,246,259), no bystander CPR given (n=100,019), unknown/unclear PAD status (n= 947). The study population composed remaining 61,838 witnessed cardiogenic OHCA with bystander CPR was extract (Figure 1).

Group and parameters

A total of 61,838 cases of witnessed cardiogenic OHCA with bystander CPR between in Jan 1 2005 and Dec 31 2012 were used in this study (Figure 1). We divided these cases into two groups: PAD delivered group (as PAD group; n = 2,643); and No-PAD delivered group (as No-PAD group; n = 59,195).

Following parameters were compared between the groups: Facial year trend of PAD, age, sex, bystander CPR, the classification of bystanders; EMS Advanced Life Support (ALS), call-to-contact time interval, and the arrival to hospital time. Return of Spontaneous Circulation (ROSC) and CPC scores 1 to 5 (CPC scores at one month post-arrest were used, where CPC 1 was 'Good cerebral performance' ,CPC 2 'Moderate cerebral disability', CPC 3 'Fair cerebral disability', CPC 4 'Poor cerebral disability', CPC 5 'very poor cerebral disability') at one month post-arrest. Also, initial ECG rhythm upon EMS arrival including, Ventricular Fibrillation (VF), pulseless Ventricular Tachycardia (VT), Pulseless Electrical Activity (PEA), and Asystole are compared between the groups.

Outcomes

We compared the background of patients of the PAD delivered group (PAD group) with the No-PAD delivered group (No-PAD group). The primary outcomes examined were as follows: year trend of PAD, age, sex, the classification of bystanders, bystander CPR, EMS treatment, call-to-contact time interval (Response time), and hospital arrival time.

We also analyzed the initial ECG upon arrival of the EMS, including Ventricular Fibrillation (VF), pulseless Ventricular Tachycardia (VT), Pulseless Electrical Activity (PEA), and Asystole between the two groups.

Study end point

Return of Spontaneous Circulation (ROSC) and CPC scores 1 to 5 were used. For the definition of favorable cerebral outcomes, CPC scores at one month post-arrest were used, where CPC 1 was 'Good cerebral performance,' CPC 2 'Moderate cerebral disability,' CPC 3 'Fair cerebral disability,' CPC 4 'Poor cerebral disability' and CPC 5 'very poor cerebral disability.' The primary outcomes were rate of field ROSC and the occurrence of CPC scores 1 and 2 at one month post-arrest sorted by ECG rhythm upon EMS arrival.

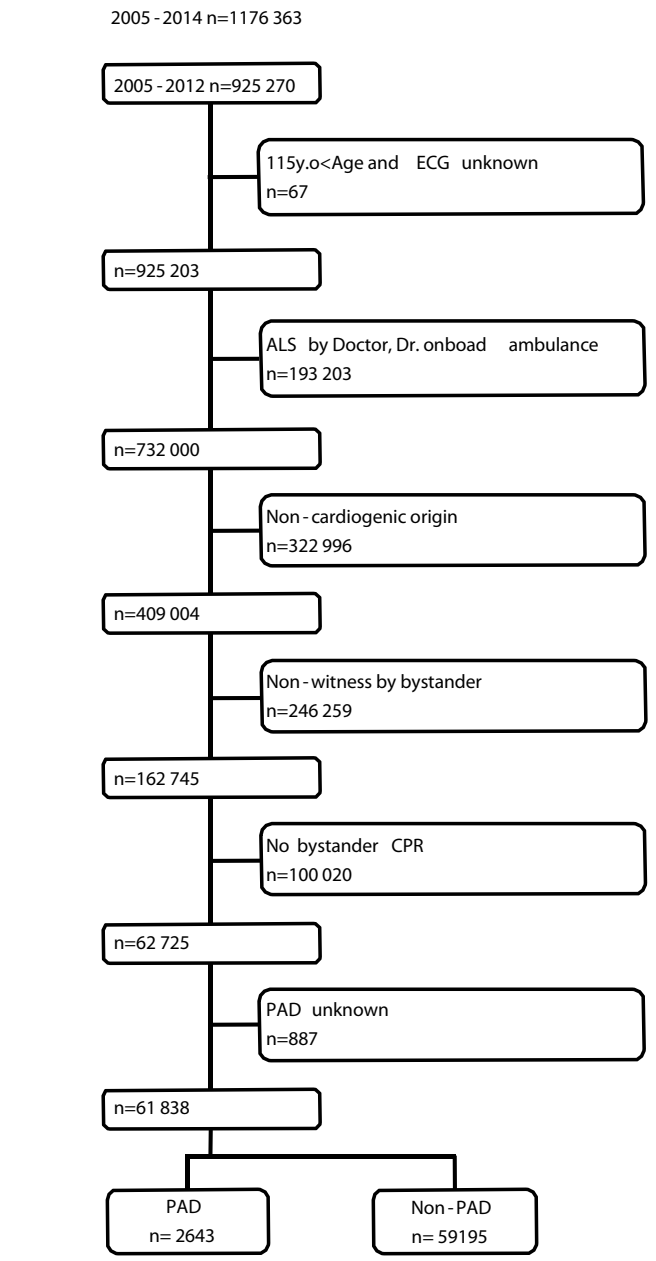

Figure 1: Study exclusion and inclusion criteria.

Statistical analysis

We used standardized difference to compare the patients' characteristics. Statistical tests depending on the number of cases were not used. Univariable logistic regression was fitted to estimate effect of PAD on favorable outcomes after OHCA. Odds ratio and 95% confidence was estimated. All analysis were performed by using JMP ver. 11.2 (the SAS Institute Inc., Cary, NC).

RESULTS

Group characteristics

The background factors categorizing the PAD delivered and No-

PAD delivered groups are shown in (Table 1). Number of PAD use increased year on year as only 26 cases (0.4 %) were recorded in 2005, but there were 725 cases (6.6 %) in 2012. In terms of gender, 77.5 % of the PAD delivered group were males; and 58.6 % of the No-PAD group were females (Table 1). From this result, it can be seen female patients received PAD less frequently than male patients, and that bystanders are more hesitant in using AED on females.

In the PAD group, 49.7 % of the bystander CPR performed was by others, followed by 15.1 % by colleague, 11.8 % by friends, and 11.7 % by pedestrian (Table 1). However, family members prominently performed CPR in 56.7 % and others performed CPR in 30.4 % of the No-PAD group. In other words, the No-PAD group took place the most at home, whereas the PAD group held outdoors in many cases.

Significant difference was found in the EMS defibrillation between the two groups (Table 1). Regarding the standing order from online medical control, there was 37.3 % of the PAD delivered group performed EMS defibrillation, but only 26.8 % of the No-PAD group did it. No difference was found in the use of airway control and epinephrine administration. There was no difference in response time and hospital arrival time between the two groups.

Initial ECG upon EMS arrival, ROSC and CPC1-2

The relation between the results of the initial ECG upon EMS arrival and ROSC and neurological outcomes of the two groups are shown in Table 2. On the ECG upon EMS arrival, VF and pulseless VT were shown in 29.7 % of the PAD group; PEA in 18.9 %; Asystole in 20.2 %; and other ECG wave (include sinus rhythm) in 31.2 % (Table 2). We found that in 68.8 % of the PAD delivered cases, patients were in cardiac arrest, with VF, pulseless VT, PEA, and Asystole readings. In other words, 68.8 % had a cardiac arrest waveform. Only 31.2 % were presumed to be achieved ROSC due to the delivery of PAD.

In the No-PAD group, VF and pulseless VT were present in 22.8 %; PEA in 27.5 %; Asystole in 45.6 %; and others in 4.0 % (Table 2). Approximately 96 % of the No-PAD groups were in cardiac arrest when the EMS arrived. Only 13.8 % of the No-PAD group achieved field ROSC, whereas 49.8 % of the PAD group achieved.

CPC 1 or 2 at one month post-arrest were achieved in 38.4 % of the PAD group and 7.2% of the No-PAD group. The rate of CPC 3-5 at one month post-arrest was significantly higher in the No-PAD group, at 86.2 %, when compared to the PAD group, which stood at 61.6 %. It is therefore clear that early PAD delivery is significantly effective in improving subsequent neurological function outcomes. The delivery of PAD was directly linked to increased rates of ROSC and CPC1-2 at one month survival (PAD group: adjusted odds ratio [AOR], 6.01: 95 % Confidence Interval [CI], 5.55 to 6.51; No-PAD group: AOR, 8.10: 95 % CI, 7.44 to 8.81).

Table 1: Group Characteristics.

	PAD Group (n=2643) (%)		No-PAD Group (n=59195) (%)		Standardized Difference %
Year Trend, n (%)					
2005	26	(1.0)	6033	(10.2)	-40.9
2006	96	(3.6)	6611	(11.2)	-29.1
2007	215	(8.1)	6669	(11.3)	-10.6
2008	324	(12.3)	7868	(13.3)	-3.1
2009	120	(4.5)	2567	(4.3)	1.0
2010	522	(19.8)	8946	(15.1)	12.3
2011	615	(23.3)	10210	(17.3)	15.0
2012	725	(27.4)	10291	(17.4)	24.3
Age, mean (S.D.)	63.6	(18.7)	74.5	(16.7)	11.0
Male, n (%)	2047	(77.5)	34683	(58.6)	41.3
Bystander, n (%)					
Family	245	(9.3)	33589	(56.7)	-116.9
Friend	311	(11.8)	2420	(4.1)	28.7
Colleague	398	(15.1)	2135	(3.6)	40.1
Pedestrian	310	(11.7)	1817	(3.1)	33.5
Fire fighter	12	(0.5)	113	(0.2)	4.6
EMT	17	(0.6)	307	(0.5)	1.6
Paramedic	36	(1.4)	782	(1.3)	0.3
Others	1313	(49.7)	18015	(30.4)	40.1
Unknown	1	(0.0)	16	(0.0)	-2.4
Bystander CPR, n (%)					
Chest compression only	1190	(47.1)	39502	(68.2)	-43.8
Conventional CPR	1336	(52.9)	18383	(31.8)	43.8
EMS treatment, n (%)					
defibrillation	985	(37.3)	15886	(26.8)	22.6
epinephrine	386	(14.6)	8571	(14.5)	0.5
advanced airway manage	759	(28.8)	28230	(47.7)	-39.7
Response time, min (S.D.)	9	(3.6)	8.8	(3.4)	4.0
Hospital arrival time, min (S.D.)	32.7	(11.7)	32.2	(11.0)	6.5

PAD, public access defibrillation; S.D., standard deviation; CPR, cardiopulmonary resuscitation; EMS: Emergency Medical Service
Categorical factors; no. %, Continuous factors; mean SD

Table 2: Initial ECG at EMS arrival and treatment between the groups.

	PAD Group n=2643		No-PAD group n=59195		Odd Ratio
Initial ECG rhythm at EMT					
VF pulseless VT	786	(29.7)	13515	(22.8)	1.43 (1.31-1.56)
PEA	499	(18.9)	16276	(27.5)	0.61 (0.56-0.68)
Asystole	533	(20.2)	27012	(45.6)	0.30 (0.27-0.33)
Others	825	(31.2)	2391	(4.0)	10.78 (9.83-11.82)
ROSC					
Field ROSC	1295	(49.0)	8163	(13.8)	6.01 (5.55-6.51)
Neurological outcome					
CPC 1 to 2	1016	(38.4)	4234	(7.2)	8.10 (7.44-8.81)
CPC 3 to 5	1627	(1.6)	51031	(86.2)	0.12 (0.11-0.13)

PAD, public access defibrillation; ECG, electrocardiogram; EMT, Emergency Medical Technician; VF, ventricular fibrillation; VT, ventricular tachycardia; PEA, pulseless electrical activity; ROSC, return of spontaneous circulation; CPC, Cerebral performance category

Relationship between the initial ECG upon EMS arrival and favorable neurological outcomes in the PAD and No-PAD groups

Favorable neurological outcomes sorted by the initial ECG upon EMS arrival between the PAD and No-PAD groups given in Table 3. In the PAD group, 29.4 % of patients were presented VF and pulseless VT on the scene achieved CPC 1 or 2 at one month post-arrest; PEA in 7.8 %; Asystole in 1.2 %; and others including sinus rhythm in 61.3 % (Table 3). Approximately 30 % of PAD delivered cases were indicated the presence of refractory VF and pulseless VT. The remaining 70 % were not reached ROSC when the EMS arrived, which confirmed the effectiveness of the delivery of PAD indicating more prominent in field ROSC than CPC1-2. Favorable cerebral function was present in over 61.3 % of cases of miscellaneous rhythm. VF and pulseless VT were continuously maintained in 29.4 % of cases, so we assumed that was refractory VF, which suggests EMTs need to provide more aggressive ALS treatment.

In terms of the ratio for the achievement of CPC 1 or 2 at one month post-arrest in the No-PAD group, 67.8 % of patients who were presented VF and pulseless VT on the scene achieved CPC 1 or 2 at one month post-arrest; PEA in 7.4 %; Asystole in 3.3 %; and miscellaneous in 21.5 % (Table 3).

DISCUSSION

In this study, we compared the readings of CPC 1 and 2 and field ROSC at one month post-arrest in OHCA with or without PAD delivered group. We found that 68.8 % of the PAD group were considered to still be in cardiac arrest waveform (VF, pulseless VT, PEA, and Asystole) when the initial ECG was taken by the EMS arrival. Therefore, PAD use was strongly related to increased rates of field ROSC and CPC1-2 at one month survival.

To improve OHCA outcomes, the following factors are particularly important: early recognition of cardiac arrest by the layperson, dispatcher-assisted CPR, PAD, and improvements in the EMS system. Advanced Life Support (ALS) is believed to directly increase the chances of OHCA patient survival, and the effectiveness of PAD and EMS defibrillation depends on how promptly these can be delivered [2]. In recent years, delivery of PAD has led to increasing survival rates around the world, and that it is a major factor in improving favorable cerebral outcomes [7-9].

Kitamura et al. reported that favorable cerebral outcomes at one month post-arrest improved to 19.2 % from 10.6 % in cardiac arrest cases where AED was used, during the three years, with AED implementation increasing tenfold during this period [4]. A previous study by Kiyohara et al. indicated only 3.5 % of OHCA cases involved the applying of public-access AED pads [5,6]. In terms of a favorable neurological outcome at one month, 19.4 % of patients who had had an AED applied had such an outcome; whereas those who did not were just 3.0 %. Researchers concluded that AED application leads to favorable outcomes in OHCA cases, but that the usage of available equipment was insufficient. However, Hedge et al. suggested that the combination of bystander CPR and AED use was much more effective than AED use only [8,9]. We have emphasized the importance of bystander CPR in cases where PAD has been delivered.

From our results, we would like to emphasize the fact that only 31.2 % of cases in the PAD group reached ROSC when EMS arrived on the scene; the remaining 68.8 % were still in cardiac arrest. This is a significantly important result. In the No-PAD group, 96.0 % of cases were still in cardiac arrest, as follows: 22.8 % in VF/pulseless VT; 27.5 % in PEA; 45.6 % in Asystole; and 4.0 % in miscellaneous. Continuous bystander CPR is desirable after PAD delivery, as is Advanced Life Support (ALS) by the EMS crew, including early defibrillation and CPR. Even in the PAD group, EMS treatments are extremely important for improving favorable cerebral outcomes. The rate of field ROSC in PAD group increased to 49.8 % until they were transported to the hospital. For this result, ALS treatment by EMS on the field is extremely important.

Upon EMS arrival, VF and pulseless VT were present in 22.8 % of cases, and these rhythms usually have a particular time-frame. Early bystander contact and prompt EMS response will increase the possibility of successful defibrillation, thus improving favorable cerebral outcomes.

Since 2004, the use of AED by non-healthcare professionals has been legally permitted by the Ministry of Health, Labor and Welfare in Japan, leading to the creation of the PAD system. Since then, Japan has provided AEDs at public facilities, residential blocks, and mass gathering events. Only 7,151 AEDs were provided in 2004; however, the placement of 330,000 AEDs was reported in 2010 and 650,000 in 2106, which indicates future growth of this provision. Recently, AEDs have been placed with vending machines, on a sightseeing bus, and in

Table 3: Favorable neurological outcome between the groups sorted by initial ECG rhythm.

Favorable neurological outcome sorted by Initial ECG rhythm by Initial ECG rhythm	PAD Group (n=2643)		No-PAD group (n=59195)	
VF pulseless VT	302	(29.4)	2873	(67.8)
PEA	79	(7.8)	313	(7.4)
Asystole	12	(1.2)	139	(3.3)
Others	623	(61.3)	909	(21.5)

PAD: public access defibrillation; ECG: electrocardiogram; VF: ventricular fibrillation; VT: ventricular tachycardia; PEA: pulseless electrical activity

taxis [10]. At the 2005 Aichi International Exposition, an AED was provided for every 300 meters, and was used in five cardiac arrests [11]. Four cardiac arrests occurred at the Tokyo Marathon between 2007 and 2011, and all survived thanks to the use of AEDs, which played an important part in raising national awareness of AEDs [12]. Besides that, the following factors are considered the reason why its use is not increased: anxiety about the treatment and legal liability, a mismatch between the number of installations and the usage rate of AED [10].

However, only little is known about PAD treated OHCA cases often requires multiple defibrillations due to the presence of refractory VFs. In this reason, we carefully analyzed the ECGs of OHCA survival cases upon EMS arrival, comparing two groups. Higher VF and pulseless VT rate were present in the PAD group (29.7 %) than that of No-PAD group (22.8%). Higher PEA (27.5 %) and Asystole (45.6%) rate were present in the No-PAD group than that of the PAD group (18.9 % and 20.2 %, respectively) in the PAD group. Approximately 70 % of the PAD group were in cardiac arrest, but the fact that all resuscitated and had favorable cerebral outcomes on account of ALS treatment by EMS was found.

We assume that favorable cerebral outcomes could further improve if earlier defibrillation could be performed by citizens and EMS crew. From our data, the rate of field ROSC reached 49.8 % in the PAD group and 13.8 % in the No-PAD group. The rate of EMS defibrillation reached 37.3 % in the PAD group and 26.8 % in the No-PAD group. It significantly relates to field ROSC (AOR, 6.01; 95% CI, 5.55 to 6.51) and CPC1 or 2 (AOR, 8.10; 95% CI, 7.44 to 8.81) in the PAD group.

For the future, in order to increase the favorable neurological outcomes in cases of cardiogenic OHCA, we propose four measures in particular for improving the Chain of Survival: 1) to educate bystanders in continuous CPR, 2) to place AED appropriate location where citizens are able to access it at any time, 3) an improvement in response times on the part of the EMS, to allow speedy performing of appropriate BLS/ALS treatment.

CONCLUSION

In our study, we compared the field ROSC and CPC 1-2 at one month post-arrest in OHCA between two groups, PAD or No-PAD group. When the ECG was taken by the EMS, we found that 68.8 % of the PAD group was still in cardiac arrest waveform including VF, pulseless VT, PEA, and Asystole. Therefore, the delivery of PAD was strongly increased rates of field ROSC and CPC 1-2 at one month survival. Regarding the rate of field ROSC, 49.8 % was found in the PAD group, and 13.8% was found in the No-PAD group. The rate of EMS defibrillation was higher in the PAD group than that of the No-PAD group (37.3% and 26.8%, respectively). This indicated that the prompt ALS treatment upon EMS arrival was essential and had a positive impact on the patient's chances of survival, following delivery of PAD.

Also, our results highlighted the importance of bystander CPR. The performing of bystander CPR is important during the time period between PAD delivery and EMS arrival. There is therefore a clear need to educate bystanders in what to do after the delivery of PAD. There is also a need to change in the law to allow the performing of additional, advanced treatment. These measures would significantly help in improving Japanese favorable neurological outcomes in cases of cardiogenic OHCA.

ACKNOWLEDGMENTS

We would like to express our great thank and respect for all Fire department EMTs, and ELSTs in Japan for their tireless efforts.

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