Impact of Automated External Defibrillator as a Recent Innovation for the Resuscitation of Cardiac Arrest Patients in an Urban City of Japan

Ikuto Takeuchi, Hiroki Nagasawa, Kei Jitsuiki, Akhiko Kondo, Hiromichi Ohsaka, Youichi Yanagawa
Department of Acute Critical Care Medicine, Shizuoka Hospital, Juntendo University, Tokyo, Japan

Abstract

Context/Aims: We retrospectively analyzed the characteristics of prehospital care for cardiopulmonary arrest (CPA) to identify the predictors of a good recovery (GR) among the recent changes in the management of Japanese prehospital care. Settings and Design: This study was a retrospective medical chart review. Subjects and Methods: We reviewed the transportation records written by emergency medical technicians and the characteristics of prehospital management of out-of-hospital (oh) CPA described by the Sunto-Izu Fire Department from April 2016 to March 2017. The cases were divided into two groups: a GR group (cerebral performance category of 1–3 at 1 month after CPA) and a poor recovery (PR) group. Results: During the analysis period, there were 545 cases of CPA. The average age in the GR group (n = 19) was significantly younger than that in the PR group. The proportions of patients with witnessed collapse, automated external defibrillator (AED) executed by a bystander, ventricular fibrillation during prehospital cardiopulmonary resuscitation (CPR), defibrillation-induced cardioversion, cardiogenic arrest, and oh-return of spontaneous circulation (ROSC) were significantly greater in the GR group than in the PR group. The proportions of telephone CPR conducted by operator, instrumentally secured airways, and administration of epinephrine were significantly smaller in the GR group than in the PR group. A multivariate analysis showed that the significant predictors of GR were bystander AED, ROSC, not instrumentally secured airway, and younger age. Conclusions: This study showed that patients with CPA who were younger, underwent AED executed by a bystander, and obtained oh-ROSC had a higher chance of a favorable outcome.

Keywords: Adrenaline, automated external defibrillator, prehospital care, supraglottic airway, telephone cardiopulmonary resuscitation

INTRODUCTION

In Japan, the rate of a favorable outcome after cardiopulmonary arrest (CPA) is still low at 1.9%–3.1%.[1] Efforts have been made to improve the chance of obtaining a favorable outcome after cardiac arrest, including the provision of advanced cardiac life support by emergency medical technicians (EMTs), the dispatch of physician-staffed helicopters, the application of hands-only cardiopulmonary resuscitation (CPR), the conduct of telephone CPR by an operator of the fire department, and the placement of automated external defibrillators (AEDs) in public spaces, such as hotels, corner stores, and police boxes in Japan.[2-6]

In Japan, the guidelines for prehospital care for CPA are changing. Local governments have established the emergency medical system (EMS) as a public service, and anyone can call an ambulance free of charge by dialing 119. Most local governments use a one-tier emergency system, with the fire department usually dispatching an EMS team of three EMTs in an ambulance after receiving a 119 call. However, in some areas, another ambulance carrying a team including a medical doctor from a local hospital may arrive at the scene at the same time. In 1991, EMTs who had undergone the necessary training were allowed to use semiautomatic defibrillators, secure peripheral venous access, and establish a supraglottic airway with an esophageal tracheal combitube, laryngeal mask, or tube. Since 2004, some EMTs have been allowed to
perform tracheal intubation after receiving special training. In addition, all EMTs can now use a semiautomatic defibrillator, while members of the public are able to use AEDs. Since 2006, some EMTs have been approved to administer 1 mg of epinephrine intravenously every 5 min until obtaining the return of spontaneous circulation (ROSC) after successfully securing venous access and obtaining permission from a medical doctor by telephone.[2-6] The Sunto-Izu Fire Department is located approximately 130 km from Tokyo and covers Numazu, Ito, Izu, Izunokuni, Higashi Izu, Kannami, and Shimizu City of Shizuoka Prefecture, which has a population of approximately 460,000. The Red Cross of Shizuoka Prefecture has published the location of AEDs in these areas. The Sunto-Izu Fire Department also provides basic life support (BLS) training for citizens, including instructions on how to use AEDs and how to perform hands-only CPR. In 2016, this fire department provided BLS 417 times and trained 11,109 citizens in BLS. Given the above-mentioned recent changes in the management of Japanese prehospital care, we retrospectively analyzed the characteristics of prehospital care for CPA to identify predictors of a good recovery (GR) in the area under the jurisdiction of the Sunto-Izu Fire Department.

**Subjects and Methods**

The protocol of this retrospective study was approved by the institutional review board, and the examinations were conducted in accordance with the standards of good clinical practice and the Declaration of Helsinki.

We retrospectively reviewed the transportation records written by EMTs and the characteristics of prehospital management of out-of-hospital (oh) CPA described by the Sunto-Izu Fire Department using the modified Utstein-style template from April 2016 to March 2017. All oh-CPA patients transported by the EMS were eligible for the study. We excluded patients who were neither treated nor transported by the EMS because of signs of death, such as rigor mortis or postmortem lividity, or unsurvivable injury (scoring 6 on the abbreviated injury scale). The EMS of the Sunto-Izu Fire Department of Shizuoka prefecture has five central stations (Numazu, Shimizu, Tagata, Ito, and Higashi-Izu), 597 staff members, and 139 vehicles. Each central station has 0–4 substations in 921 Km.[2] In this area, there were two acute critical care centers that mainly received patients with CPA. When the central station receives a 119 call, the nearest substation dispatches an EMS team in an ambulance. Each EMS team consists of three members.

The cases were divided into two groups: a GR group (cerebral performance category [CPC] of 1–3 at 1 month after CPA) and a poor recovery (PR) group (CPC of 4–5). CPC was defined as follows: (1) normal or mild cerebral disability; (2) moderate cerebral disability; (3) severe cerebral disability; (4) coma/vegetative state; and (5) dead.

The following variables were, respectively, analyzed between the two groups: sex, age, duration from first call to hospital arrival, witnessed collapse, telephone CPR conducted by operator, bystander CPR, bystander AED use, cause of arrest (presumed cardiogenic or noncardiogenic), rhythm strip electrocardiogram at scene, ventricular fibrillation during prehospital resuscitation, defibrillation, type of airway (tracheal intubation, supraglottic airway, or mask ventilation only), intravenous cannulation, administration of epinephrine, and ROSC.

Both the Chi-squared test and the nonpaired Student’s t-test were used for statistical analyses. A P value of <0.05 was considered statistically significant. A multivariate analysis using a partition analysis was used to evaluate the independent factors associated with GR separately using the JMP 12.0 statistical software program (SAS Japan Incorporation, Tokyo, Japan). The variables included in the multivariate analysis were those with significance levels of $P < 0.05$ based on a univariate analysis. Data are represented as the mean ± standard deviation.

**Results**

During the analysis period, there were 928 cases of CPA in the Sunto-Izu Fire Department of Shizuoka prefecture. Among them, 383 untransported cases were excluded due to the signs of death. The overall oh-ROSC rate was 3.8% ($n = 21$), and 3.4% of patients ($n = 19$) made a GR. Table 1 shows a comparison between the GR and PR groups. The average age in the GR group was significantly younger than that in the PR group. The proportions of patients with witnessed collapse, AED executed by a bystander, ventricular fibrillation during prehospital CPR, defibrillation-induced cardioversion, cardiogenic arrest, and oh-ROSC were significantly greater in the GR group than in the PR group. The proportions of telephone CPR conducted by an operator, instrumentally secured airways, and administration of epinephrine were significantly smaller in the GR group than in the PR group. The proportion of tracheal intubations did not differ significantly between the two groups. No patients obtained a GR after the prehospital administration of epinephrine.

A multivariate analysis revealed the following significant predictors of GR: bystander AED (LogWorth 5.4, $P < 0.0001$), ROSC (LogWorth 2.8, $P = 0.001$), not instrumentally secured airway (LogWorth 1.8, $P = 0.01$), and age (LogWorth 1.6, $P < 0.05$).

**Discussion**

This study showed that patients with CPA who were younger, underwent AED executed by a bystander, and obtained oh-ROSC had a higher chance of obtaining a favorable outcome. In contrast, a supraglottic airway was a negative predictor for a favorable outcome among the recent changes in the management of Japanese prehospital care.

This study demonstrated the importance of AED executed by a bystander among recent endeavors for improving the prognosis
Takeuchi, et al.: Impact of automated external defibrillator

In addition, not obtaining ROSC makes oh-ROSC had a higher chance of obtaining a favorable outcome among the recent changes in the management of Japanese prehospital care. Future studies should explore how patients with CPA receive AED. Based on the present findings, we do not recommend that EMTs try to establish a supraglottic airway.

### Table 1: Results of analysis between two groups

|                     | Good (CPC 1-3) (n=19), n (%) | Poor (CPC 4, 5) (n=526), n (%) | P       |
|---------------------|------------------------------|--------------------------------|---------|
| Sex (male/female)   | 9/10                         | 310/216                        | Not significant |
| Age (year)          | 64.2±12.4                    | 76.3±14.7                      | <0.0001 |
| Verbally instruction (yes/no) | 7/12 (36.8)                  | 330/196 (62.7)                 | <0.05   |
| Witness collapse (yes/no) | 17/2 (89.4)                  | 231/295 (43.9)                 | <0.0001 |
| Bystander (yes/no)  | 13/6 (68.4)                  | 247/279 (46.9)                 | 0.06    |
| Initial rhythm at scene |                             |                                |         |
| Sinus               | 11 (57.9)                    | 21 (3.9)                       | <0.0001 |
| VF                  | 5 (26.3)                     | 25 (4.7)                       |         |
| Pulseless electrical activity | 3 (15.8)                    | 130 (24.8)                     |         |
| Asystole            | 0                            | 350 (66.6)                     |         |
| VF during resuscitation (yes/no) | 7/12 (36.8)                  | 40/486 (7.6)                   | <0.0001 |
| Electrical shock (yes/no) | 5/14 (26.3)                  | 36/490 (6.8)                   | <0.05   |
| Return of spontaneous circulation (yes/no) | 4/15 (21.0)                  | 17/509 (3.2)                   | <0.0001 |
| AED executed by bystander (yes/no) | 8/11 (42.1)                  | 6/520 (1.1)                    | <0.0001 |
| Supraglottic airway (yes/no) | 3/16 (15.8)                  | 234/292 (44.4)                 | <0.01   |
| Tracheal intubation (yes/no) | 2/17 (10.5)                  | 20/506 (3.8)                   | Not significant |
| Venous route (yes/no) | 3/16 (15.8)                  | 184/342 (34.9)                 | Not significant |
| Adrenaline (yes/no) | 0                            | 87/439 (16.5)                  | <0.01   |
| Cardiogenic arrest (yes/no) | 15/4 (78.9)                  | 266/260 (50.5)                 | 0.01    |

Mean±SD. SD: Standard deviation, VF: Ventricular fibrillation, CPC: Cerebral performance category, AED: Automated external defibrillator

### Conclusions

This study showed that patients with CPA who were younger, underwent AED executed by a bystander, and obtained oh-ROSC had a higher chance of obtaining a favorable outcome among the recent changes in the management of Japanese prehospital care. Future studies should explore how patients with CPA receive AED. Based on the present findings, we do not recommend that EMTs try to establish a supraglottic airway.
Financial support and sponsorship
This work received funds from the Ministry of Education, Culture, Sports, Science and Technology (MEXT)-Supported Program for the Strategic Research Foundation at Private Universities, 2015-2019. The title is the constitution of total researching system for comprehensive disaster, medical management, corresponding to wide-scale disaster.

Conflicts of interest
There are no conflicts of interest.

REFERENCES
1. Hasegawa K, Tsugawa Y, Camargo CA Jr., Hiraide A, Brown DF. Regional variability in survival outcomes of out-of-hospital cardiac arrest: The all-Japan usstein registry. Resuscitation 2013;84:1099-107.
2. SOS-KANTO Study Group. Cardiopulmonary resuscitation by bystanders with chest compression only (SOS-KANTO): An observational study. Lancet 2007;369:920-6.
3. Murakami Y, Iwami T, Kitamura T, Nishiyama C, Nishiuchi T, Hayashi Y, et al. Outcomes of out-of-hospital cardiac arrest by public location in the public-access defibrillation era. J Am Heart Assoc 2014;3:e000533.
4. Dameff C, Vadeboncoeur T, Tully J, Panczyk M, Dunham A, Murphy R, et al. A standardized template for measuring and reporting telephone pre-arrival cardiopulmonary resuscitation instructions. Resuscitation 2014;85:869-73.
5. Morley PT. The key to advanced airways during cardiac arrest: Well trained and early. Crit Care 2012;16:104.
6. Mitamura H. Overview of recent findings on prevention of sudden cardiac death. Jpn J Electrocardiology 2015;35:205-12.
7. Mitamura H. Public access defibrillation: Advances from Japan. Nat Clin Pract Cardiovasc Med 2008;5:690-2.
8. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Hiraide A, et al. Nationwide public-access defibrillation in Japan. N Engl J Med 2010;362:994-1004.
9. Health Quality Ontario. Use of automated external defibrillators in cardiac arrest: An evidence-based analysis. Ont Health Technol Assess Ser 2005;5:1-29.
10. Lee M, Demirtas D, Buick JE, Feldman MJ, Cheskes S, Morrison LJ, et al. Increased cardiac arrest survival and bystander intervention in enclosed pedestrian walkway systems. Resuscitation 2017;118:1-7.
11. Yamaguchi Y, Woodin JA, Gibo K, Zive DM, Daya MR. Improvements in out-of-hospital cardiac arrest survival from 1998 to 2013. Prehosp Emerg Care 2017;1:1-2.
12. Stein P, Sphahn GH, Müller S, Zollinger A, Baulig W, Bräies M, et al. Impact of city police layperson education and equipment with automatic external defibrillators on patient outcome after out of hospital cardiac arrest. Resuscitation 2017;118:27-34.
13. Ringh M, Rosenqvist M, Hällenberg J, Jonsson M, Fredman D, Nordberg P, et al. Mobile-phone dispatch of laypersons for CPR in out-of-hospital cardiac arrest. N Engl J Med 2015;372:2316-25.
14. Boutillier JJ, Brooks SC, Jannmohamed A, Byers A, Buick JE, Zhan C, et al. Optimizing a drone network to deliver automated external defibrillators. Circulation 2017;135:2454-65.
15. Reynolds JC, Grunau BE, Rittenberger JC, Sawyer KN, Kurz MC, Callaway CW, et al. Association between duration of resuscitation and favorable outcome after out-of-hospital cardiac arrest: Implications for prolonging or terminating resuscitation. Circulation 2016;134:2084-94.
16. Cournoyer A, Notebaert É, Iseppon M, Cossette S, Londei-Leduc L, Lamarche Y, et al. Prehospital advanced cardiac life support for out-of-hospital cardiac arrest: A Cohort study. Acad Emerg Med 2017.
17. Cook TM, Hommers C. New airways for resuscitation? Resuscitation 2006;69:371-87.
18. Benoit JL, Gerecht RB, Steuerwald MT, McMullan JT. Endotracheal intubation versus supraglottic airway placement in out-of-hospital cardiac arrest: A meta-analysis. Resuscitation 2015;93:20-6.
19. Taylor J, Black S, J Brett S, Kirby N, Nolan JP, Reeves BC, et al. Design and implementation of the AIRWAYS-2 trial: A multi-centre cluster randomised controlled trial of the clinical and cost effectiveness of the i-gel supraglottic airway device versus tracheal intubation in the initial airway management of out of hospital cardiac arrest. Resuscitation 2016;109:25-32.
20. Lee KS, Lee SE, Choi JY, Gho YR, Chue MK, Park EJ, et al. Useful computed tomography score for estimation of early neurologic outcome in post-cardiac arrest patients with therapeutic hypothermia. Circ J 2017.
21. Martinell L, Nielsen N, Herlitz J, Karlsson T, Horn J, Wise MP, et al. Early predictors of poor outcome after out-of-hospital cardiac arrest. Crit Care 2017;21:96.
22. Lee BK, Lee SJ, Park CH, Jeung KW, Jung YH, Lee DH, et al. Relationship between age and outcomes of comatose cardiac arrest survivors in a setting without withdrawal of life support. Resuscitation 2017;115:75-81.
23. Nolan J, European Resuscitation Council. European resuscitation council guidelines for resuscitation 2005. Section 1. Introduction. Resuscitation 2005;67 Suppl 1:S3-6.
24. Bunch TJ, White RD, Khan AH, Packer DL. Impact of age on long-term survival and quality of life following out-of-hospital cardiac arrest. Crit Care Med 2004;32:963-7.
25. Rogove HJ, Safar P, Sutton-Tyrrell K, Abramson NS. Old age does not negate good cerebral outcome after cardiopulmonary resuscitation: Analyses from the brain resuscitation clinical trials. The brain resuscitation clinical trial I and II study groups. Crit Care Med 1995;23:18-25.
26. Andersen LW, Bivens MJ, Giberson T, Giberson B, Mottley JL, Gautam S, et al. The relationship between age and outcome in out-of-hospital cardiac arrest patients. Resuscitation 2015;94:49-54.
27. Finnet LJ. Psychological frailty in the aging patient. Nestle Nutr Inst Workshop Ser 2015;83:45-53.
28. Squarzoni P, Tanashiro-Duran J, Souza Duran FL, Santos LC, Vallada HP, Menezes PR, et al. Relationship between regional brain volumes and cognitive performance in the healthy aging: An MRI study using voxel-based morphometry. J Alzheimers Dis 2012;31:45-58.
29. Clewett DV, Lee TH, Greening S, Ponzio A, Margalit E, Mather M, et al. Neuromelanin marks the spot: Identifying a locus coeruleus biomarker of cognitive reserve in healthy aging. Neurobiol Aging 2016;37:117-26.
30. Libungan B, Lindqvist J, Strömöe A, Nordberg P, Hällenberg J, Albertsson P, et al. Out-of-hospital cardiac arrest in the elderly: A large-scale population-based study. Resuscitation 2015;94:28-32.
31. Grimaldi D, Dumas F, Perier MC, Charpentier J, Varenne O, Zuber B, et al. Short- and long-term outcome in elderly patients after out-of-hospital cardiac arrest: A cohort study. Crit Care Med 2014;42:2350-6.
32. Arai H, Ouchi Y, Yokode M, Ito H, Uematsu H, Eto F, et al. Toward the realization of a better aged society; Messages from gerontology and geriatrics. Geriatr Gerontol Int 2012;12:16-22.