

## References

- Nichol G, Stiell IG, Laupacis A, Pham B, De Maio VJ, Wells GA: A cumulative meta-analysis of the effectiveness of defibrillator-capable emergency medical services for victims of out-of-hospital cardiac arrest. *Ann Emerg Med* 1999, **34**(4 Pt 1):517-525.
- Kellum MJ, Kennedy KW, Ewy GA: Cardiocerebral resuscitation improves survival of patients with out-of-hospital cardiac arrest. *Am J Med* 2006, **119**(4):335-340.
- Wachelder EM, Moulart VR, van Heugten C, Verbunt JA, Bekkers SC, Wade DT: Life after survival: long-term daily functioning and quality of life after an out-of-hospital cardiac arrest. *Resuscitation* 2009, **80**(5):517-522.
- Grmec S, Strnad M, Podgorsek D: Comparison of the characteristics and outcome among patients suffering from out-of-hospital primary cardiac arrest and drowning victims in cardiac arrest. *International j emergency med* 2009, **2**(1):7-12.
- Peberdy MA, Silver A, Ornato JP: Effect of caregiver gender, age, and feedback prompts on chest compression rate and depth. *Resuscitation* 2009, **80**(10):1169-1174.
- Arrich J, Zeiner A, Sterz F, Janata A, Uray T, Richling N, Behringer W, Herkner H: Factors associated with a change in functional outcome between one month and six months after cardiac arrest: a retrospective cohort study. *Resuscitation* 2009, **80**(8):876-880.
- Kvaloy JT, Skogvoll E, Eftestol T, Gundersen K, Kramer-Johansen J, Olasveengen JM, Steen PA: Which factors influence spontaneous state transitions during resuscitation? *Resuscitation* 2009, **80**(8):863-869.
- Jackson RE, Swor RA: Who gets bystander cardiopulmonary resuscitation in a witnessed arrest? *Acad Emerg Med* 1997, **4**(6):540-544.
- Herlitz J, Eek M, Holmberg M, Engdahl J, Holmberg S: Characteristics and outcome among patients having out of hospital cardiac arrest at home compared with elsewhere. *Heart* 2002, **88**(6):579-582.
- Weisfeldt ML, Everson-Stewart S, Sitlani C, Rea T, Aufderheide TP, Atkins DL, Bigham B, Brooks SC, Foerster C, Gray R, Ornato JP, Powell J, Kudenchuk PJ, Morrison LJ: Ventricular tachyarrhythmias after cardiac arrest in public versus at home. *N Engl J Med* 2011, **364**(4):313-321.
- Jacobs I, Nadkarni V, Bahr J, Berg RA, Billi JE, Bossaert L, Cassan P, Coovadia A, D'Este K, Finn J, Halperin H, Handley A, Herlitz J, Hickey R, Idris A, Kloeck W, Larkin GL, Mancini ME, Mason P, Mears G, Monsieurs K, Montgomery W, Morley P, Nichol G, Nolan J, Okada K, Perlman J, Shuster M, Steen PA, Sterz F, Tibballs J, Timmerman S, Truitt T, Zideman D: Cardiac arrest and cardiopulmonary resuscitation outcome reports: update and simplification of the Utstein templates for resuscitation registries: a statement for healthcare professionals from a task force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian Resuscitation Council, New Zealand Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Councils of Southern Africa). *Circulation* 2004, **110**(21):3385-3397.
- Akahane M, Ogawa T, Koike S, Tanabe S, Horiguchi H, Mizoguchi T, Yasunaga H, Imamura T: The effects of sex on out-of-hospital cardiac arrest outcomes. *Am J Med* 2011, **124**(4):325-333.
- Ogawa T, Akahane M, Koike S, Tanabe S, Mizoguchi T, Imamura T: Outcomes of chest compression only CPR versus conventional CPR conducted by lay people in patients with out of hospital cardiopulmonary arrest witnessed by bystanders: nationwide population based observational study. *BMJ* 2011, **342**:c7106.
- Akahane M, Ogawa T, Tanabe S, Koike S, Horiguchi H, Yasunaga H, Imamura T: Impact of telephone dispatcher assistance on the outcomes of pediatric out-of-hospital cardiac arrest. *Crit Care Med* 2012, **40**(5):1410-1416.
- Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Hiraide A: Nationwide public-access defibrillation in Japan. *N Engl J Med* 2010, **362**(11):994-1004.
- Cummins RO, Chamberlain DA, Abramson NS, Allen M, Baskett PJ, Becker L, Bossaert L, DeLooz HH, Dick WF, Eisenberg MS, et al: Recommended guidelines for uniform reporting of data from out-of-hospital cardiac arrest: the Utstein Style. A statement for health professionals from a task force of the American Heart Association, the European Resuscitation Council, the Heart and Stroke Foundation of Canada, and the Australian Resuscitation Council. *Circulation* 1991, **84**(2):960-975.
- Tresch DD, Thakur RK, Hoffmann RG, Olson D, Brooks HL: Should the elderly be resuscitated following out-of-hospital cardiac arrest? *Am J Med* 1989, **86**(2):145-150.
- Tresch DD, Thakur R, Hoffmann RG, Brooks HL: Comparison of outcome of resuscitation of out-of-hospital cardiac arrest in persons younger and older than 70 years of age. *Am J Cardiol* 1988, **61**(13):1120-1122.
- Bonnin MJ, Pepe PE, Clark PS Jr: Survival in the elderly after out-of-hospital cardiac arrest. *Crit Care Med* 1993, **21**(11):1645-1651.
- Longstreth WT Jr, Cobb LA, Fahrenbruch CE, Copass MK: Does age affect outcomes of out-of-hospital cardiopulmonary resuscitation? *JAMA* 1990, **264**(16):2109-2110.
- Kim C, Becker L, Eisenberg MS: Out-of-hospital cardiac arrest in octogenarians and nonagenarians. *Arch Intern Med* 2000, **160**(22):3439-3443.
- Hauff SR, Rea TD, Culley LL, Kerry F, Becker L, Eisenberg MS: Factors impeding dispatcher-assisted telephone cardiopulmonary resuscitation. *Ann Emerg Med* 2003, **42**(6):731-737.
- Deasy C, Bray JE, Smith K, Harriss LR, Bernard SA, Cameron P: Out-of-hospital cardiac arrests in the older age groups in Melbourne, Australia. *Resuscitation* 2011, **82**(4):398-403.
- Mohler MJ, Wendel CS, Mosier J, Itty A, Fain M, Clark L, Bobrow B, Sanders AB: Cardiocerebral resuscitation improves out-of-hospital survival in older adults. *J Am Geriatr Soc* 2011, **59**(5):822-826.
- Stiell IG, Wells GA, Field BJ, Spaite DW, De Maio VJ, Ward R, Munkley DP, Lyver MB, Luinstra LG, Campeau T, Maloney J, Dagnone E: Improved out-of-hospital cardiac arrest survival through the inexpensive optimization of an existing defibrillation program: OPALS study phase II Ontario Prehospital Advanced Life Support. *JAMA* 1999, **281**(13):1175-1181.
- Feero S, Hedges JR, Stevens P: Assessing the need for bystander CPR training. *Acad Emerg Med* 1995, **2**(1):74-76.
- Lejeune PO, Deloos HH: Why did persons invited to train in cardiopulmonary resuscitation not do so? *Eur Heart J* 1987, **8**(3):224-228.
- Nakanishi N, Nishizawa S, Kitamura Y, Nakamura T, Matsumuro A, Sawada T, Matsubara H: The increased mortality from witnessed out-of-hospital cardiac arrest in the home. *Prehosp Emerg Care* 2011, **15**(2):271-277.
- Lerner EB, Sayre MR, Brice JH, White LJ, Santin AJ, Billittier AJ, Cloud SD: Cardiac arrest patients rarely receive chest compressions before ambulance arrival despite the availability of pre-arrival CPR instructions. *Resuscitation* 2008, **77**(1):51-56.

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# Comparison of Outcomes After Use of Biphasic or Monophasic Defibrillators Among Out-of-Hospital Cardiac Arrest Patients

## A Nationwide Population-Based Observational Study

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**Background**—The use and popularity of the biphasic waveform defibrillator as a replacement for the monophasic waveform defibrillator are increasing, but it is unclear whether this can improve the rate of survival among out-of-hospital cardiac arrest patients. This study aimed to verify the hypothesis that the outcome of out-of-hospital cardiac arrest patients who received defibrillation shock with the biphasic waveform defibrillator was better than that of patients who received defibrillation shock with the monophasic defibrillator.

**Methods and Results**—This prospective, nationwide, population-based, observational study included 21 172 out-of-hospital cardiac arrest patients with initial ventricular fibrillation or pulseless ventricular tachycardia from January 1, 2005, through December 31, 2007. Defibrillation shock was performed by monophasic defibrillator on 8224 (39%) patients and by biphasic defibrillator on 12948 (61%) patients. The rate of survival at 1 month with minimal neurological impairment was 11.6% (951/8192) in the monophasic defibrillator group and 12.8% (1653/12928) in the biphasic defibrillator group. Hierarchical logistic regression analysis using a generalized estimation equation showed no significant difference between the biphasic and monophasic groups in 1-month survival with minimal neurological impairment (adjusted odds ratio, 1.07; 95% confidence interval, 0.91–1.26;  $P=0.42$ ). Confirmatory propensity score analyses showed similar results.

**Conclusions**—Although monophasic defibrillators are being replaced by biphasic defibrillators, our nationwide population-based observational study failed to demonstrate a statistically significant association between defibrillation waveform and 1-month survival rate with minimal neurological impairment. (*Circ Cardiovasc Qual Outcomes*. 2012;5:00-00.)

**Key Words:** cardiopulmonary resuscitation ■ defibrillation ■ heart arrest ■ registries

Sudden cardiac arrest is a major public health problem in the industrialized countries of the world,<sup>1</sup> and the outcome of patients with out-of-hospital cardiac arrest (OHCA) remains poor.<sup>2</sup> Early defibrillation is critical for survival from OHCA.<sup>1</sup> There are currently 2 types of defibrillator, according to the type of waveform used to shock the patients: the monophasic defibrillator and the biphasic defibrillator. Defibrillation with a biphasic waveform shock has been reported to be safer and more effective than a monophasic waveform shock in a controlled laboratory,<sup>3,4</sup> in-hospital,<sup>5,6</sup> and out-of-hospital.<sup>7-9</sup> A biphasic defibrillator has lower energy requirements and is smaller and lighter in weight than a monophasic defibrillator and thus has the advantage

of portability to the scene of a medical emergency.<sup>10-12</sup> Accordingly, almost all defibrillators currently available commercially are biphasic defibrillators,<sup>1</sup> and out-of-hospital defibrillators are gradually being changed from the traditional monophasic defibrillators to biphasic defibrillators. However, it is not yet clear whether the outcome of patients with OHCA has improved by replacement of the monophasic defibrillators with the biphasic defibrillators.

In January 2005, the Fire and Disaster Management Agency (FDMA) of Japan started enrollment of patients with OHCA in a prospective nationwide population-based study.<sup>13</sup> This study, using a large Japanese nationwide OHCA database, aimed to verify the hypothesis that the

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survival of patients at 1 month with minimal neurological impairment who received defibrillation shock with the biphasic defibrillator is better than the survival of patients who received defibrillation shock with the monophasic defibrillator.

### WHAT IS KNOWN

- Defibrillation with a biphasic waveform shock has been reported to be safer and more effective than a monophasic waveform in a controlled laboratory, in-hospital, and out-of-hospital.
- Accordingly, defibrillators are gradually being changed from the traditional monophasic defibrillators to biphasic ones. However, it is not yet clear whether the outcome of patients with out-of-hospital cardiac arrest has been improved by this conversion effort.

### WHAT THIS ARTICLE ADDS

- Leveraging a prospective registry of out-of-hospital cardiac arrest in China, we sought to examine whether or not survival was improved in patients treated with newer, biphasic defibrillators compared with traditional monophasic ones.
- This study found no significant advantage of biphasic defibrillators over monophasic defibrillators on meaningful clinical outcomes. Although some EMS systems may replace monophasic defibrillators with biphasic ones because of their lighter weight and increased portability, there is no outcome-based reason to do so.

## Methods

### Study Design

The all-Japan Utstein Registry is a prospective, nationwide, population-based registry system of OHCA patients who are transferred to hospital by the emergency medical services (EMS).<sup>13</sup> This observational study enrolled all OHCA patients  $\geq 18$  years old, who were transported to hospital by EMS personnel during 3 consecutive years from January 1, 2005, to December 31, 2007. The Japanese EMS system for OHCA is a government-provided, nationally standardized system. Registration of OHCA patients in the registry is mandatory. Cardiac arrest is defined as the cessation of cardiac mechanical activity, as confirmed by the absence of signs of circulation.<sup>13-15</sup> EMS personnel generally confirm the absence of signs of circulation by palpating the patient's carotid artery. Almost all patients who have an OHCA who are treated by EMS personnel are transported to hospital, excluding those with decapitation, incineration, decomposition, rigor mortis, or dependent cyanosis.<sup>13</sup> Therefore, patients in the present study are representative of cardiac arrest patients in Japan. The study was approved by the Institution Review Board in Nara Medical University (Approval No. 260).

### EMS System in Japan

Japan has  $\approx 128$  million residents (2010) in an area of  $\approx 378\,000$  km<sup>2</sup>. The population is served by 807 fire stations (2007). The universal emergency telephone number of 119 is directly connected to the dispatch center of the regional fire defense headquarters. Upon

acceptance of an emergency call, the nearest available ambulance is dispatched to an incident.<sup>16</sup> All expenses of the EMS system are covered by the local government, so there is no charge to the patient for emergency treatment and transportation.<sup>16</sup> The EMS system in Japan is a 1-tiered response system, except for limited areas, where physician-manned ambulances or helicopters are available.<sup>16</sup> Each ambulance has 3 staff, who can all perform cardiopulmonary resuscitation (CPR) according to the Japanese guidelines, which, until September 2006, were based on the International Liaison Committee on Resuscitation<sup>17</sup> and the American Heart Association 2000 guidelines.<sup>18</sup> Since October 2006, CPR has been based on the respective 2005 guidelines.<sup>13,19</sup>

Do-not-resuscitate orders or living wills are not generally accepted, and EMS personnel are not allowed to terminate or withhold resuscitation out of hospital. Therefore, most patients who have an OHCA who are treated by EMS personnel are transported to hospital, excluding those with decapitation, incineration, decomposition, rigor mortis, or dependent cyanosis.<sup>13</sup>

### Automated External Defibrillator Descriptions

Most ambulances have only 1 defibrillator. Either a biphasic defibrillator or a monophasic defibrillator was applied to the OHCA patients, according to the type of defibrillator supplied in the EMS ambulance. All ambulance vehicles used to have a monophasic defibrillator until biphasic defibrillators became available, when monophasic defibrillators were gradually (one by one) replaced by biphasic defibrillators. Biphasic defibrillator models used in the study were Heart Start MRx, Heart Start FR2/FR2+, Heart Start 4000, Heart Start HS1, Heart Start XL (Philips Medical Systems, Seattle, WA), automated external defibrillator (AED)-9200/9210, AED-9231/9211/9201, AED-1200, TEC-2312/2313 (Nihon Kohden, Tokyo, Japan), LIFEPAK 500B, and LIFEPAK 12B (Medtronic, Minneapolis, MN). All the biphasic defibrillators adopted the biphasic truncated exponential waveform.

The monophasic defibrillator models used in the study were Heart Start 3000/3000QR (Laerdal Medical, Stavanger, Norway), LIFEPAK 12A (Medtronic), and TEC 2212/2213 (Nihon Kohden). The monophasic defibrillator delivered either monophasic truncated exponential or monophasic damped sine defibrillation waveforms, depending on the model used in each ambulance. EMS personnel are not allowed to use defibrillators in manual mode. Both monophasic and biphasic defibrillators are used in AED mode. The energy dose of the monophasic defibrillator was initially 200 J and, thereafter, 360 J. The energy dose of the biphasic defibrillator was set at the level recommended by the manufacturer.

### Data Collection and Quality Control

All information was collated at local fire departments by EMS personnel using an online entry form, which conformed to the Utstein form,<sup>14,15,20</sup> with some additions. Data on the characteristics of the OHCA patients were collected, including age, sex, whether the collapse was witnessed by a bystander, whether bystander CPR was performed, whether the patient was defibrillated by the EMS, type of waveform of defibrillation shock, the cause of the cardiac arrest such as cardiac or noncardiac origin, whether the patient was intubated, whether epinephrine was administered, the first documented cardiac rhythm, and the time course of resuscitation. In addition, outcome data, such as information on whether spontaneous circulation was restored before hospital arrival, survival, and neurological status 1 month after the event, were also collected. One-month survival and neurological status data were collected by EMS personnel from the hospitals that received the patients, in cooperation with the physicians in charge of the patients.<sup>13,21</sup> To collect 1-month follow-up data, EMS personnel had a face-to-face meeting with the hospital physician in charge at the hospital to which the OHCA patient was transferred or sent a questionnaire form asking the physician in charge to provide outcome data. If the patient was discharged from the hospital within 1 month, the EMS personnel conducted a follow-up search.<sup>22</sup> This registry system is operated by the FDMA.

Thus, the data regarding 1-month follow-up (1-month survival and neurological status) are collected systematically. Survival at 1 month with minimal neurological impairment was not documented for 52 (<0.3%) patients, 32 in the monophasic group and 20 in the biphasic group. They were excluded for subsequent analyses of the primary outcome measures. Survival at 1 month was documented in all eligible patients.

The times of the emergency call receipt and hospital arrival were recorded according to the times on the clock used by the EMS that responded to the call. Information on witness status and bystander CPR was collected by EMS personnel by interviewing the bystander. The cause of cardiac arrest was determined by the physician in charge<sup>23,24</sup> based on physical, laboratory, and radiological findings, together with scene information obtained from EMS crew. It was presumed to be cardiac in origin unless unequivocal evidence suggested respiratory diseases, cerebrovascular diseases, external causes (trauma, hanging, drowning, drug overdose, asphyxia), or any other noncardiac cause.<sup>21</sup> Data were verified by EMS personnel and anonymized at the local fire stations, then transferred and stored in the database at the FDMA.<sup>25</sup> The data were checked by computer, and if there were any inconsistencies or missing data, the FDMA consulted the corresponding regional fire stations and the data were corrected when necessary.<sup>13,25</sup>

### Study Targets and End Points

In the present study, we focused on patients whose first documented rhythms were ventricular fibrillation (VF) or pulseless ventricular tachycardia. The primary outcome measure was survival at 1 month with minimal neurological impairment, which was defined as Glasgow-Pittsburgh cerebral performance category 1 (good cerebral performance) or 2 (moderate cerebral disability),<sup>14,15</sup> as evaluated by the physician in charge at 1 month after the event. The secondary outcome measures were survival at 1 month and return of spontaneous circulation before hospital arrival.

### Statistical Analysis

The time from the emergency call to CPR by the EMS was subdivided into the following 3 categories: early response (0–6 minutes), moderate response (7–12 minutes), and late response (13–18 minutes). The cause of the cardiac arrest was categorized into cardiac or noncardiac origin subgroups. Patients received CPR based on 2 American Heart Association CPR guidelines (2000 and 2005 American Heart Association Guidelines). Patient characteristics were evaluated using the unpaired Student *t* test for numerical variables and the  $\chi^2$  test for categorical variables. The outcomes were compared between the subgroups using  $\chi^2$  tests.

To identify the association between defibrillator type (monophasic or biphasic) and outcomes, we performed multivariate logistic regression analyses with adjustment for age, sex, cause of arrest, the type of bystander CPR performed (no bystander CPR, compression only CPR, or conventional CPR), the type of guideline-based CPR performed (2000 Guideline-based or 2005 Guideline-based), time from emergency call to CPR by EMS (early, moderate, or late response), whether the collapse was witnessed by a bystander, whether an advanced airway device was inserted, whether epinephrine was injected, and calendar year. We assumed that data were structured hierarchically into 2 levels: communities and patients. We accounted for clustering of outcomes within communities using a generalized estimation equation (GEE). This is commonly used in place of a basic regression approach because outcomes of patients in the same community may be correlated, thus violating independence assumptions made by traditional regression procedures.<sup>26</sup> We also performed logistic GEE regression analyses focusing on the following subgroups: (1) early response subgroup (0–6 minutes from the time of the emergency call to CPR by the EMS) (*n*=7036), (2) cardiac origin subgroup (*n*=18 173), and (3) 2005 Guideline-based subgroup (*n*=9024).

We performed additional confirmatory logistic GEE regression analyses for all patients with adjustment for propensity to receive biphasic defibrillation. The propensity score approach addresses selection bias that is inherent in retrospective observational studies, where outcomes can reflect a lack of comparability in treatment groups rather than the effects of treatment.<sup>27</sup> To estimate the propensity score, we fitted a logistic regression model for the receipt of biphasic defibrillation as a function of the reported covariates. The *c*-statistic for evaluating the goodness of fit was calculated. First, we added the estimated propensity scores to the logic GEE models as a covariate (ie, propensity-score-adjusted analyses). Second, we performed a one-to-one matching between the monophasic and biphasic defibrillation groups on the basis of estimated propensity scores of each patient using a nearest neighbor matching within a caliper. The caliper size was set as a quarter of an SD of the sample estimated propensity scores. The covariate imbalance was checked using the standardized differences in covariates in the matched samples.<sup>27</sup> All statistical analyses were conducted using SAS version 9.2 (SAS, Cary, NC). All tests were 2-tailed, and *P*<0.05 was regarded as significant.

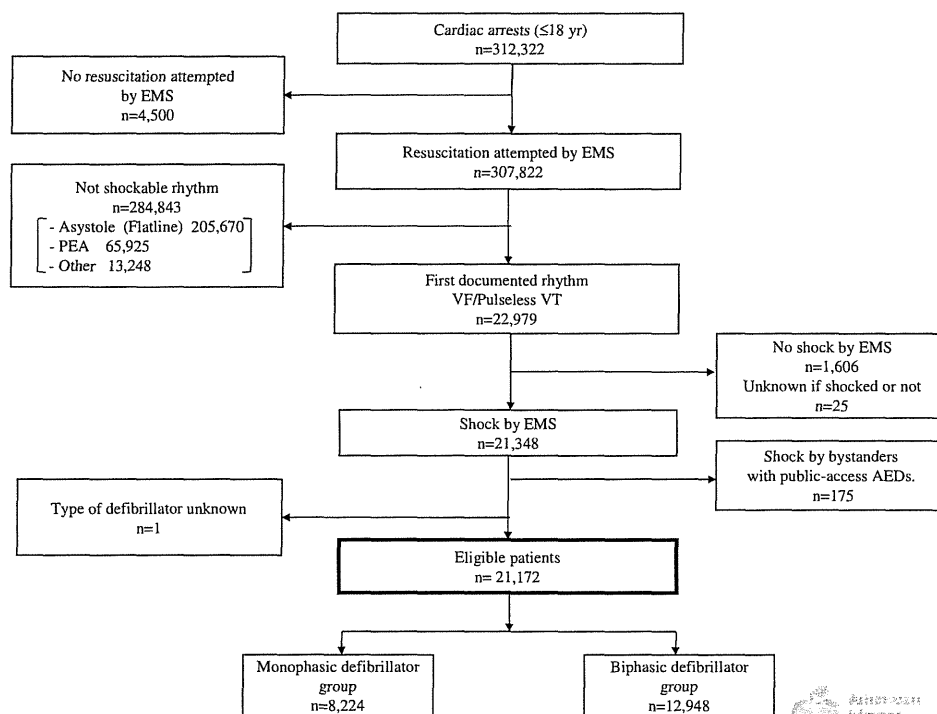
### Results

The documented number of OHCA patients  $\geq 18$  years of age was 312 322. We excluded patients who had no attempted resuscitation by the EMS (*n*=4500), whose initial rhythms were not VF nor pulseless ventricular tachycardia (*n*=284 843), who were not shocked by the EMS (*n*=1606), and who lacked information on receiving defibrillation shock (*n*=25). Consequently, the number of VF/pulseless ventricular tachycardia patients who were shocked for defibrillation by the EMS at least once before their arrival at the hospital was 21 348. Patients who underwent defibrillation by a public-access AED by bystanders (*n*=175) and patients shocked with an unknown type of defibrillator (*n*=1) were then excluded, leaving 21 172 patients eligible for inclusion in the study. Figure 1 shows a flow diagram of the study. Of the eligible patients, 8224 (39%) patients were shocked with a monophasic defibrillator and 12 948 (61%) patients were shocked with a biphasic defibrillator.

Table 1 presents the demographic and medical characteristics of the included patients. Figure 2 shows the annual changes in the number of patients by defibrillator type. The proportion of patients who were shocked with the monophasic defibrillator decreased each year. Figure 3 shows the cerebral performance category status of survivors by defibrillator type (monophasic/biphasic).

Table 2 shows the outcomes by type of defibrillator of eligible patients and of subgroups of patients.  $\chi^2$  tests showed significant differences in survival at 1 month with minimal neurological impairment (11.6% versus 12.8%) and return of spontaneous circulation before hospital arrival (21.2% versus 22.3%) between monophasic and biphasic groups.

Table 3 shows the results of logistic GEE regression analyses. There were no significant differences between the monophasic and biphasic groups in all outcome measures of eligible patients, including return of spontaneous circulation before hospital arrival (odds ratio, 1.03; 95% confidence interval, 0.91–1.16; *P*=0.64), survival at 1 month (odds ratio, 1.02; 95% confidence interval, 0.92–1.14; *P*=0.69), and survival at 1 month with minimal neurological impairment (odds ratio,



**Figure 1.** Study flow diagram. During the 3 years of the study, 312322 out-of-hospital cardiac arrest patients  $\geq 18$  years old were documented. AED indicates automated external defibrillator; EMS, emergency medical service; VF, ventricular fibrillation; VT, ventricular tachycardia; and PEA, pulseless ventricular activity.

1.07; 95% confidence interval, 0.91–1.26;  $P=0.42$ ). No significant association between defibrillator type and outcomes was shown in any of the 3 subgroup analyses (ie, early response subgroup, cardiac origin subgroup, or 2005 Guideline-based subgroup).

Table 3 also shows the results of the propensity-score-adjusted analyses and propensity-score-matched analyses for all patients. The c-statistic for goodness of fit was 0.641 in the propensity score model. By one-to-one propensity-score matching, 7293 pairs of the monophasic and biphasic groups were selected ( $n=14\,586$ ). The standardized differences in covariates in the matched samples were all  $<0.1$ . Again, there were no significant differences between the monophasic and biphasic groups in all outcome measures.

## Discussion

In our study, no significant difference was observed in multivariate logistic regression analyses between the patients who were shocked with a biphasic defibrillator or with a monophasic defibrillator, either in the primary outcome or in the secondary outcomes. To date, it has been indicated that biphasic waveform shock is superior to monophasic waveform shock with respect to safety and efficacy under controlled laboratory and in-hospital conditions.<sup>3–6</sup> An observational study of subjects with OHCA indicated that biphasic waveform shock afforded a higher probability of terminating VF than monophasic waveform shock.<sup>7–9</sup> With regard to the long-term outcome, no significant difference was observed between the 2 types of waveform for defibrillation in any of the 4 randomized trials.<sup>28–31</sup> These studies focused

on differences in the waveforms among defibrillators. However, compared with the monophasic defibrillator, the commercialized biphasic defibrillator not only has a different waveform but also has differences in the amount and duration of defibrillation energy. Furthermore, the equipment is smaller and lighter.<sup>10–12</sup> Sellers of defibrillators seem to consider that biphasic defibrillators are equal to or better than the monophasic defibrillator in improving outcomes of OHCA patients. Purchasers are also assumed to expect improved outcomes of OHCA patients with the biphasic defibrillator, and this may be a factor in replacing the monophasic defibrillator with the biphasic defibrillator. The FDMA of Japan has encouraged fire stations nationwide to replace the monophasic defibrillators with biphasic defibrillators by assisting each fire station with the expense of purchasing new defibrillators. Consequently, a majority of the patients underwent shock by biphasic defibrillator (Figure 2).

Biphasic defibrillators have several advantages compared with monophasic defibrillators, including a lower burden for EMS personnel because of their lower weight and greater portability. However, despite theoretical advantages of biphasic waveforms and some limited evidence about their better surrogate outcomes, the present study showed no significant advantage of biphasic defibrillators over monophasic defibrillators on meaningful clinical outcomes. Although some EMS systems may replace monophasic defibrillators with biphasic ones because of their lighter weight and increased portability, there is no patient-safety, outcome-based reason to do so. There are mainly 2 reasons why no significant association could be confirmed. First, there was no difference in the association with outcome of OHCA

**Table 1. Characteristics of the Study Participants**

	Total (n=21 172)	Monophasic (n=8224)	Biphasic (n=12 948)	P
Age, mean (SD)	65.3 (15.2)	64.8 (15.1)	65.6 (15.3)	<0.001
Male, n (%)	16 400 (77.5)	6468 (78.6)	9932 (76.7)	0.001
Witnessed by laypersons, n (%)	14 962 (70.7)	5862 (71.3)	9100 (70.3)	0.12
Type of bystander-initiated CPR*				
No CPR, n (%)	12 599 (60.1)	4974 (60.9)	7625 (59.6)	<0.001
Compression-only CPR, n (%)	4393 (21.0)	1594 (19.5)	2799 (21.9)	
Conventional CPR, n (%)	3963 (18.9)	1599 (19.6)	2364 (18.5)	
Advanced airway management†, n (%)	10 616 (50.5)	4209 (51.5)	6407 (49.9)	0.025
Adrenaline‡, n (%)	907 (4.4)	257 (3.2)	650 (5.1)	<0.001
Call to CPR by EMS, min, mean (SD)§	8.8 (5.5)	8.8 (5.5)	8.8 (5.4)	0.68
0–6 min, n (%)	7036 (34.6)	2719 (34.4)	4317 (34.8)	
7–12 min, n (%)	11 527 (56.8)	4526 (57.3)	7001 (56.4)	
13–18 min  , n (%)	1748 (8.6)	654 (8.3)	1094 (8.8)	
CPR by EMS to hospital arrival, min, mean (SD)#	22.2 (10.1)	22.4 (10.0)	22.0 (10.2)	0.012
Origin of cardiac arrest				
Cardiac, n (%)	18 173 (85.8)	7130 (86.7)	11 043 (85.3)	0.004
Noncardiac, n (%)	2999 (14.2)	1094 (13.3)	1905 (14.7)	
CPR guidelines				
2000 AHA Guideline-based, n (%)	12 148 (57.4)	5786 (70.4)	6362 (49.1)	<0.001
2005 AHA Guideline-based, n (%)	9024 (42.6)	2438 (29.6)	6586 (50.9)	
No. of shocks administered to patients who had ROSC before hospital arrival				
Median (25%–75%)	1 (1–3)	2 (1–3)	1 (1–3)	0.93
Year				
2005	6797 (32.1)	3642 (44.3)	3155 (24.4)	<0.001
2006	7183 (33.9)	2783 (33.8)	4400 (34.0)	
2007	7192 (34.0)	1799 (21.9)	5393 (41.7)	

AHA indicates American Heart Association; CPR, cardiopulmonary resuscitation; and EMS, Emergency Medical Services.

\*Two hundred seventeen (1.0%) patients with missing data were excluded. Percentages were calculated on the basis of the total number of events, including those excluded.

†One hundred sixty-three (0.8%) patients with missing data were excluded. Percentages were calculated on the basis of the total number of events, including those excluded.

‡Three hundred sixty-four (1.7%) patients with missing data were excluded. Percentages were calculated on the basis of the total number of events, including those excluded.

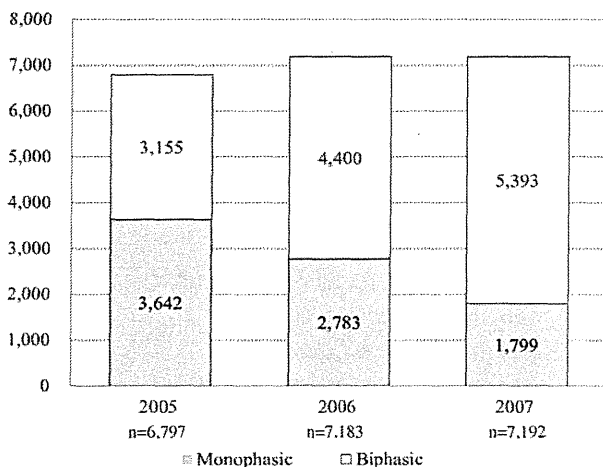
§Twenty-six (0.1%) patients whose data were missing were excluded. The mean value and SD were calculated without the excluded data.

||Eight hundred thirty-five (3.9%) patients in whom there was >18 min between the time of call to CPR by EMS were excluded. Percentages were calculated on the basis of the total number of events, including the excluded data.

#Twenty-three (0.1%) patients whose data were missing were excluded. The mean value and SD were calculated without the excluded data.

patients between monophasic and biphasic defibrillators. Second, because many factors contribute to the outcome of 1-month cerebral function, such as where cardiac arrest occurs, bystander treatment, prehospital EMS treatment, and intensive care at the admitting hospital, any association may be decreased to an extent that it cannot be detected. When the second case was considered, although good neurological outcome is the ultimate desired outcome of all resuscitations, as an index to measure the direct effects of different defibrillators, we consider it would be desirable to include whether a defibrillation terminated VF. However, because we did not collect data on whether VF was terminated by each shock,

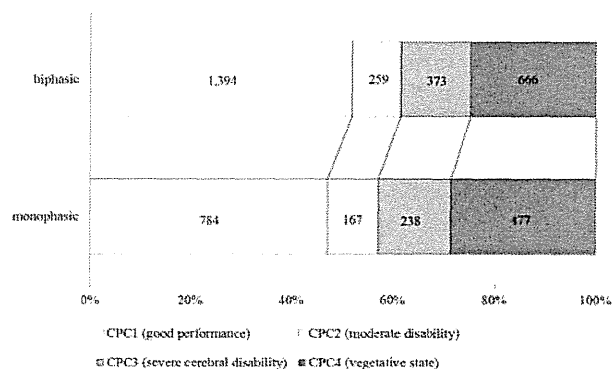
we could not compare the probability of terminating VF and the number of shocks necessary to terminate VF between the different types of defibrillators. Our study was an observational study that compared the association of the biphasic defibrillator and monophasic defibrillator with outcome in a large number of OHCA patients. Because the monophasic defibrillator is being replaced by the biphasic defibrillator in Japan (Figure 2), as in other developed countries,<sup>1</sup> this study may be the last large-scale observational study to compare outcomes by type of defibrillator—monophasic and biphasic—and provide a valuable comparison in OHCA patients.



**Figure 2.** Number of patients who received shocks by monophasic and biphasic defibrillator by year. The proportion in the biphasic defibrillator group increased year on year.

**Study Limitations**

This study has several limitations. First, bias on the basis of its observational design is a potential limitation. It is possible that EMS personnel who used the monophasic defibrillator were



**Figure 3.** The cerebral performance category (CPC) status of survivors of eligible patients by defibrillator type (monophasic/biphasic).

less well supported by public funds, thus received a lower frequency of training, and this could have influenced the results. Second, as mentioned above, data on whether VF was terminated by shock were not collected, so we could not directly compare the probability of terminating VF. However, to investigate the association of replacing the monophasic defibrillator by the biphasic defibrillator, a comparison of the survival at 1

**Table 2. Outcomes of All Patients and Subgroups**

	ROSC Before Hospital Arrival			Survival at 1 mo			Survival at 1 mo With Minimal Neurological Impairment		
	n	(%)	P	n	(%)	P	n	(%)	P
All patients (n=21 172)									
Monophasic (n=8224)	1740	21.2%	0.043	1641	20.0%	0.080	951	11.6%	0.011
Biphasic (n=12 948)	2892	22.3%		2713	21.0%		1653	12.8%	
Time from emergency call to CPR by EMS									
Early response (0–6 min)									
Monophasic (n=2719)	706	26.0%	0.046	694	25.5%	0.099	402	14.8%	0.019
Biphasic (n=4317)	1215	28.1%		1179	27.3%		731	17.0%	
Moderate response (7–12 min)									
Monophasic (n=4526)	809	17.9%	0.17	744	16.4%	0.057	397	8.8%	0.045
Biphasic (n=7001)	1323	18.9%		1247	17.8%		694	9.9%	
Late response (>12 min)									
Monophasic (n=654)	123	18.8%	0.70	102	15.6%	0.33	65	10.0%	0.85
Biphasic (n=1094)	197	18.0%		152	13.9%		112	10.3%	
Origin of cardiac arrest									
Cardiac									
Monophasic (n=7130)	1574	22.1%	0.007	1505	21.1%	0.008	888	12.5%	0.002
Biphasic (n=11 043)	2629	23.8%		2516	22.8%		1554	14.1%	
Noncardiac									
Monophasic (n=1094)	166	15.2%	0.30	136	12.4%	0.079	63	5.8%	0.49
Biphasic (n=1950)	263	13.8%		197	10.3%		99	5.2%	
CPR guidelines									
2000 Guideline-based									
Monophasic (n=5786)	1189	20.5%	0.66	1097	19.0%	0.49	607	10.5%	0.55
Biphasic (n=6362)	1287	20.2%		1175	18.5%		648	10.2%	
2005 Guideline-based									
Monophasic (n=2438)	551	22.6%	0.080	544	22.3%	0.30	344	14.1%	0.17
Biphasic (n=6586)	1605	24.4%		1538	23.4%		1005	15.3%	

ROSC indicates return of spontaneous circulation; CPR, cardiopulmonary resuscitation; and EMS, Emergency Medical Services.



**Table 3. Odds ratios of Outcomes for Biphasic vs Monophasic Defibrillators in the Logistic Regression Models**

	ROSC Before Hospital Arrival			Survival at 1 mo			Survival at 1 mo With Minimal Neurological Impairment		
	OR	(95% CI)	P	OR	(95% CI)	P	OR	(95% CI)	P
All patients (n=21 172)	1.03	(0.91–1.16)	0.64	1.02	(0.92–1.14)	0.69	1.07	(0.91–1.26)	0.42
All patients, propensity-score-adjusted analysis (n=21 172)	1.04	(0.94–1.16)	0.44	1.03	(0.93–1.14)	0.57	1.07	(0.93–1.23)	0.34
Propensity-score-matched patients (n=14 586)	1.05	(0.94–1.17)	0.42	1.06	(0.94–1.18)	0.39	1.07	(0.92–1.25)	0.36
Early response subgroup (0–6 min for the time from emergency call to CPR by EMS) (n=7036)	1.06	(0.90–1.25)	0.45	1.04	(0.86–1.26)	0.70	1.10	(0.86–1.40)	0.45
Cardiac origin subgroup (n=18 173)	1.05	(0.93–1.19)	0.45	1.05	(0.94–1.17)	0.42	1.09	(0.93–1.29)	0.30
2005 AHA Guideline-based subgroup (n=9024)	1.11	(0.93–1.33)	0.24	1.08	(0.93–1.25)	0.31	1.16	(0.94–1.43)	0.17

ROSC indicates return of spontaneous circulation; OR, odds ratio; CI, confidence interval; CPR, cardiopulmonary resuscitation; EMS, Emergency Medical Services; and AHA, American Heart Association.

All models included age, sex, cause of arrest, the type of bystander CPR performed (no bystander CPR, compression only CPR, or conventional CPR), the type of guideline-based CPR performed (2000 AHA Guideline-based or 2005 AHA Guideline-based), time from emergency call to CPR by the EMS (early response, moderate response, or late response), time from CPR by EMS to hospital arrival, and whether the collapse was witnessed by a bystander, whether an advanced airway device was inserted, whether epinephrine was injected, and calendar year. Regression analyses did not include patients with missing data.

month with minimal neurological impairment is considered to be a good index. Third, because of the lack of data, we were unable to account for several potential confounders, including body mass index and preshock pause of chest compressions (time for ECG analysis and energy charge). In particular, postcardiac arrest care (eg, therapeutic hypothermia and percutaneous coronary intervention) that became increasingly adopted over the study period deserves attention as one of the major confounders. However, we believe this was partly, if not completely, accounted for by incorporating the calendar year in our multivariable logistic regression analysis. Furthermore, considering that the use of a biphasic defibrillator also increased over the study period, improvement of postcardiac arrest care would have affected the odds ratio in favor of the biphasic defibrillator, but we still failed to find a statistically significant difference in the primary outcome. Fourth, the present study did not compare individual defibrillator types but rather collapsed the defibrillator models into 2 groups according to the type of waveform. Fifth, this study is based on a retrospective observational design and, therefore, more susceptible to bias and confounding when compared with randomized controlled trials. However, we believe our study have strength in that it reflects daily clinical practice more closely than randomized controlled trials, as well as in that it includes a large number of patients. Sixth, accuracy of the recorded cerebral performance category scores was not confirmed. Despite these limitations, we believe that our results are valid, given the use of uniform data collection and consistent definitions based on the Utstein guidelines,<sup>14,15,20</sup> the large sample size, and the nationwide, population-based design. In addition, because all consecutive cases of OHCA patients transferred by the EMS in Japan were included in the database, selection and reporting bias was minimal.

### Conclusion

Although monophasic defibrillators are being replaced by biphasic defibrillators, our nationwide population-based observational study could not confirm a parallel improvement in survival at 1 month with minimal neurological impairment.

### Acknowledgments

We thank all the Emergency Medical Service personnel and participating physicians in Japan and the Fire and Disaster Management Agency for their generous cooperation in establishing and maintaining the database.

### Disclosures

None.

### References

- 2005 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2005;112:IV1–IV203.
- McNally B, Robb R, Mehta M, Vellano K, Valderrama AL, Yoon PW, et al. Out-of-hospital cardiac arrest surveillance — Cardiac Arrest Registry to Enhance Survival (CARES), United States, October 1, 2005–December 31, 2010. *MMWR Surveill Summ*. 2011;60:1–19.
- Osswald S, Trouton TG, O’Nunain SS, Holden HB, Ruskin JN, Garan H. Relation between shock-related myocardial injury and defibrillation efficacy of monophasic and biphasic shocks in a canine model. *Circulation*. 1994;90:2501–2509.
- Gliner BE, Lyster TE, Dillion SM, Bardy GH. Transthoracic defibrillation of swine with monophasic and biphasic waveforms. *Circulation*. 1995;92:1634–1643.
- Bardy GH, Gliner BE, Kudenchuk PJ, Poole JE, Dolack GL, Jones GK, et al. Truncated biphasic pulses for transthoracic defibrillation. *Circulation*. 1995;91:1768–1774.
- Bardy GH, Marchlinski FE, Sharma AD, Worley SJ, Luceri RM, Yee R, et al. Multicenter comparison of truncated biphasic shocks and standard damped sine wave monophasic shocks for transthoracic ventricular defibrillation. Transthoracic Investigators. *Circulation*. 1996;94:2507–2514.
- White RD. Early out-of-hospital experience with an impedance-compensating low-energy biphasic waveform automatic external defibrillator. *J Interv Card Electrophysiol*. 1997;1:203–8; discussion 209.
- Poole JE, White RD, Kanz KG, Hengstenberg F, Jarrard GT, Robinson JC, et al. Low-energy impedance-compensating biphasic waveforms terminate ventricular fibrillation at high rates in victims of out-of-hospital cardiac arrest. LIFE Investigators. *J Cardiovasc Electrophysiol*. 1997;8:1373–1385.
- Gliner BE, Jorgenson DB, Poole JE, White RD, Kanz KG, Lyster TD, et al. Treatment of out-of-hospital cardiac arrest with a low-energy impedance-compensating biphasic waveform automatic external defibrillator. The LIFE Investigators. *Biomed Instrum Technol*. 1998;32:631–644.
- Winkle RA, Mead RH, Ruder MA, Gaudiani V, Buch WS, Pless B, et al. Improved low energy defibrillation efficacy in man with the use of a biphasic truncated exponential waveform. *Am Heart J*. 1989;117:122–127.



11. Bardy GH, Ivey TD, Allen MD, Johnson G, Mehra R, Greene HL. A prospective randomized evaluation of biphasic versus monophasic waveform pulses on defibrillation efficacy in humans. *J Am Coll Cardiol*. 1989;14:728–733.
12. Swartz JF, Fletcher RD, Karasik PE. Optimization of biphasic waveforms for human nonthoracotomy defibrillation. *Circulation*. 1993;88:2646–2654.
13. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Hiraide A; Implementation Working Group for the All-Japan Utstein Registry of the Fire and Disaster Management Agency. Nationwide public-access defibrillation in Japan. *N Engl J Med*. 2010;362:994–1004.
14. Cummins RO, Chamberlain DA, Abramson NS, Allen M, Baskett PJ, Becker L, et al. Recommended guidelines for uniform reporting of data from out-of-hospital cardiac arrest: the Utstein Style. A statement for health professionals from a task force of the American Heart Association, the European Resuscitation Council, the Heart and Stroke Foundation of Canada, and the Australian Resuscitation Council. *Circulation*. 1991;84:960–975.
15. Jacobs I, Nadkarni V, Bahr J, Berg RA, Billi JE, Bossaert L, et al; International Liaison Committee on Resuscitation; American Heart Association; European Resuscitation Council; Australian Resuscitation Council; New Zealand Resuscitation Council; Heart and Stroke Foundation of Canada; InterAmerican Heart Foundation; Resuscitation Councils of Southern Africa; ILCOR Task Force on Cardiac Arrest and Cardiopulmonary Resuscitation Outcomes. Cardiac arrest and cardiopulmonary resuscitation outcome reports: update and simplification of the Utstein templates for resuscitation registries: a statement for healthcare professionals from a task force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian Resuscitation Council, New Zealand Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Councils of Southern Africa). *Circulation*. 2004;110:3385–3397.
16. Tanigawa K, Tanaka K. Emergency medical service systems in Japan: past, present, and future. *Resuscitation*. 2006;69:365–370.
17. 2005 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations. Part 2: Adult basic life support. *Resuscitation*. 2005;67:187–201.
18. Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Part 3: adult basic life support. The American Heart Association in collaboration with the International Liaison Committee on Resuscitation. *Circulation*. 2000;102:122–159.
19. Koike S, Tanabe S, Ogawa T, Akahane M, Yasunaga H, Horiguchi H, et al. Immediate defibrillation or defibrillation after cardiopulmonary resuscitation. *Prehosp Emerg Care*. 2011;15:393–400.
20. Yasunaga H, Horiguchi H, Tanabe S, Akahane M, Ogawa T, Koike S, et al. Collaborative effects of bystander-initiated cardiopulmonary resuscitation and prehospital advanced cardiac life support by physicians on survival of out-of-hospital cardiac arrest: a nationwide population-based observational study. *Crit Care*. 2010;14:R199.
21. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Nadkarni VM, et al; implementation working group for All-Japan Utstein Registry of the Fire and Disaster Management Agency. Conventional and chest-compression-only cardiopulmonary resuscitation by bystanders for children who have out-of-hospital cardiac arrests: a prospective, nationwide, population-based cohort study. *Lancet*. 2010;375:1347–1354.
22. Hagihara A, Hasegawa M, Abe T, Nagata T, Wakata Y, Miyazaki S. Pre-hospital epinephrine use and survival among patients with out-of-hospital cardiac arrest. *JAMA*. 2012;307:1161–1168.
23. Tanabe S, Ogawa T, Akahane M, Koike S, Horiguchi H, Yasunaga H, et al. Comparison of neurological outcome between tracheal intubation and supraglottic airway device insertion of out-of-hospital cardiac arrest patients: a nationwide, population-based, observational study. *J Emerg Med*. 2012. Epub ahead of print.
24. Akahane M, Ogawa T, Koike S, Tanabe S, Horiguchi H, Mizoguchi T, et al. The effects of sex on out-of-hospital cardiac arrest outcomes. *Am J Med*. 2011;124:325–333.
25. Ogawa T, Akahane M, Koike S, Tanabe S, Mizoguchi T, Imamura T. Outcomes of chest compression only CPR versus conventional CPR conducted by lay people in patients with out of hospital cardiopulmonary arrest witnessed by bystanders: nationwide population based observational study. *BMJ*. 2011;342:c7106.
26. Hubbard AE, Ahern J, Fleischer NL, Van der Laan M, Lippman SA, Jewell N, et al. To GEE or not to GEE: comparing population average and mixed models for estimating the associations between neighborhood risk factors and health. *Epidemiology*. 2010;21:467–474.
27. RosenbaumPR, Rubin DB. Constructing a control group using multivariate matched sampling methods that incorporate the propensity score. *Am Stat*. 1985;39:33–38.
28. Schneider T, Martens PR, Paschen H, Kuisma M, Wolcke B, Gliner BE, et al. Multicenter, randomized, controlled trial of 150-J biphasic shocks compared with 200- to 360-J monophasic shocks in the resuscitation of out-of-hospital cardiac arrest victims. Optimized Response to Cardiac Arrest (ORCA) Investigators. *Circulation*. 2000;102:1780–1787.
29. Morrison LJ, Dorian P, Long J, Vermeulen M, Schwartz B, Sawadsky B, et al; Steering Committee, Central Validation Committee, Safety and Efficacy Committee. Out-of-hospital cardiac arrest rectilinear biphasic to monophasic damped sine defibrillation waveforms with advanced life support intervention trial (ORBIT). *Resuscitation*. 2005;66:149–157.
30. van Alem AP, Chapman FW, Lank P, Hart AA, Koster RW. A prospective, randomised and blinded comparison of first shock success of monophasic and biphasic waveforms in out-of-hospital cardiac arrest. *Resuscitation*. 2003;58:17–24.
31. Kudenchuk PJ, Cobb LA, Copass MK, Olsufka M, Maynard C, Nichol G. Transthoracic incremental monophasic versus biphasic defibrillation by emergency responders (TIMBER): a randomized comparison of monophasic with biphasic waveform ascending energy defibrillation for the resuscitation of out-of-hospital cardiac arrest due to ventricular fibrillation. *Circulation*. 2006;114:2010–2018.

# Impact of telephone dispatcher assistance on the outcomes of pediatric out-of-hospital cardiac arrest

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**Objective:** Most previous studies of pediatric out-of-hospital cardiac arrest have typically examined relatively small datasets from small study regions. Although several studies have reported the impact on adult out-of-hospital cardiac arrest, little information is available on the impact of telephone dispatcher assistance on the outcomes of pediatric out-of-hospital cardiac arrest. We set out to examine the impact of cardiopulmonary resuscitation instruction by telephone dispatcher on the outcomes of pediatric out-of-hospital cardiac arrest.

**Design:** Population-based, observational study.

**Setting:** Japan-wide population-based setting.

**Patients:** We identified 1,780 pediatric out-of-hospital cardiac arrest patients (67.8% male) with witnessed collapse from a nationwide, population-based, out-of-hospital cardiac arrest database.

**Intervention:** None.

**Measurement and Main Results:** We assessed the impact of telephone dispatcher assistance on the outcomes of 1-month survival rates and favorable neurologic status among the groups. The overall rate of bystander-performed chest compression and mouth-to-mouth ventilation among the witnessed pediatric out-of-hospital cardiac arrests were 39.5% and 25.6%, respectively. Telephone dispatcher assistance was offered in 28.4% of the witnessed pediatric out-of-hospital cardiac arrest cases and resulted

in a significant increase in both chest compression (adjusted odds ratio 6.04; 95% confidence interval 4.72–7.72) and mouth-to-mouth ventilation (adjusted odds ratio 3.10; 95% confidence interval 2.44–3.95), and a significant improvement in 1-month survival rate (adjusted odds ratio 1.46; 95% confidence interval 1.05–2.03), but no significant effect on favorable neurologic outcomes at 1 month (adjusted odds ratio 1.15; 95% confidence interval 0.70–1.88). Potential confounding factors included age categories, sex, bystander type, cause of cardiac arrest, bystander cardiopulmonary resuscitation, and attempted defibrillation.

**Conclusions:** Telephone dispatcher assistance could significantly increase bystander cardiopulmonary resuscitation among witnessed pediatric out-of-hospital cardiac arrests. Although there was only a small, nonsignificant effect on the improvement in favorable neurologic outcome at 1 month, the improved survival associated with telephone dispatcher assistance in pediatric out-of-hospital cardiac arrest is clinically important, and is of major public health importance. In cases where cardiac arrest was uncertain from the bystander's replies during the call to emergency medical services, telephone dispatcher assistance was not offered, which could affect the adjusted odds ratio of the present study. (*Crit Care Med* 2012; 40:000–000)

**KEY WORDS:** bystander effect; cardiopulmonary resuscitation; heart arrest; pediatrics; survival rate; telephone

Sudden out-of-hospital cardiac arrest (OHCA) is associated with a high mortality rate, even when patients receive appropriate treatment in accord with the “chain of survival” concept, consisting of rapid access to the emergency medical service (EMS),

cardiopulmonary resuscitation (CPR), and defibrillation. Although OHCA is one of the most common causes of death in middle and old age, it is uncommon in the young.

Most previous studies of pediatric OHCA typically examined relatively small datasets in North America (1–4). The survival rate to hospital discharge following pediatric OHCA was reported as approximately 10% (5, 6). Although recent studies reported the outcomes of pediatric OHCA in a prospective, population-based study in a large area (7, 8), data from a large, nationwide population-based study is still lacking. Recently, a cohort study of pediatric OHCA reported the characteristics and outcomes of pediatric OHCA (9). However, only a small study reported the impact of telephone dispatcher assistance on the outcomes of pediatric OHCA (10), whereas several studies have reported the impact on adult OHCA (11–14). The small pediatric study reported that

although telephone dispatcher-assisted CPR instructions improves the numbers of children in whom bystander CPR is attempted, the effectiveness is likely to be limited by significant delays in actually delivering basic life support (10). However, this study was limited because of its size and was not a population-based study.

The aim of the present study was to assess the impact of CPR instruction by telephone dispatcher on the attempted rate of bystander CPR and the outcomes of pediatric OHCA events. We analyzed a Japan-wide population-based database of OHCA between 2005 and 2008.

## PATIENTS AND METHODS

### Study Design and Data Source

Japan has approximately 128 million residents in an area of 377,914 km<sup>2</sup>. The Fire and

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Disaster Management Agency (FDMA) of Japan administers the EMS, providing the only ambulance service system in Japan. There are 807 local fire departments with dispatch centers, and this service can be accessed by all citizens. All OHCA cases transported to hospital by the EMS are recorded in a national OHCA database by the FDMA. In the present study, we extracted data from the national database to perform a nationwide, population-based observational study of all recorded cases of OHCA in Japan over a 4-yr period from January 2005 to December 2008.

Data were gathered by EMS personnel into a database belonging to local fire departments in Japan (15, 16). All data were verified and anonymized locally, then transferred and stored in the national OHCA database at the FDMA. We analyzed this database with the permission of the FDMA and the study was approved by the Ethical Committee of Nara Medical University (Authorization Code: 260).

### Items and Outcome of the Database

The OHCA data entry form was largely based on the Utstein form (17), and extended to include details of OHCA of noncardiac origin and nonwitnessed cases (15, 16, 18). Thus the database included OHCA of cardiac and noncardiac origin, such as stroke, asphyxia, trauma, etc. In addition, the data included witnessed as well as nonwitnessed cases.

The main items of the database were as follows: patient information, including age and sex; the cause of OHCA (cardiac or noncardiac); the initially identified cardiac rhythm; whether OHCA was bystander witnessed or not; whether bystander CPR was performed; bystander category (whether they were a family member, a layperson other than family, or EMS personnel); the interval from a call to arrival of the EMS (minutes); and the outcome in terms of survival and cerebral performance category (CPC) level 1 month after OHCA. The initial cardiac rhythm data were categorized by EMS personnel, and included ventricular fibrillation (VF), pulseless ventricular tachycardia (VT), pulseless electrical activity, and asystole. Bystander CPR was defined as either chest compression only or mouth-to-mouth ventilation in the present study. The etiology of cardiac arrest was determined clinically by the physician in charge, in collaboration with EMS personnel.

The presence or absence of telephone dispatcher assistance was also recorded in the database. The FDMA provided a standard outline for telephone dispatcher assistance and recommended local fire departments to modify the contents of telephone dispatcher assistance according to the actual circumstances of the local area. Telephone dispatcher assistance was offered when the

dispatcher judged the necessity of the assistance to the bystander of OHCA. The dispatcher asked the bystander whether they had any skill or knowledge to perform mouth-to-mouth ventilation. For a bystander with the skill and knowledge, the dispatcher offered instruction in CPR, including chest compression and mouth-to-mouth ventilation. For a bystander without the skill and knowledge, the dispatcher offered instruction in chest compression with or without mouth-to-mouth ventilation, depending on the operational procedure of the local fire department. In cases where a bystander refused to accept assistance, as a result of panic or a barrier to attempted CPR, such as being trapped, the dispatcher discontinued the offer of assistance. Dispatcher assistance for bystander CPR was not offered in cases where cardiac arrest was uncertain during the call.

Outcomes, including the 1-month survival and neurologic outcome, were collected by EMS personnel from the hospitals that received the patients, in cooperation with the physicians in charge of the patients. All OHCA patients were followed up by the EMS personnel in charge for up to 1 month to determine whether they survived after the OHCA event. The neurologic status was determined with the CPC at 1 month by follow-up interview.

### Subjects

During the 4-yr study period, data of 431,950 patients who suffered an OHCA were included in the national database. Of these, 9,308 patients were younger than 20 yrs (defined as pediatric OHCA in the present study). To determine the impact of telephone dispatcher assistance, we selected witnessed pediatric OHCA patients, with cases of VF/VT, pulseless electrical activity, and asystole as initial cardiac rhythm, and an interval between the call to the EMS and their arrival on the scene of  $\leq 60$  min. We excluded cases with bystander-performed automatic external defibrillation, or with EMS personnel as a bystander, and cases of unknown etiology or malignant tumors. In total, data from 1,780 pediatric OHCA cases were analyzed. Figure 1 shows a flow diagram depicting the inclusion/exclusion criteria used in the present study.

### Data Analysis

To assess the characteristics of witnessed pediatric OHCA patients, we stratified the cases into three age groups as follows: infants (<1 yr: 390 patients), children (1–11 yrs: 543 patients), and adolescents (12–19 yrs: 847 patients). For each group we determined the sex of the cases, whether bystander CPR was performed, whether an initial VF/VT cardiac rhythm was exhibited, and whether the cause of cardiopulmonary arrest was cardiac or noncardiac in origin. We

measured outcomes in terms of the 1-month survival and favorable neurologic outcome at 1 month in the three groups. "Favorable neurologic outcome" was defined as category 1 (good cerebral performance) or 2 (moderate cerebral disability) of the CPC (19). These characteristics were compared according to the three age groups.

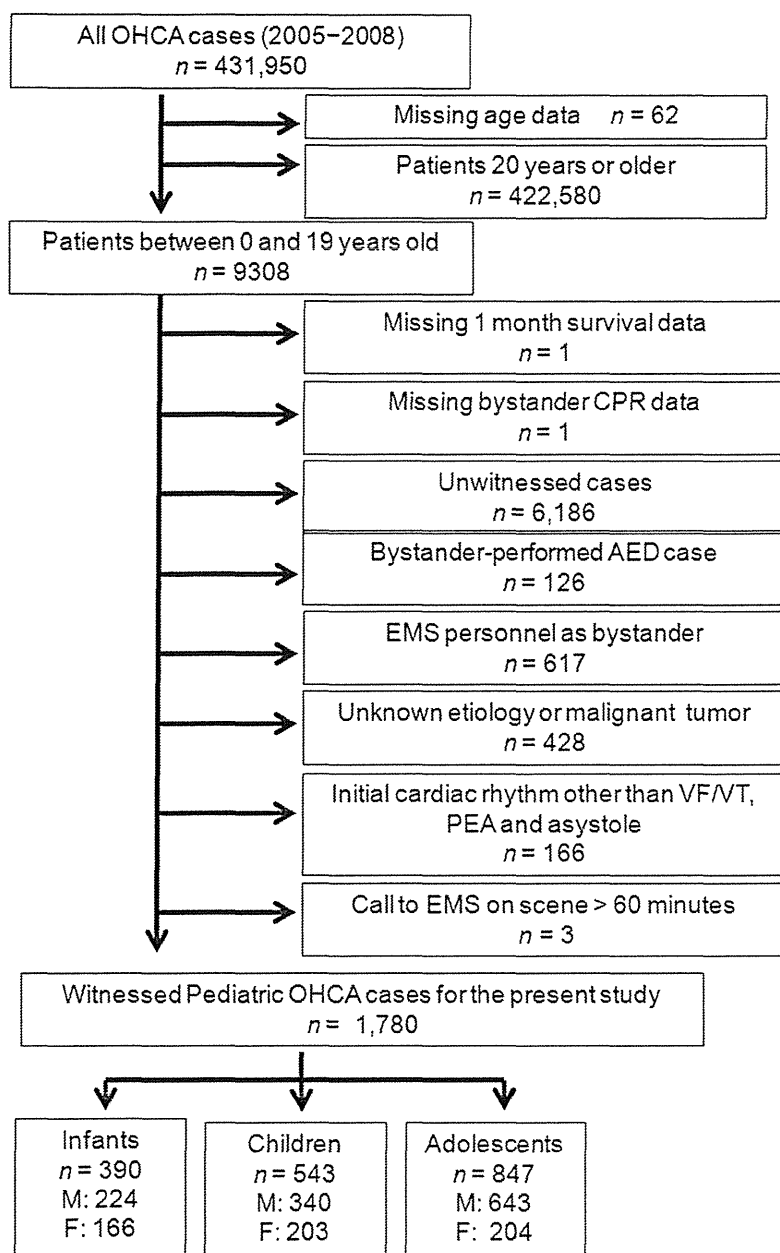
Statistical analyses were conducted using the chi-square test. Logistic regression analyses were performed to identify the effects of telephone dispatcher assistance on bystander CPR rate, using "not offered" as a reference. Potential confounding factors included age groups, sex, bystander type, cause of cardiac arrest, and the interval between call to the EMS and arrival at the scene. Logistic regression analyses were also performed to identify the effects of telephone dispatcher assistance for outcomes at 1 month, with the potential confounding factors of age groups, bystander CPR, attempted defibrillation, cause of cardiac arrest, and the time between call to the EMS and arrival at the scene. Statistical significance was defined as  $p < .05$ . All statistical analyses were conducted using PASW version 18 (SPSS, Chicago, IL).

## RESULTS

Among the 1,780 witnessed pediatric OHCA patients, males accounted for 67.8%. The proportion of VF/VT as an initial cardiac rhythm was higher in adolescents (21.3%) than in infants (11.8%) and children (6.6%). The overall bystander-performed CPR rate of each maneuver, chest compression and mouth-to-mouth ventilation, were 39.4% and 25.5%, respectively.

The overall survival rate for all pediatric patients was 13.4%. Table 1 shows 1-month survival and favorable CPC rates by initial cardiac rhythm, bystander CPR, age group and cause of OHCA. Chest compression with mouth-to-mouth ventilation showed the highest survival and favorable CPC rates compared with other resuscitation maneuvers. Although the 1-month survival rates of OHCA of noncardiac and cardiac origin were very similar in infants and children, a marked difference in adolescent survival rates was seen in 1-month survival rates between OHCA of noncardiac (4.8%) and of cardiac origin (32.8%).

Telephone dispatcher assistance was offered in 505 cases among 1,780 witnessed pediatric OHCA cases (28.4%). In cases where telephone dispatcher assistance was given, the numbers of patients with VF/VT, pulseless electrical activity, and asystole as initial cardiac rhythm were 82 (16.2%), 131 (25.9%), and 292



**Figure 1.** Flow diagram of inclusion/exclusion criteria. Infants, <1 yr; children, 1–11 yrs; adolescents, 12–19 yrs. *OHCA*, out-of hospital cardiac arrest; *CPR*, cardiopulmonary resuscitation; *AED*, automatic external defibrillation; *EMS*, emergency medical service; *VF*, ventricular fibrillation; *VT*, pulseless ventricular tachycardia; *PEA*, pulseless electrical activity; *M*, male; *F*, female.

(57.8%), respectively. In nonoffered cases, the numbers were 180 (14.1%), 366 (28.7%), and 729 (57.2%), respectively. Table 2 shows the rate of bystander-performed CPR and unadjusted 1-month outcomes by presence or absence of telephone dispatcher assistance in the witnessed pediatric OHCA. Thus, 27.8% (354 of 1275 cases) and 68.7% (347 of 505) received chest compression in nonoffered and offered cases of telephone dispatcher assistance, respectively;

18.4% (234 of 1275) and 43.6% (220 of 505) received mouth-to-mouth ventilation in nonoffered and offered cases, respectively. In nonoffered and offered cases of telephone dispatcher assistance, 16.2% (207 of 1275) and 37.6% (190 of 505) patients, respectively, received both chest compression and mouth-to-mouth ventilation. Telephone dispatcher assistance was mostly given to a family member. Telephone dispatcher assistance was associated with a significant increase in

the rates of bystander-performed CPR, including chest compression (68.7% vs. 27.8% with no assistance,  $p < .001$ ) and mouth-to-mouth ventilation (43.6% vs. 18.4% with no assistance,  $p < .001$ ).

Tables 3 and 4 show the results of logistic regression analyses for bystander-performed CPR rate and for outcomes at 1 month. Telephone dispatcher assistance significantly increased both chest compression (odds ratio [OR] 6.04; 95% confidence interval [CI] 4.72–7.72) and mouth-to-mouth ventilation (OR 3.10; 95% CI 2.44–3.95) (Table 3). This was also associated with a significant improvement in 1-month survival (OR 1.46; 95% CI 1.05–2.03), although there was a smaller effect on the improvement in favorable neurologic outcome at 1 month (OR 1.15; 95% CI 0.70–1.88) (Table 4).

## DISCUSSION

The present study clearly revealed that telephone dispatcher assistance improved the rate of bystander-performed CPR in witnessed cases of pediatric OHCA. When telephone dispatcher assistance was offered, the rate of bystander-performed chest compression and mouth-to-mouth ventilation increased, with a concomitant increase in 1-month survival rate.

Several papers have described the effects of dispatcher-assisted telephone CPR instruction in adult OHCA cases (10–14). Generally, dispatcher-assisted telephone CPR instruction can increase the frequency of bystander-performed CPR, resulting in an improved survival rate from OHCA. One study reported that dispatcher-assisted, bystander-performed CPR was associated with a 25% increase in the proportion of arrest patients who received bystander CPR, and concluded that dispatcher-assisted, bystander-performed CPR seems to increase survival after a cardiac arrest (11). However, only a small study described the impact of telephone dispatcher assistance on the outcomes of survival rate and neurologic status as well as the rate of bystander-performed CPR after a pediatric OHCA event (10).

Although the present study analyzed witnessed cases of pediatric OHCA, the rate of bystander-performed CPR was 27.8% and 18.4% for chest compression and mouth-to-mouth ventilation, respectively, in cases where telephone dispatcher assistance was not offered. The rate in the present study was similar to a previous report that only 17% of pediatric

**Table 1.** Overall 1-month survival and favorable cerebral performance category rates by initial cardiac rhythm and each bystander cardiopulmonary resuscitation

Variable	n (%)	1-Month Survival	Favorable Cerebral Performance Category
<b>Initial cardiac rhythm, n (%)</b>			
Ventricular fibrillation/pulseless ventricular tachycardia	262 (14.7)	101 (38.5)	66 (25.2)
Pulseless electrical activity	497 (27.9)	59 (11.9)	18 (3.6)
Asystole	1021 (57.4)	79 (7.7)	17 (1.7)
<b>Bystander cardiopulmonary resuscitation, n (%)</b>			
No bystander cardiopulmonary resuscitation	1022 (57.4)	91 (8.9)	32 (3.1)
Chest compression only	304 (17.1)	51 (16.8)	26 (8.6)
Mouth-to-mouth ventilation only	57 (3.2)	8 (14.0)	2 (3.5)
Chest compression with mouth-to-mouth ventilation	397 (22.3)	89 (22.4)	41 (10.3)
<b>Age group, n (%)</b>			
<b>Infant</b>			
Overall	390 (21.9)	54 (13.8)	19 (4.9)
Cardiac causes	235 (13.2)	34 (14.5)	14 (6.0)
Noncardiac causes	155 (8.7)	20 (12.9)	5 (3.2)
<b>Children</b>			
Overall	543 (30.5)	70 (12.9)	14 (2.6)
Cardiac causes	178 (10.0)	22 (12.4)	7 (3.9)
Noncardiac causes	365 (20.5)	48 (13.2)	7 (1.9)
<b>Adolescent</b>			
Overall	847 (47.6)	115 (13.6)	68 (8.0)
Cardiac causes	265 (14.9)	87 (32.8)	57 (21.5)
Noncardiac causes	582 (32.7)	28 (4.8)	11 (1.9)

Infants (<1 yr), children (1–11 yrs), adolescents (12–19 yrs).

**Table 2.** Bystander cardiopulmonary resuscitation and 1-month outcomes of patients with or without telephone instruction among the witnessed pediatric out-of-hospital cardiac arrest

Characteristic and outcome	Telephone Instruction		p
	Not Offered (1275)	Offered (505)	
<b>Bystander type, n (%)</b>			
Nonfamily	794 (62.3)	142 (28.1)	<.001
Family	481 (37.7)	363 (71.9)	
<b>Bystander cardiopulmonary resuscitation maneuver, n (%)</b>			
<b>Chest compression maneuver performed</b>			
Overall	354 (27.8)	347 (68.7)	<.001
Nonfamily bystander	221 (27.8)	107 (75.3)	<.001
Family bystander	133 (27.7)	240 (66.1)	<.001
<b>Mouth-to-mouth ventilation maneuver performed</b>			
Overall	234 (18.4)	220 (43.6)	<.001
Nonfamily bystander	146 (18.4)	46 (32.4)	<.001
Family bystander	88 (18.3)	174 (47.9)	<.001
<b>One-month outcomes, n (%)</b>			
<b>Survival</b>			
Overall	143 (11.2)	96 (19.0)	<.001
<b>Bystander type</b>			
Nonfamily bystander	79 (9.9)	29 (20.4)	.001
Family bystander	64 (13.3)	67 (18.5)	.044
<b>Favorable cerebral performance category (cerebral performance categories 1 and 2)</b>			
Overall	64 (5.0)	37 (7.3)	.068
<b>Bystander type</b>			
Nonfamily bystander	46 (5.8)	17 (12.0)	.011
Family bystander	18 (3.7)	20 (5.5)	.243

p values were calculated by chi-square test.

OHCA patients received bystander CPR, even when the event occurred at home with family members (20). In the present study, the overall rate of bystander-performed CPR increased with telephone dispatcher assistance from 27.8% to 69.0% for chest compression, and from 18.4% to 43.8% for mouth-to-mouth ventilation, compared with cases without telephone assistance. Subsequently, telephone dispatcher assistance significantly improved overall unadjusted 1-month survival rates, whereas no significant difference was observed for favorable neurologic outcome. The multivariate adjusted OR for survival was 1.46 (95% CI: 1.05–2.03,  $p = .02$ ) for telephone dispatcher assistance offered to OHCA cases using not-offered cases as reference, whereas no significant effect was observed for favorable neurologic outcome. A possible reason for the lack of improvement in neurologic outcome might be the quality of CPR performed by the bystander. To improve the rates of favorable neurologic outcome, further effort may be necessary, e.g., effective public training program of bystander CPR to improve the quality of CPR for pediatric OHCA patients.

In the present study, telephone dispatcher assistance had a greater impact on the use of mouth-to-mouth ventilation in children aged 1–11 yrs than in the other age groups. Our detailed analysis (data not shown) indicated that nonfamily bystanders tended to attempt CPR for OHCA of cardiac origin rather than noncardiac origin, regardless of the patients' age. In contrast, a family bystander tended to attempt mouth-to-mouth ventilation in children regardless of the cause of the arrest. The results in Table 3 included cases with either family or nonfamily bystanders: the rate of mouth-to-mouth ventilation for children was affected by family bystander behavior. Even in analyses of family and nonfamily bystanders separately, telephone dispatcher assistance had a significant impact on the rate of performed bystander CPR. We think that further study will be necessary regarding this point, i.e., on which cases bystanders are willing to perform each resuscitation maneuver of chest compression and mouth-to-mouth ventilation.

Performing mouth-to-mouth ventilation can be one of the barriers to bystanders attempting CPR. Furthermore, chest compression with mouth-to-mouth ventilation may be regarded as a complex task that is difficult to teach, learn, and attempt. Therefore, chest compression only

Table 3. Multivariate logistic regression analyses for bystander cardiopulmonary resuscitation rate

Factor	n (%)	Chest Compression Attempt			Mouth-to-Mouth Ventilation Attempt		
		Odds Ratio	95% Confidence Interval	p	Odds Ratio	95% Confidence Interval	p
Telephone instruction							
Not offered	1275 (71.6)		Reference			Reference	
Offered	505 (28.4)	6.04	4.72–7.72	<.001	3.10	2.44–3.95	<.001
Age group							
Infants	390 (21.9)		Reference			Reference	
Children	543 (30.5)	1.10	0.82–1.48	.54	1.47	1.08–1.99	.01
Adolescents	847 (47.6)	0.98	0.73–1.33	.91	0.86	0.62–1.19	.36
Sex							
Male	1207 (67.8)		Reference			Reference	
Female	573 (32.2)	1.03	0.82–1.30	.79	1.04	0.82–1.32	.76
Bystander type							
Nonfamily	844 (47.4)		Reference			Reference	
Family	936 (52.6)	0.69	0.53–0.90	.01	0.94	0.72–1.24	.68
Causes of arrest							
Noncardiac	1102 (61.9)		Reference			Reference	
Cardiac	678 (38.1)	2.67	2.13–3.35	<.001	1.91	1.51–2.42	<.001
Call to emergency medical service on scene time (1-min increase)		1.03	1.01–1.06	.01	1.03	1.00–1.05	.07

Infants (<1 yr), children (1–11 yrs), adolescents (12–19 yrs). Odds ratios were obtained by multivariate logistic regression analyses with potential confounding factors, including age group, sex, bystander type, cause of cardiac arrest, and the interval between call to the emergency medical service and arrival at the scene.

Table 4. Multivariate logistic regression analyses for outcomes at 1 month

Factor	n (%)	Survival at 1 Month			Favorable Cerebral Performance Category at 1 Month		
		Odds Ratio	95% Confidence Interval	p	Odds Ratio	95% Confidence Interval	p
Telephone instruction							
Not offered	1275 (71.6)		Reference			Reference	
Offered	505 (28.4)	1.46	1.05–2.03	.02	1.15	0.70–1.88	.58
Age group							
Infants	390 (21.9)		Reference			Reference	
Children	543 (30.5)	1.06	0.71–1.59	.77	0.62	0.30–1.29	.20
Adolescents	847 (47.6)	0.77	0.51–1.15	.20	1.06	0.58–1.95	.85
Bystander cardiopulmonary resuscitation							
Not performed	1022 (57.4)		Reference			Reference	
Performed	758 (42.6)	1.79	1.29–2.48	<.001	2.01	1.21–3.34	.01
Defibrillation							
Not performed	1503 (84.4)		Reference			Reference	
Performed	276 (15.5)	4.20	2.88–6.13	<.001	6.89	4.01–11.86	<.001
Causes of arrest							
Noncardiac	1102 (61.9)		Reference			Reference	
Cardiac	678 (38.1)	1.37	0.98–1.91	.06	2.18	1.24–3.82	.01
Call to emergency medical service on scene time (1-min increase)		0.84	0.80–0.89	<.001	0.82	0.75–0.90	<.001

Odds ratios were obtained by multivariate logistic regression analyses with potential confounding factors, including age groups, bystander cardiopulmonary resuscitation, attempted defibrillation, cause of cardiac arrest, and the time between call to the emergency medical service and arrival at the scene.

was recommended for bystander CPR in OHCA, especially for cases of cardiac origin (21). Recently, however, a few studies reported that chest compression with mouth-to-mouth ventilation is associated with better outcomes for selected patients, such as pediatric patients (18, 22). Thus, instruction for mouth-to-mouth ventilation may be included in dispatcher-assisted instruction during pediatric

OHCA where bystanders are willing to attempt CPR.

In literature describing pediatric OHCA, the neurologic outcome was generally determined by pediatric CPC (PCPC) (23, 24), developed from the CPC for adult patients. The adult CPC consists of five categories: 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; the PCPC has one additional category for mild disability. This category was added because even mild functional impairment has a more significant impact on development in children than in adults. The neurologic outcome in the present study was not defined by the PCPC, thus we could not compare the present result with

previous studies that used the PCPC. In this regard, outcomes for pediatric patients, such as PCPC and pediatric overall performance category, should be added to the database used in the present study.

The overall survival rates were very similar in infants, children, and adolescents in the witnessed pediatric OHCA, but the survival rates of noncardiac and cardiac origin OHCA in adolescents were lower and higher, respectively, than in infants and children. The higher VF/VT rate in adolescents compared with infants and children could account for the difference in survival rates. The present result also indicated that presentation with a VF rhythm could be a predictor of survival after an OHCA event in pediatric patients.

### Limitations

Several limitations of our study should be acknowledged. First, the database did not include information about the bystander, i.e., age and gender, quality of bystander CPR, including chest compression and mouth-to-mouth ventilation, or whether the bystander had taken a basic life support or advanced life support training course previously. In the case where a bystander was a child, the EMS dispatcher might discontinue telephone assistance. Therefore, we could not assess whether telephone dispatcher assistance improved the quality of bystander CPR and whether age and gender of the bystander affected the outcomes. Second, in cases where cardiac arrest was uncertain from the bystander's replies during the call to EMS, telephone dispatcher assistance was not offered, resulting in lower 1-month survival rates than if assistance had been offered in all cases of OHCA. There was no information in the database regarding the number of OHCA cases in which assistance was not offered due to this uncertainty. Although we suppose that the percentage of these cases among the OHCA in the present study was not very high, this could affect the adjusted OR of the present study. Third, the neurologic outcome in the database was not defined by PCPC (23), thus we could not compare our results with previous results that used PCPC. Fourth, the content of telephone dispatcher assistance might vary among local dispatch centers, i.e., whether the instruction to perform mouth-to-mouth ventilation was offered to a bystander lacking the skill and knowledge. The database did not include this information, thus we could not assess what types of instruction were effective

to facilitate the bystander CPR. Fifth, the outcomes, such as survival and neurologic outcomes, in pediatric OHCA might vary among hospitals, with the medical staff in children's hospitals or certain emergency centers with tertiary care having a greater knowledge and experience of pediatric OHCA patient care compared with staff in general hospitals. Donoghue et al (25) reported the effect of hospital and physician staffing characteristics on 24-hr survival after in-hospital CPR in children, where improved survival was associated with the presence of pediatric residents and fellows. The database also did not include hospital information, such as physician staffing characteristics. As such, we were unable to adjust for this factor in the present study. However, we assumed that the characteristics were distributed similarly among infants, children, and adolescents because the current database was huge and nationwide, thus we believe that any differences in hospital characteristics did not affect the results. Sixth, there was no intervention in the present study because the study was an observational study using a nationwide, population-based, prospectively registered database. Therefore, interventions, such as a randomized controlled trial, may be needed to confirm the present results.

### CONCLUSION

Telephone dispatcher assistance could significantly increase the rate of bystander-performed CPR among witnessed pediatric OHCA. Although there was a small, nonsignificant effect on the improvement in favorable neurologic outcome at 1 month, the improved survival associated with telephone dispatcher assistance in pediatric OHCA is clinically important, and is of major public health importance.

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### REFERENCES

1. Berg MD, Samson RA, Meyer RJ, et al: Pediatric defibrillation doses often fail to terminate prolonged out-of-hospital ventricular fibrillation in children. *Resuscitation* 2005; 67:63–67
2. Gerein RB, Osmond MH, Stiell IG, et al: What are the etiology and epidemiology of out-of-hospital pediatric cardiopulmonary arrest

- in Ontario, Canada? *Acad Emerg Med* 2006; 13:653–658
3. Schindler MB, Bohn D, Cox PN, et al: Outcome of out-of-hospital cardiac or respiratory arrest in children. *N Engl J Med* 1996; 335:1473–1479
4. Young KD, Gausche-Hill M, McClung CD, et al: A prospective, population-based study of the epidemiology and outcome of out-of-hospital pediatric cardiopulmonary arrest. *Pediatrics* 2004; 114:157–164
5. Kämäräinen A: Out-of-hospital cardiac arrests in children. *J Emerg Trauma Shock* 2010; 3:273–276
6. Tress EE, Kochanek PM, Saladino RA, et al: Cardiac arrest in children. *J Emerg Trauma Shock* 2010; 3:267–272
7. Atkins DL, Everson-Stewart S, Sears GK, et al: Epidemiology and outcomes from out-of-hospital cardiac arrest in children: The Resuscitation Outcomes Consortium Epistry-Cardiac Arrest. *Circulation* 2009; 119:1484–1491
8. Park CB, Shin SD, Suh GJ, et al: Pediatric out-of-hospital cardiac arrest in Korea: A nationwide population-based study. *Resuscitation* 2010; 81:512–517
9. Moler FW, Donaldson AE, Meert K, et al: Multicenter cohort study of out-of-hospital pediatric cardiac arrest. *Crit Care Med* 2011; 39:141–149
10. Deakin CD, Evans S, King P: Evaluation of telephone-cardiopulmonary resuscitation advice for paediatric cardiac arrest. *Resuscitation* 2010; 81:853–856
11. Rea TD, Eisenberg MS, Culley LL, et al: Dispatcher-assisted cardiopulmonary resuscitation and survival in cardiac arrest. *Circulation* 2001; 104:2513–2516
12. Eisenberg MS, Hallstrom AP, Carter WB, et al: Emergency CPR instruction via telephone. *Am J Public Health* 1985; 75:47–50
13. O'Neill JF, Deakin CD: Evaluation of telephone CPR advice for adult cardiac arrest patients. *Resuscitation* 2007; 74:63–67
14. Bång A, Örtengren PO, Herlitz J, et al: Dispatcher-assisted telephone CPR: A qualitative study exploring how dispatchers perceive their experiences. *Resuscitation* 2002; 53:135–151
15. Akahane M, Ogawa T, Koike S, et al: The effects of sex on out-of-hospital cardiac arrest outcomes. *Am J Med* 2011; 124:325–333
16. Yasunaga H, Horiguchi H, Tanabe S, et al: Collaborative effects of bystander-initiated cardiopulmonary resuscitation and prehospital advanced cardiac life support by physicians on survival of out-of-hospital cardiac arrest: A nationwide population-based observational study. *Crit Care* 2010; 14:R199
17. Jacobs I, Nadkarni V, Bahr J, et al: Cardiac arrest and cardiopulmonary resuscitation outcome reports: Update and simplification of the Utstein templates for resuscitation registries: A statement for healthcare professionals from a task force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian Resuscitation Council, New



- Zealand Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Councils of Southern Africa). *Circulation* 2004; 110:3385–3397
18. Ogawa T, Akahane M, Koike S, et al: Outcomes of chest compression only CPR versus conventional CPR conducted by lay people in patients with out of hospital cardiopulmonary arrest witnessed by bystanders: Nationwide population based observational study. *BMJ* 2011; 342:c7106
  19. Cummins RO, Chamberlain DA, Abramson NS, et al: Recommended guidelines for uniform reporting of data from out-of-hospital cardiac arrest: The Utstein Style. A statement for health professionals from a task force of the American Heart Association, the European Resuscitation Council, the Heart and Stroke Foundation of Canada, and the Australian Resuscitation Council. *Circulation* 1991; 84:960–975
  20. Sirbaugh PE, Pepe PE, Shook JE, et al: A prospective, population-based study of the demographics, epidemiology, management, and outcome of out-of-hospital pediatric cardiopulmonary arrest. *Ann Emerg Med* 1999; 33:174–184
  21. Sayre MR, Berg RA, Cave DM, et al: Hands-only (compression-only) cardiopulmonary resuscitation: A call to action for bystander response to adults who experience out-of-hospital sudden cardiac arrest: A science advisory for the public from the American Heart Association Emergency Cardiovascular Care Committee. *Circulation* 2008; 117:2162–2167
  22. Kitamura T, Iwami T, Kawamura T, et al: Conventional and chest-compression-only cardiopulmonary resuscitation by bystanders for children who have out-of-hospital cardiac arrests: A prospective, nationwide, population-based cohort study. *Lancet* 2010; 375:1347–1354
  23. Iser DH: Assessing the outcome of pediatric intensive care. *J Pediatr* 1992; 121:68–74
  24. López-Herce J, García C, Domínguez P, et al: Outcome of out-of-hospital cardiorespiratory arrest in children. *Pediatr Emerg Care* 2005; 21:807–815
  25. Donoghue AJ, Nadkarni VM, Elliott M, et al: Effect of hospital characteristics on outcomes from pediatric cardiopulmonary resuscitation: A report from the national registry of cardiopulmonary resuscitation. *Pediatrics* 2006; 118:995–1001

## 病院外心停止傷病者への胸骨圧迫のみと従来法 (胸骨圧迫+人工呼吸) の予後に関する一考察

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抄 録：病院外で発生した心停止傷病者（病院外心停止傷病者）に対する一般市民による心肺蘇生の予後に与える影響について、胸骨圧迫のみと従来法（胸骨圧迫および人工呼吸）の両手技の効果について議論となっており、決着がつかない。本稿では、筆者らが2011年に英国医学雑誌（BMJ）に発表した胸骨圧迫のみと従来法の予後を比較した研究結果を中心に概説する。

従来法実施症例は胸骨圧迫のみ実施症例に比べて1カ月生存率が高く、有意差がみられた（8.7% vs 10.3%，調整済みオッズ比：1.17，95%信頼区間：1.06～1.29）。脳機能カテゴリー良好割合でも同様に有意差がみられた（4.6% vs 5.6%，調整済みオッズ比：1.17，95%信頼区間：1.01～1.35）。また、非心原性症例では年齢が若くなるほどその予後が良く有意差（ $P=0.025$ ）がみられたほか、目撃から心肺蘇生開始までの時間が長いほど、非心原性（ $P=0.015$ ）および全症例（ $P=0.037$ ）で従来法の予後が良く、有意差がみられた。

【結論】従来法のみは、胸骨圧迫のみに比べ全体として予後が良く、有意差がみられた。この傾向は、若年層の非心原性症例や目撃から時間が経過した全症例および非心原性症例で顕著であった。本研究の結果は、今後のガイドライン作成等に活用できるものと期待される。

キーワード：心肺蘇生，バイスタンダー，胸骨圧迫，人工呼吸，生存率

Key words：cardiopulmonary resuscitation (CPR)，bystander，chest compression only CPR，conventional CPR，survival rate

### はじめに

病院外で発生した心停止傷病者（病院外心停止傷病者）に対しては、早期の通報や、心肺蘇生、除細動、高度医療処置のいずれもが円滑に実施されることが重

要であり、これらは「救命の連鎖」と呼ばれている<sup>1)</sup>。このうち、早期の通報や、心肺蘇生、除細動については、心停止時点で近くにいた通行人や家族などのいわゆるバイスタンダーの役割が重要である<sup>2)</sup>。

バイスタンダーによる心肺蘇生については、従来は人工呼吸と胸骨圧迫を併用した心肺蘇生（以下、従来法）が推奨されてきたが、昨今は胸骨圧迫のみの心肺蘇生も普及しつつある。その理由として、人工呼吸の実施が、一般市民には技術的にやや難しいことや、感染症の危険性などが心理的な抵抗となり心肺蘇生の実施率の低迷や実施遅れの原因となることが懸念されていることがあげられる<sup>3,4)</sup>。また、従来法と胸骨圧迫のみの予後の比較において、条件によっては胸骨圧迫のみのほうが良いとの報告<sup>5)</sup>、あるいはほぼ同等との研究結果が報告され

Analysis of outcomes of chest compression only CPR versus conventional CPR conducted by lay people in patients with out of hospital cardiopulmonary arrest witnessed by bystanders

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ていることも大きな理由である<sup>6,8)</sup>。これらを踏まえ、アメリカ心臓病学会 (AHA: American Heart Association) の 2005 年の心肺蘇生ガイドライン<sup>9)</sup> では、バイスタンダーによる心肺蘇生は従来法が良いとしながらも、胸骨圧迫のみの心肺蘇生も推奨している。また、2008 年の AHA の科学調査委員会 (Science Research Committee)<sup>10)</sup> によると、従来法は十分に訓練を受け、また実施が可能であると自ら判断したバイスタンダーにより実施されるべきで、一般のバイスタンダーによる心肺蘇生は胸骨圧迫のみで良いと結論づけられている。しかしながら、従来法のほうが胸骨圧迫のみによる心肺蘇生よりも予後が良いとの意見も根強く残っている<sup>11)</sup>。

このような状況において、筆者らは、わが国の「救急蘇生統計」の 2005～2007 年のデータを用いて胸骨圧迫のみと従来法の予後の比較を実施し、その結果を 2011 年 2 月に英国医学雑誌 (BMJ) に発表した (以下、BMJ 研究)<sup>12)</sup>。本稿では、筆者らの研究結果を概観したうえで 2010 年の AHA ガイドラインを踏まえ、バイスタンダーによる心肺蘇生について考察を行う。

## 1. BMJ 発表論文で用いた方法

### 1) 分析対象

わが国において院外発生で救急搬送されたすべての心停止傷病者の情報は、総務省消防庁により集計され「救急蘇生統計」として整備されている。「救急蘇生統計」は平成 17 年 (2005 年) より集計が開始されており、心停止傷病者を搬送した各消防本部によって、ウツタイン様式でのデータ収集・入力を実施されている。「救急蘇生統計」には、傷病者の性、年齢などの基本情報に加え、心停止の目撃に関する情報、バイスタンダーの種別と実施された心肺蘇生の内容、初期心電図波形、救命救急処置等の内容、目撃、覚知から病院収容に至るまでの時間経過、心停止の推定原因、1 ヶ月後の転帰および予後などの情報が記載されている。データには、消防隊員によりバイスタンダーや担当医師へのインタビュー等で収集されたものも含まれている。「救急蘇生統計」における予後としては、心停止の発生より 1 ヶ

月後の生存の有無と、グラスゴー・ピッツバーグ脳機能・全身機能カテゴリによる脳機能、全身機能の評価が記載されている。そのうち脳機能カテゴリ (CPC: cerebral performance categories) とは、発生より 1 ヶ月後の脳機能の状態を、CPC 1 は機能良好、CPC 2 は中等度障害、CPC 3 は高度障害、CPC 4 は昏睡、植物状態、CPC 5 は死亡もしくは脳死、の 5 段階で評価されている。収集された情報は救急隊員によりオンラインなどで入力され、匿名化された後に消防庁に送られる。消防庁ではデータのチェックを行い、必要に応じて消防本部に再確認し、その精度向上を図っている。筆者らは BMJ 研究の執筆に際し、総務省消防庁に対してこのデータ利用申請を行い、使用許可を得て分析を実施した。なお、BMJ 研究は公立大学法人奈良県立医科大学倫理委員会の承認を受けて実施した (承認番号: 260)。

BMJ 研究で用いた「救急蘇生統計」の 2005～2007 年データには、318,141 例の心停止傷病者の情報が記載されている。BMJ 研究では、これらのデータのうち、家族、同僚、友人、通行人など一般市民により心停止を目撃され、また一般市民により胸骨圧迫のみ、あるいは従来法 (胸骨圧迫および人工呼吸) のいずれかを実施された症例を抽出した。非目撃症例 (190,646 例) や救急隊員などによる目撃症例 (25,521 例)、目撃した人が不明な症例 (193 例) などは除外し、さらにバイスタンダーによる心肺蘇生が実施されなかった症例 (56,851 例) と、人工呼吸だけ実施された症例 (1,670 例)、さらに心肺蘇生を実施したバイスタンダーが不明な症例 (3,225 例) を分析から除外した。その結果、胸骨圧迫のみの実施の 20,707 例、従来法の実施 19,328 例を分析対象症例として抽出した。なお、これらの分析対象症例にはすべての年齢層が含まれているほか、心停止の原因としては心原性のみならず、溺水や呼吸器系疾患、循環器系疾患など非心原性症例が含まれている。

### 2) 統計解析

BMJ 研究においては、一般市民により目撃され、かつ胸骨圧迫のみあるいは従来法の実施された症例の予後を比較した。分析に用いた予後としては、1 ヶ月後の生存率と脳機能カテゴリ良好

	胸骨圧迫のみ	従来法	調整済みオッズ比	
			ratio	p
一ヶ月生存率	8.7% (1799/20707)	10.3% (1997/19327)	1.17 (1.06-1.29)	0.002*
脳機能カテゴリー 良好割合	4.6% (943/20662)	5.6% (1070/19247)	1.17 (1.01-1.35)	0.037*

\* 有意差あり

表1 胸骨圧迫のみと従来法（胸骨圧迫+人工呼吸）の予後比較（小川ら<sup>12)</sup>より筆者改変）

割合（CPC 1あるいは2）<sup>13)</sup>を用いた。分析にあたり、心停止傷病者は原因別（心原性、非心原性）ごとに分析したほか、心停止傷病者を20歳ごとの年齢階級群（1～19歳、20～39歳、40～59歳、60～79歳、80～99歳、100歳以上）で分析した。また、バイスタンダーによる目撃からバイスタンダーによる心肺蘇生実施までの経過時間を2分ごとの時間階級群（0、1～2分、3～4分、5～6分、7～8分、9～10分）で分析を実施した。なお、バイスタンダーによる目撃から心肺蘇生実施までの時間が10分以上の症例（3,237例）と、経過時間が不明の症例（1,387例）は、時間階級群の分析からは除外した。

統計解析にあたり、有意差の検定方法として、カイ二乗検定および信頼区間95%のオッズ比を算出し $p < 0.05$ を有意差とした。平均値の比較には、独立したサンプルのt検定を実施した。予後の比較は、ロジスティック回帰分析により信頼区間95%の調整済みオッズ比を算出して比較した。両手技の比較にあたっては、ロジスティック回帰分析により予後に関連する各種要因を調整した。また心肺蘇生と年齢群、心肺蘇生と経過時間それぞれの交互作用について、交絡因子を調整した多項相互作用分析（multi-adjusted interaction model）を実施した。これらの統計解析はすべてPASW v.18（現SPSS v.18, IBM社）を用いた。

## 2. BMJ 発表論文で得られた結果

胸骨圧迫のみと従来法の実施症例の1カ月生存率を比較すると、従来法実施症例の1カ月生存率が高く、有意差がみられた（8.7% vs 10.3%, 調整済みオッズ比: 1.17, 95%信頼区間: 1.06～1.29, 表1）。同

様に、脳機能カテゴリー良好割合も従来法実施症例が高く、有意差がみられた（4.6% vs 5.6%, 調整済みオッズ比: 1.17, 95%信頼区間: 1.01～1.35, 表1）。

次に、脳機能カテゴリー良好割合を用いて、年齢階級別・原因別にその予後を比較した結果、非心原性症例では年齢が若くなるほどその予後が良く、有意差がみられた（ $P=0.025$ ）。一方、全症例（ $P=0.109$ ）と心原性症例（ $P=0.951$ ）では有意差はみられなかった（図1）。また、目撃から一般市民による心肺蘇生法開始までの時間が長いほど、非心原性（ $P=0.015$ ）および全症例（ $P=0.037$ ）で従来法の予後が良く、有意差がみられた。一方で心原性症例では有意差がみられなかった（ $P=0.369$ , 図1）。

## 3. 考 察

BMJ 研究によると従来法は胸骨圧迫のみに比べ全体として予後が良く、有意差がみられ、この傾向は、若年層の非心原性症例や、目撃から時間が経過した全症例および非心原性症例で顕著であった。本研究の結果は、胸骨圧迫のみと従来法の両手技の予後がほぼ同等である<sup>6,8)</sup>、あるいは胸骨圧迫のみのほうが予後は良い<sup>5)</sup>という既存研究とは異なった傾向であることが示唆された。その理由は、分析に用いたサンプルサイズの違いがまず考えられる。BMJ 研究では、2005年から2007年の3年間でわが国において院外発生 of 救急搬送された全心停止傷病者のうち、一般市民により目撃され、かつ心肺蘇生が実施された症例を抽出しており、分析対象の症例数は両群を合わせて約4万件であった。この症例数はこれまでにわが国<sup>5,7)</sup>や北欧<sup>6,8)</sup>、シンガポール<sup>14)</sup>などで実施されたとの既存研究よりも大きな

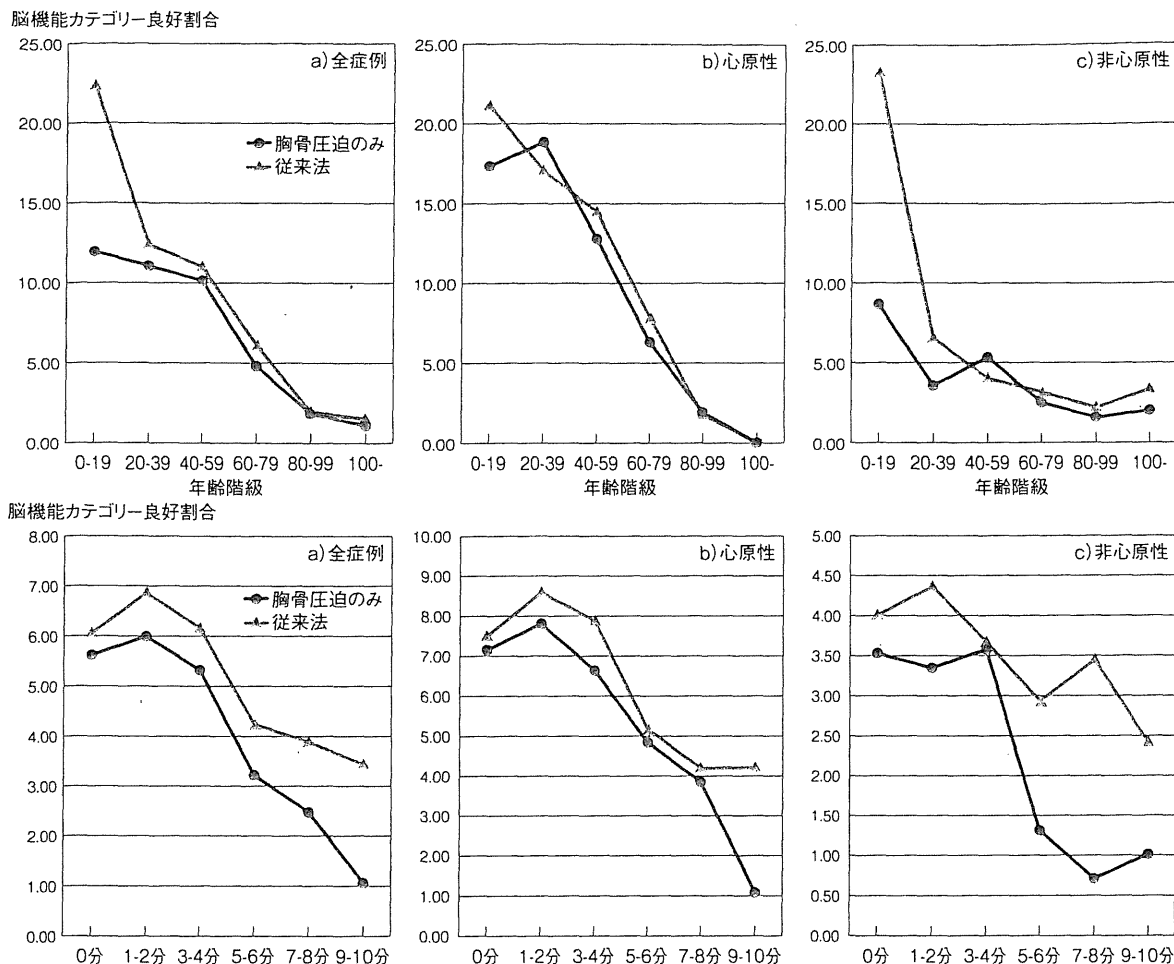


図1 胸骨圧迫のみと従来法の年齢階級別（上段），時間階級別（下段）の予後比較（総数，心原性，非心原性）（小川ら<sup>12)</sup>より筆者改変）

ものであり，そのため統計的に有利であったといえよう。また，わが国で発生した全症例を用いた分析であることから，症例選択によるバイアスは最小に抑えられていると考えられる。

BMJ 研究により，20歳未満の若年層かつ非心原性の症例においては，従来法は胸骨圧迫よりも予後が良いことが示唆された。特に若年層において，溺水や外傷などを含む外因性の非心原性症例において従来法の予後が胸骨圧迫のみに比べて顕著に良い傾向が見られたことから，これらの症例の予後が従来法全体の予後を引き上げた可能性が考えられる。なお，若年層での両手技の予後については，北村らが同じ救急蘇生統計の17歳以下の症例を用いて分析しているが，彼らもBMJ研究と同様に従来法の予後が良いと結論づけている<sup>15)</sup>。

20歳以上の成人症例については，BMJ研究により胸骨圧迫のみと従来法の両手技の予後に差がな

いことが示唆された。この結果は，わが国で18歳以上の心原性症例について石見ら<sup>7)</sup>およびSOS-KANTO<sup>5)</sup>によって実施された既存研究の結果と同様であった。一方Hupflら<sup>16)</sup>は成人症例のメタアナリシスを実施し，胸骨圧迫のみのほうが従来法に比べて予後が良い，あるいはほぼ同等と結論づけている。この結果はBMJ研究とは異なった結論であるが，その理由としては，メタアナリシスの対象文献では心原性のみを選択したものや，年齢の一部に限定した分析であったのに対して，BMJ研究では心原性，非心原性の両方を含み，またすべての年齢を含む分析であったことが，その結果の違いを生んだと考えられる。

バイスタンダーによる目撃から心肺蘇生実施までの経過時間による胸骨圧迫のみと従来法の両手技の予後の違いについては，目撃から時間が経過した症例では，胸骨圧迫のみに比べて従来法の予後が全症