

# Cardiopulmonary resuscitation by bystanders with chest compression only (SOS-KANTO): an observational study

SOS-KANTO study group

## Summary

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**Background** Mouth-to-mouth ventilation is a barrier to bystanders doing cardiopulmonary resuscitation (CPR), but few clinical studies have investigated the efficacy of bystander resuscitation by chest compressions without mouth-to-mouth ventilation (cardiac-only resuscitation).

**Methods** We did a prospective, multicentre, observational study of patients who had out-of-hospital cardiac arrest. On arrival at the scene, paramedics assessed the technique of bystander resuscitation. The primary endpoint was favourable neurological outcome 30 days after cardiac arrest.

**Findings** 4068 adult patients who had out-of-hospital cardiac arrest witnessed by bystanders were included; 439 (11%) received cardiac-only resuscitation from bystanders, 712 (18%) conventional CPR, and 2917 (72%) received no bystander CPR. Any resuscitation attempt was associated with a higher proportion having favourable neurological outcomes than no resuscitation (5·0% vs 2·2%,  $p < 0·0001$ ). Cardiac-only resuscitation resulted in a higher proportion of patients with favourable neurological outcomes than conventional CPR in patients with apnoea (6·2% vs 3·1%;  $p = 0·0195$ ), with shockable rhythm (19·4% vs 11·2%,  $p = 0·041$ ), and with resuscitation that started within 4 min of arrest (10·1% vs 5·1%,  $p = 0·0221$ ). However, there was no evidence for any benefit from the addition of mouth-to-mouth ventilation in any subgroup. The adjusted odds ratio for a favourable neurological outcome after cardiac-only resuscitation was 2·2 (95% CI 1·2–4·2) in patients who received any resuscitation from bystanders.

**Interpretation** Cardiac-only resuscitation by bystanders is the preferable approach to resuscitation for adult patients with witnessed out-of-hospital cardiac arrest, especially those with apnoea, shockable rhythm, or short periods of untreated arrest.

## Introduction

Cardiopulmonary resuscitation (CPR) consisting of chest compression plus mouth-to-mouth ventilation done by bystanders is a major element in the so-called chain of survival for people with cardiac arrest.<sup>1–4</sup>

Although bystander CPR improves likelihood of survival,<sup>1–8</sup> reports<sup>9–14</sup> have shown that bystander CPR was attempted for less than a-third of patients who had collapsed. Surveys have identified reluctance of bystanders to undertake mouth-to-mouth ventilation as a substantial barrier to CPR attempts.<sup>10,15–17</sup> This reluctance is partly caused by fear of transmission of infectious diseases. Despite the remote chance of such infection, fears about disease transmission are common in the present era of universal precautions.<sup>10,15</sup> Another barrier to bystanders attempting CPR is the complexity of the technique as presently taught.<sup>18–20</sup> In CPR guidelines, cardiac-only resuscitation by bystanders is recommended in dispatcher-assisted resuscitation or if a rescuer is unwilling or unable to do mouth-to-mouth ventilation.<sup>2–4</sup> However, this technique is not generally known, recommended, or taught to the public. Since few clinical studies have focused on the efficacy of cardiac-only resuscitation,<sup>8,21,22</sup> we sought to compare the outcomes for patients who underwent cardiac-only resuscitation or conventional CPR by bystanders. If cardiac-only resuscitation is as effective as conventional CPR by bystanders, rescuers might be more willing and able to provide this simple intervention than they are at present. Furthermore, clinical studies have established that interruptions to chest compressions during out-of-hospital cardiac arrest are common, even by trained emergency medical staff.<sup>3,23,24</sup> Studies suggest

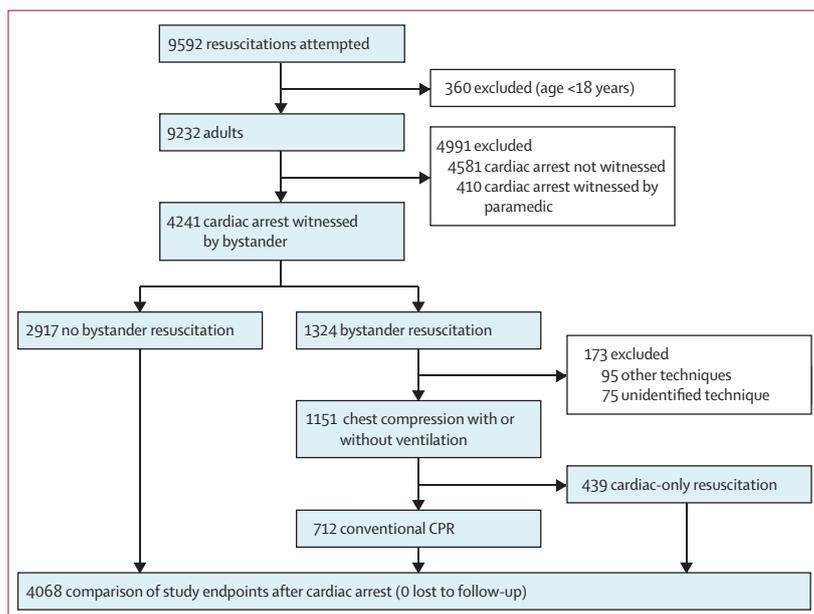


Figure 1: Study profile

that such interruptions can have lethal consequences.<sup>25-27</sup> Kern and colleagues<sup>26</sup> showed that cardiac-only resuscitation results in substantially better survival without neurological impairment 24 h after cardiac arrest than conventional CPR.

We therefore assessed the effect of cardiac-only resuscitation by bystanders on adults who had out-of-hospital cardiac arrest. We expected that cardiac-only resuscitation or conventional CPR would be better than no bystander intervention and that cardiac-only resuscitation would show similar neurological outcome to conventional CPR.

## Methods

### Participants

A survey of survivors of out-of-hospital cardiac arrest in the Kanto region of Japan (SOS-KANTO) was done by the Association for Acute Medicine of Kanto and included 58 emergency hospitals and emergency medical service units. Between Sept 1, 2002, and Dec 31, 2003, patients who had out-of-hospital cardiac arrest witnessed by bystanders and who were subsequently transported by paramedics to emergency hospitals participating in SOS-KANTO were included in the study. Exclusion criteria were: patients younger than 18 years of age; further cardiac arrest after the arrival of paramedics; documented terminal illness; presence of a do-not-resuscitate order; and bystander resuscitation without documented chest compressions.

### Procedures

The study was a prospective, multicentre, observational trial that followed Utstein style reporting guidelines.<sup>1</sup> The study was approved by the SOS-KANTO Research Ethics Board, and the requirement for informed consent was waived according to Japanese government guidelines.<sup>28</sup> Paramedics observed the technique of bystander resuscitation and asked additional questions of bystanders to assess the characteristics of resuscitation.<sup>1,2</sup> The technique during bystander resuscitation was identified as cardiac-only resuscitation, conventional CPR, pulmonary-only resuscitation, unidentified resuscitation technique (including change of technique), or chest compression not documented. Chest compression rate and depth were not assessed. The person attempting bystander resuscitation was classified as a lay person with basic CPR training, a lay person assisted by a dispatcher, a lay person without either training or dispatcher assistance, or an off-duty health worker. All event times were measured by the dispatch centre clock, and times of collapse and first bystander resuscitation attempts were obtained from the bystanders. Cardiac arrest was defined as the cessation of cardiac mechanical activity, manifesting as unresponsiveness, apnoea (or gasping breathing), and absence of pulse. The arrest was presumed to be from a cardiac cause, unless it was known to have been caused

by a non-cardiac cause including trauma, drowning, and asphyxia.<sup>1</sup>

Resuscitation attempts were documented by both paramedics and attending physicians according to Utstein style reporting guidelines.<sup>1</sup> Data for individual patients were entered into a database by SOS-KANTO members at each hospital and were independently cross-checked twice by different investigators. Original data were made available to the data and safety monitoring committee for independent scrutiny.

### Study endpoints

The primary endpoint was favourable neurological outcome 30 days after cardiac arrest, defined as a Glasgow-Pittsburgh cerebral-performance category of

	Any bystander resuscitation	No bystander resuscitation	p value
Age (years)	68 (55-80)	68 (57-78)	0.8450
Male sex	778/1151 (68%)	2022/2917 (69%)	0.2848
Cardiac cause	806/1151 (70%)	1836/2917 (63%)	<0.0001
Location of cardiac arrest			<0.0001
Home or other residence	598/1138 (53%)	1790/2879 (62%)	
Public, indoors	413/1138 (36%)	623/2879 (22%)	
Public, outdoors	127/1138 (11%)	466/2879 (16%)	
First physical findings at arrival of EMS			
Gasping breathing	123/1151 (11%)	166/2917 (6%)	<0.0001
Pupillometer (mm*)	5.0 (5.0-6.0)	6.0 (5.0-6.0)	0.0002
Initial cardiac rhythm			<0.0001
VF/pulseless VT	329/1151 (29%)	549/2917 (19%)	
PEA	239/1151 (21%)	755/2917 (26%)	
Asystole	584/1151 (51%)	1613/2917 (55%)	
Treatment			
Defibrillatory shock	440/1151 (38%)	839/2917 (29%)	<0.0001
Tracheal intubation	1119/1151 (97%)	2804/2917 (96%)	0.0901
Epinephrine	1047/1151 (91%)	2681/2917 (92%)	0.3266
Hypothermia	28/1151 (2%)	48/2917 (2%)	0.0949
Medical history			
Coronary heart disease	122/1118 (11%)	287/2838 (10%)	0.4570
Hypertension	178/1118 (16%)	424/2838 (15%)	0.4392
Heart failure	35/1118 (3%)	106/2838 (4%)	0.3588
Diabetes	139/1118 (12%)	332/2838 (12%)	0.5207
Time (min)			
From collapse to call receipt†	3.0 (1.0-5.0)	3.0 (1.0-5.0)	0.6396
From call receipt to first AED analysis	10.0 (8.0-12.0)	10.0 (8.0-12.0)	0.4422
From first AED analysis to departure from scene‡	14.0 (10.0-17.0)	14.0 (10.0-18.0)	0.8066
From departure to arrival at hospital§	10.0 (6.0-13.0)	10.0 (6.0-13.0)	0.7415

Data are median (IQR) or numerator/total number (%). Calculations based on available data. AED=automated external defibrillator. CPR=cardiopulmonary resuscitation. EMS=emergency medical services. PEA=pulseless electrical activity. VF=ventricular fibrillation. VT=ventricular tachycardia. \*The pupil was measured by EMS workers using one patient's checklist card with pupillometer rulers, and was recorded for 1080 patients in the any resuscitation group and for 2764 in the no bystander resuscitation group. †Time recorded for 850 patients in the any resuscitation group and for 2046 in the no bystander resuscitation group. ‡Time recorded for 1125 in the any resuscitation group and for 2861 in the no bystander resuscitation group. §Time recorded for 1073 in the any resuscitation group and for 2716 in the no bystander resuscitation group.

**Table 1: Baseline characteristics of the patients**

	Cardiac-only resuscitation	Conventional CPR	p value
Age (years)	69 (55–80)	68 (55–80)	0.3002
Male sex	316/439 (72%)	462/712 (65%)	0.0125
Cardiac cause	305/439 (69%)	501/712 (70%)	0.7491
Location of cardiac arrest			0.0063
Home or other residence	253/432 (59%)	345/706 (49%)	
Public, indoors	136/432 (31%)	277/706 (40%)	
Public, outdoors	43/432 (10%)	84/706 (12%)	
First physical findings at arrival of EMS			
Gasping breathing	50/439 (11%)	73/712 (10%)	0.5443
Pupillometer (mm*)	5.0 (5.0–6.0)	5.0 (5.0–6.0)	0.7251
Initial cardiac rhythm			0.9116
VF/pulseless VT	124/439 (28%)	205/712 (29%)	
PEA	94/439 (21%)	145/712 (20%)	
Asystole	221/439 (50%)	362/712 (51%)	
Treatment			
Defibrillatory shock	173/439 (39%)	267/712 (38%)	0.5177
Tracheal intubation	424/439 (97%)	695/712 (98%)	0.3022
Epinephrine	397/439 (90%)	650/712 (91%)	0.6213
Hypothermia	10/439 (2%)	18/712 (3%)	0.7890
Medical history			
Coronary heart disease	52/429 (12%)	70/689 (10%)	0.3063
Hypertension	60/429 (14%)	118/689 (17%)	0.1628
Heart failure	12/429 (3%)	23/689 (3%)	0.6135
Diabetes	52/429 (12%)	81/689 (12%)	0.3848
Performer of bystander resuscitation			<0.0001
Off-duty medical staff	97/439 (22%)	350/712 (49%)	
Lay person with CPR training	70/439 (16%)	128/712 (18%)	
Lay person with dispatcher-assisted resuscitation	139/439 (32%)	133/712 (19%)	
Lay person with no training or assisted resuscitation	133/439 (30%)	101/712 (14%)	
Time (min)			
From collapse to first bystander resuscitation attempt†	4.0 (2.0–5.0)	4.0 (2.0–5.0)	0.8080
From first bystander resuscitation attempt to first AED analysis	9.0 (8.0–11.0)	9.0 (7.0–11.0)	0.3846
From first AED analysis to departure from scene‡	14.0 (10.0–18.0)	14.0 (11.0–18.0)	0.7379
From departure to arrival at hospital§	10.0 (6.0–13.0)	10.0 (6.0–13.0)	0.8020

Data are median (IQR) or numerator/total number (%). Calculations based on available data. AED=automated external defibrillator. CPR=cardiopulmonary resuscitation. EMS=emergency medical services. PEA=pulseless electrical activity. VF=ventricular fibrillation. VT=ventricular tachycardia. \*The pupil was measured by EMS workers using one patient's checklist card with pupillometer rulers, and was recorded for 421 patients in the cardiac-only resuscitation group, and for 659 in the conventional CPR group. †The time was recorded for 323 patients in the cardiac-only resuscitation group, and for 527 in the conventional CPR group. ‡The time was recorded for 436 in the cardiac-only resuscitation group, and for 689 in the conventional CPR group. §The time was recorded for 414 in the cardiac-only resuscitation group, and for 659 in the conventional CPR group.

Table 2: Baseline characteristics of the patients receiving bystander CPR

1 (good performance) or 2 (moderate disability) on a five-category scale.<sup>1,2</sup> The other categories of 3 (severe disability), 4 (vegetative state), and 5 (death) were regarded as unfavourable neurological outcome.<sup>1,2</sup> The secondary endpoint was survival 30 days after cardiac arrest, defined as a Glasgow-Pittsburgh cerebral-performance category of 1, 2, 3, or 4. The neurological outcome was defined by physicians who were unaware of the patient's bystander resuscitation group.

Statistical analysis

An estimate of the number of patients needed to test our hypothesis was derived from analyses of three previous large-scale studies in Japan.<sup>12–14</sup> The calculation was based on a two-fold improvement in favourable neurological outcomes from a baseline outcome of 1.6, and a 1:1:6 ratio of patients who had bystander-witnessed cardiac arrest and received cardiac-only resuscitation versus conventional CPR versus no resuscitation. The minimum sample size for comparison of favourable neurological outcome at 30 days was estimated to be 400 patients for each bystander resuscitation group, and 1120 patients for the no bystander resuscitation group on the basis of a two-sided  $\alpha$  value of 0.05 and a  $\beta$  error of 0.10. Baseline characteristics were compared by use of the  $\chi^2$  test for categorical variables and the Mann-Whitney U test for continuous variables, as appropriate. Odds ratios and their 95% CI were calculated for the study endpoints. A multiple logistic-regression analysis was done for independent predictors of resuscitation, including age, cause of cardiac arrest, technique of bystander resuscitation, resuscitation-related time intervals, and initial recorded cardiac rhythm.<sup>12</sup> The non-linear regression analysis with logarithm was used to illustrate the relation between favourable neurological outcome 30 days after cardiac arrest and the time between first bystander resuscitation attempts and first use of automated external defibrillator (AED) in patients receiving bystander CPR with ventricular fibrillation or ventricular tachycardia as an initial cardiac rhythm.

Role of the funding source

The sponsors had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data and had final responsibility for the decision to submit for publication.

Results

9592 patients received advanced life support by paramedics and were transported to emergency hospitals during the study. Of those, 5464 patients were not eligible. The SOS-KANTO study therefore included 4068 adult patients who had bystander-witnessed cardiac arrest out of hospital; 1151 (28%) received bystander resuscitation, including 439 (11%) who received cardiac-only resuscitation and 712 (18%) who received conventional CPR, and 2917 (72%) did not receive any bystander resuscitation. No patient was lost to follow-up for study endpoints at 30 days after cardiac arrest (figure 1).

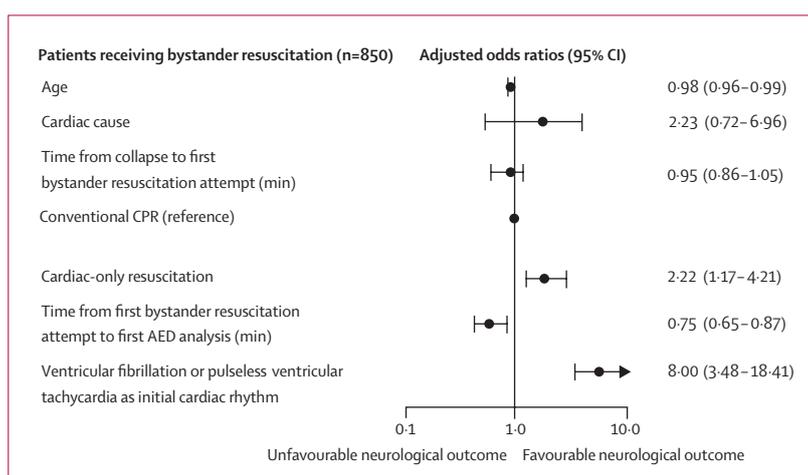
At baseline, significant differences (table 1) were seen between the any resuscitation group and the no bystander resuscitation group for cause of cardiac arrest, location where the cardiac arrest happened, proportion with gasping breathing and pupillometer reading at arrival of emergency medical services, initial recorded cardiac rhythm, and the need for defibrillation by emergency

	Cardiac-only resuscitation	Conventional CPR	No bystander resuscitation	Any resuscitation versus no bystander resuscitation	Cardiac-only resuscitation versus no bystander resuscitation	Cardiac-only resuscitation versus conventional CPR
All patients	27/439 (6%)	30/712 (4%)	63/2917 (2%)	2.4 (1.6–3.4)	3.0 (1.9–4.7)	1.5 (0.9–2.5)
Cause						
Cardiac	26/305 (9%)	27/501 (5%)	54/1836 (3%)	2.3 (1.6–3.4)	3.1 (1.9–5.0)	1.6 (0.9–2.9)
Non-cardiac	1/134 (0.7%)	3/211 (1%)	9/1081 (0.8%)	1.4 (0.4–4.6)	0.9 (0.1–7.1)	0.5 (0.1–5.1)
Findings at arrival of EMS						
Apnoea (no gasping)	24/389 (6%)	20/639 (3%)	55/2751 (2%)	2.2 (1.5–3.3)	3.2 (2.0–5.3)	2.0 (1.1–3.7)
Gasping breath	3/50 (6%)	10/73 (14%)	8/166 (5%)	2.3 (0.9–5.8)	1.3 (0.3–4.9)	0.4 (0.1–1.5)
VF/pulseless VT	24/124 (19%)	23/205 (11%)	45/549 (8%)	1.9 (1.2–2.9)	2.7 (1.6–4.6)	1.9 (1.0–3.5)
PEA	1/94 (1%)	3/145 (2%)	8/755 (1%)	1.6 (0.5–5.3)	1.0 (0.1–8.2)	0.5 (0.1–5.0)
Asystole	2/221 (0.9%)	4/362 (1%)	10/1613 (0.6%)	1.7 (0.60–4.6)	1.5 (0.3–6.7)	0.8 (0.1–4.5)
Time from EMS call to first AED analysis						
≤10 min	22/286 (8%)	22/403 (5%)	52/1801 (3%)	2.3 (1.5–3.5)	2.8 (1.7–4.7)	1.4 (0.8–2.7)
>10 min	5/153 (3%)	8/309 (3%)	11/1116 (1%)	2.9 (1.3–6.5)	3.4 (1.1–9.9)	1.3 (0.4–4.0)
Time from collapse to first bystander resuscitation attempt						
≤4 min	23/227 (10%)	18/351 (5%)				2.1 (1.1–4.0)
>4 min	2/96 (2%)	4/176 (2%)				0.9 (0.2–5.1)
Time from first bystander resuscitation attempt to first AED analysis						
≤9 min	20/210 (10%)	18/295 (6%)				1.6 (0.8–3.1)
>9 min	5/113 (4%)	4/232 (2%)				2.6 (0.7–10.0)
Performer of CPR						
Lay person	23/342 (7%)	19/362 (5%)				1.3 (0.7–2.4)
Off-duty medical worker	4/97 (4%)	11/350 (3%)				1.3 (0.4–4.3)

Data are numerator/total number or odds ratio (95% CI). AED=automated external defibrillator. CPR=cardiopulmonary resuscitation. EMS=emergency medical services. PEA= pulseless electrical activity. VF=ventricular fibrillation. VT=ventricular tachycardia.

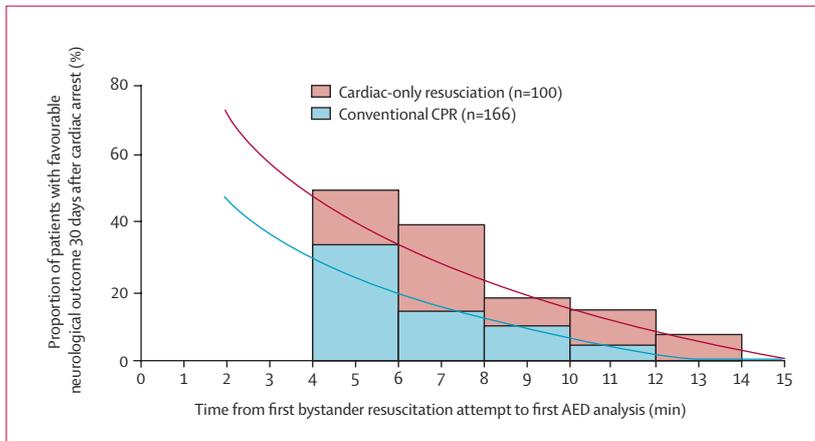
**Table 3: Patients with a favourable neurological outcome at 30 days after cardiac arrest**

medical workers. Generally, the two groups that received bystander resuscitation had similar baseline characteristics (table 2). However, higher proportions in the cardiac-only resuscitation group than in the conventional group were male, more patients had cardiac arrest at home, and more were treated by lay people. The group who had any resuscitation attempt had significantly higher frequencies of favourable neurological outcome at 30 days than the no bystander resuscitation group in the whole cohort (5% [57/1151] vs 2% [63/2917];  $p<0.0001$ ) and in the subgroups of patients with cardiac causes (7% [53/806] vs 3% [54/1836];  $p<0.0001$ ), with apnoea (4% [44/1028] vs 2% [55/2751];  $p<0.0001$ ), with ventricular fibrillation or tachycardia as initial cardiac rhythm (14% [47/329] vs 8% [45/549];  $p=0.0044$ ), and with both of the times between call to emergency medical services and first AED analysis (for interval  $\leq 10$  min; 6% [44/689] vs 3% [52/1801];  $p<0.0001$ ; for interval  $>10$  min; 3% [13/462] vs 1% [11/1116];  $p=0.0069$ ). The cardiac-only resuscitation group also had significantly higher frequencies of favourable neurological outcome at 30 days than the no bystander resuscitation group in those categories. Although the frequency of favourable neurological outcome at 30 days did not differ between the cardiac-only resuscitation group and the conventional



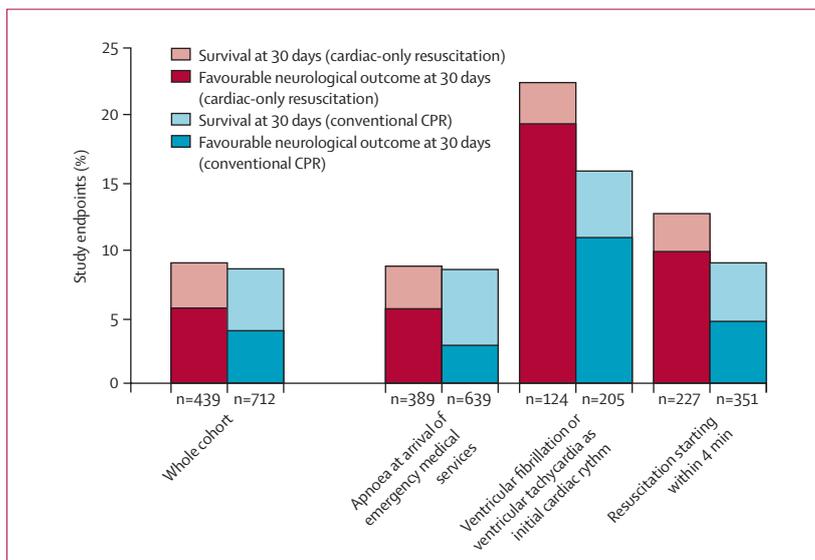
**Figure 2: Adjusted odds ratios for primary endpoint associated with selected factors in patients receiving bystander resuscitation whose bystander resuscitation-related time intervals were known**

CPR group for the whole cohort ( $p=0.1459$ , table 3), cardiac-only resuscitation resulted in a higher proportion of patients with favourable neurological outcomes than conventional CPR in the subgroups of patients with apnoea ( $p=0.0195$ ), with ventricular fibrillation or tachycardia as initial cardiac rhythm ( $p=0.041$ ), and with



**Figure 3: Relation between primary endpoint and time from first bystander resuscitation attempts to first AED analysis in patients who received bystander resuscitation with ventricular fibrillation or pulseless ventricular tachycardia**

Each curve shows predicted frequency of favourable neurological outcome at 30 days by the non-linear regression analysis with logarithm (vertical axis shows predicted frequency of favourable neurological outcome, and predicted frequency of 1 is equivalent to 100%). Each box represents the actual frequencies of favourable neurological outcome at 30 days for each bystander resuscitation group every 2 min.  $p=0.0086$  for comparison of cardiac-only resuscitation group with conventional CPR group.



**Figure 4: Frequencies of study endpoints between the cardiac-only resuscitation group and the conventional CPR group in all patients and in subgroups of patients**

resuscitation starting within 4 min of collapse ( $p=0.0221$ ). However, the bystander resuscitation groups had similar frequencies of favourable neurological outcome at 30 days in the subgroups of patients who received bystander resuscitation from a lay person or from a medically trained person. Additionally, there was no evidence for any benefit from the addition of mouth-to-mouth ventilation in any subgroup of patients who received bystander resuscitation.

Multiple logistic-regression analysis (figure 2) showed that cardiac-only resuscitation resulted in higher proportions of favourable neurological outcome than

conventional CPR ( $p=0.0144$ ), and other independent predictors of favourable outcome were age, time between first bystander resuscitation attempt and first AED analysis, and ventricular fibrillation or tachycardia as initial cardiac rhythm. When sex and gasping breathing were included in the analysis, the results did not change.

Figure 3 shows the relation between favourable neurological outcome at 30 days and the time between first bystander resuscitation attempt and first AED analysis (ie, the duration of bystander resuscitation) in patients with ventricular fibrillation or tachycardia. Cardiac-only resuscitation resulted in higher proportions of favourable neurological outcome than conventional CPR (22% [22/100] vs 10% [17/166], the odds ratio, 2.5; 95% CI, 1.2–4.9;  $p=0.0086$ ), and likelihood of a favourable neurological outcome decreased in both bystander resuscitation groups for every 1 min increment in time from first resuscitation attempt to first AED analysis ( $p=0.0105$  for the cardiac-only resuscitation and  $p=0.0003$  for conventional CPR). When the time from collapse to first AED analysis was used instead, the results were unchanged.

The proportions of people who were alive at 30 days differed from those who had favourable neurological outcome at 30 days (figure 4). In all subgroups of patients, the proportions surviving at 30 days showed no differences between the two bystander resuscitation groups, and these two groups also had similar frequencies of survival until hospital admission.

### Discussion

This report shows that bystander cardiac-only resuscitation is equivalent or superior to conventional bystander CPR in adult patients with witnessed out-of-hospital cardiac arrest, in terms of neurological benefit. Not only the any resuscitation group, but also the cardiac-only resuscitation group had higher proportions of favourable neurological outcome than the no bystander resuscitation group for the whole cohort, and cardiac-only resuscitation resulted in better outcome than conventional CPR in some important subgroups of patients. These subgroups included patients with apnoea (about 90% of patients in this study), and those with shockable cardiac rhythm or short periods of untreated arrest (CPR that started within 4 min of arrest). These patients had the greatest chance of survival (table 3, figures 3 and 4). After adjustment for resuscitation, cardiac-only resuscitation was an independent predictor of favourable neurological outcome in patients who received bystander resuscitation (figure 2). Furthermore, there was no evidence for any benefit from the addition of mouth-to-mouth ventilation in any subgroup of patients (table 3, figures 2, 3, and 4).

Some experts have expressed concern that the absence of assisted ventilation with chest compressions might result in lower survival and worse neurological outcomes in survivors of cardiac arrest.<sup>3,4</sup> Several clinical studies have

shown that cardiac-only resuscitation is at least as effective as chest compression with mouth-to-mouth ventilation.<sup>8,21,22</sup> In this study, however, cardiac-only resuscitation resulted in better or similar neurological outcome than conventional CPR. Moreover, the proportion of patients surviving, including those surviving until hospital admission, showed no differences between the cardiac-only resuscitation group and the conventional CPR group in any subgroup of patients. The number of patients who received bystander cardiac-only resuscitation was higher in this study (n=439) than in previous ones (n=273,<sup>21</sup> 241,<sup>22</sup> and 41<sup>8</sup>). We suggest that the large number of patients provided adequate power to attribute better neurological outcome to cardiac-only resuscitation, and there was no evidence of increased numbers of survivors with neurologically unfavourable outcomes in the group who had cardiac-only resuscitation compared with conventional CPR.

Several mechanisms might account for the efficacy of cardiac-only resuscitation. If the airway is open, gasping breathing and passive chest recoil provide some air exchange.<sup>15,29–33</sup> Measured minute ventilation and arterial oxygenation decrease after 4–10 min of resuscitation irrespective of attempts at ventilation.<sup>15,26,30</sup> Several studies suggest that ventilation is not essential during the initial 12 min of resuscitation with untreated arrest intervals of less than 6 min,<sup>15,25,30,31</sup> and that gasping breathing is associated with a better outcome.<sup>15,29,31,33</sup> In this study, most patients who had bystander resuscitation had an untreated arrest interval of less than 6 min and a duration of bystander resuscitation of less than 12 min, and the two bystander resuscitation groups had similar time intervals and had similar proportions of patients with gasping breath.

Another reason for the efficacy of cardiac-only resuscitation could be that mouth-to-mouth ventilation has several potential disadvantages. These disadvantages include gastric insufflations and importantly, less cycle time spent on effective compressions.<sup>2–4,15,19,23–28,34</sup> Time spent on mouth-to-mouth ventilation takes precious time away from chest compressions that support cerebral and coronary perfusion.<sup>3,4,15,19,23–28</sup> Intrathoracic pressure drops after each pause for mouth-to-mouth ventilation, and several chest compressions have to be done before previous rates of cerebral and coronary perfusion are re-established.<sup>3,4,26</sup> In this study, the quality of chest compressions might not have been as good in the cardiac-only resuscitation group as in the conventional resuscitation group, because the proportion of patients treated by people with no first-aid training, with or without dispatcher-assistance, was higher in the cardiac-only group (272/439, 62% vs 234/712, 33%). Also, the proportion treated by medically trained individuals was lower in the cardiac-only group than in the conventional CPR group (97/439, 22% vs 350/712, 49%). However, there would be less interruption of chest compressions in the cardiac-only resuscitation group. We suggest that interruption of chest compressions was the main reason why conventional

CPR did not result in better neurological outcome than cardiac-only resuscitation.

There are several limitations to our study. It was neither a randomised controlled trial nor a population-based study. However, the overall survival and patients' characteristics in this study were similar to those of population-based studies from similar large metropolitan areas—Osaka, Japan,<sup>13</sup> and New York, USA<sup>15</sup> Although the total number of patients was large, there were few patients with arrest caused by asphyxia, drowning, or traumatic brain injury. The quality of bystander resuscitation was not assessed, and resuscitation-related event times were known for only 70% of the study population. Additionally, post-resuscitation care could not be standardised. Recent studies<sup>3,4,36–38</sup> have shown that therapeutic hypothermia can result in better outcomes for patients with out-of-hospital ventricular fibrillation. In this study, few patients were treated by induction of hypothermia, and the proportions given this treatment were similar in the two bystander resuscitation groups.

On the basis of these findings, we conclude that bystander cardiac-only resuscitation is the preferred approach to resuscitation for adult patients with witnessed out-of-hospital cardiac arrest especially those with apnoea, shockable cardiac rhythm, or short periods of untreated arrest.

#### SOS-KANTO study group

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#### Contributors

K Nagao and T Sakamoto as principal investigators, participated in idea formation, study design and completion, data collection, data management, data analyses, interpretation of results and revision of the report, and contributed to the final report. K Nagao obtained funding. K Kikushima, K Koseki, M Igarashi, S Ishimatsu, A Sato, S Hori, S Kanesaka, Y Hamabe, D Saito, and S Kitamura participated in study idea formation, study design and completion, data collection, data management, and interpretation of the results. K Nagao, T Sakamoto, K Kikushima, and D Saito did the statistical analysis. All authors approved the final version.

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**Conflict of interest statement**

We declare that we have no conflict of interest.

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