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Association between $PaCO_2$ and outcomes in patients who underwent extracorporeal cardiopulmonary resuscitation for out-of-hospital cardiac arrest

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Abstract

Aim: The optimal arterial partial pressure of carbon dioxide ($PaCO_2$) for patients undergoing extracorporeal cardiopulmonary resuscitation (ECPR) remains unknown. We aimed to investigate the association between post-resuscitation $PaCO_2$ and neurological outcomes.

Methods: This retrospective cohort study analyzed data from the Study of Advanced Life Support for Ventricular Fibrillation with Extracorporeal Circulation in Japan, a multicenter registry study across 36 hospitals in Japan, including patients with out-of-hospital cardiac arrest (OHCA) admitted to intensive care units (ICU) after ECPR between 2013 and 2018. Good $PaCO_2$ management status was defined as a $PaCO_2$ value of 35–45 mmHg. We classified patients into four groups (poor–poor, poor–good, good–poor, and good–good) according to their $PaCO_2$ management status upon admission at the ICU and the following day. The primary outcome was a favorable neurological outcome, defined as cerebral performance category 1 or 2, 30 days after cardiac arrest. The secondary outcome was survival 30 days after cardiac arrest.

Results: We classified 885 eligible patients into poor–poor ($n = 361$), poor–good ($n = 231$), good–poor ($n = 155$), and good–good ($n = 138$) groups. No significant association was observed between $PaCO_2$ management and favorable 30-day neurological outcomes. Compared with the poor–poor group, the poor–good, good–poor, and good–good groups had adjusted odds ratios of 0.87 (95% confidence interval, 0.52–1.44), 1.17 (0.65–2.05), and 0.95 (0.51–1.73), respectively. The 30-day survival rates among the four groups did not differ significantly.

Conclusion: $PaCO_2$ values were not significantly associated with 30-day neurological outcomes or survival of patients with OHCA after ECPR.

KEYWORDS
arterial partial pressure of carbon dioxide, extracorporeal cardiopulmonary resuscitation, intensive care unit, neurological outcome, out-of-hospital cardiac arrest

The SAVE-J II Study Group members are listed in Acknowledgments section.

INTRODUCTION

Extracorporeal cardiopulmonary resuscitation (ECPR) is increasingly being used to treat patients with refractory out-of-hospital cardiac arrest (OHCA).[1–3] Appropriate post-resuscitation management is crucial to improve patient outcomes after ECPR.[4]

Arterial partial pressure of carbon dioxide ($PaCO_2$) modulates cerebral blood flow (CBF). Clinically, hypercapnia increases CBF and intracerebral pressure, while hypocapnia leads to cerebral ischemia by decreasing CBF.[5,6] Therefore, managing $PaCO_2$ during post-cardiac arrest management may affect neurological outcomes. Guidelines recommend maintaining normal $PaCO_2$ (35–45 mmHg) when managing patients who achieve a return of spontaneous circulation (ROSC) after cardiac arrest.[4] Notably, the results of large observational studies on hypocapnia and hypercapnia are inconsistent; some studies indicate that hypocapnia and hypercapnia are harmful, whereas others report that mild hypercapnia leads to better outcomes.[7–9] In a randomized controlled trial that compared targeted mild hypercapnia with targeted normocapnia in patients in a comatose state resuscitated after OHCA, targeted mild hypercapnia did not improve neurological outcomes.[10] Thus, the most favorable $PaCO_2$ target during post-cardiac arrest management remains unknown.

In patients undergoing ECPR, gas exchange can occur independently of the ventilator circuit, with rapid changes in blood gas levels.[11,12] Their metabolic demands differ from those of patients resuscitated with conventional cardiopulmonary resuscitation (CPR) because of artificial oxygenation using extracorporeal membrane oxygenation and associated intensive treatments.[13] Considering these differences, optimal CO_2 levels for patients after ECPR may differ from those for patients after conventional CPR. However, few studies have focused on the optimal $PaCO_2$ value in patients after ECPR for OHCA. Thus, in this study, we aimed to investigate the association between post-resuscitation $PaCO_2$ values and neurological outcomes in patients who received ECPR for OHCA.

MATERIALS AND METHODS

Study design and ethical considerations

This observational study used data from the Study of Advanced Life Support for Ventricular Fibrillation with Extracorporeal Circulation in Japan (SAVE-J II). This study was conducted in accordance with the 1975 Declaration of Helsinki (as revised in Fortaleza, Brazil, October 2013). The Metropolitan Bokutoh Hospital Institutional Ethics Committee approved the study (approval number 04-124; March 20, 2023) and waived the requirement for informed consent because the data were anonymized before analysis.

Data source

The SAVE-J II was pre-registered with the University Hospital Medical Information Network Clinical Trials Registry and the Japanese Clinical Trial Registry (registration number: UMIN000036490). We collected the data of consecutive patients with OHCA aged ≥18 years admitted to the emergency department between January 1, 2013, and December 31, 2018, and received ECPR from 36 participating institutions in Japan.[14] The data collected included patient characteristics, prehospital care information, information on hospital arrival, diagnosis and intervention in the hospital, drugs and devices used, intensive care unit (ICU) information, and patient outcomes. Activities of daily living before cardiac arrest were assessed using performance status criteria[15]: Category 0 (symptomatic), Category 1 (symptomatic but completely ambulatory), Category 2 (symptomatic, <50% in bed during the day), Category 3 (symptomatic, >50% in bed, but not bedbound), and Category 4 (bedbound). Neurological outcomes 30 days after the arrest were reported using the cerebral performance category (CPC) scale[16]: 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).

Study population

Using the SAVE-J II database, we identified patients who underwent venoarterial extracorporeal membrane oxygenation (VA-ECMO) before ICU admission. We excluded patients who experienced OHCA of non-cardiac etiology (acute aortic dissection/aortic aneurysm, hypothermia, primary cerebral disorder, infection, drug intoxication, trauma, suffocation, and drowning), achieved ROSC either at the time of hospital arrival or at the time of ECMO initiation, were transferred from different medical facilities, and died before ICU admission. In addition, patients with missing $PaCO_2$ or CPC scale values 30 days after cardiac arrest were excluded.

Exposure

The study exposure was $PaCO_2$ management, assessed using $PaCO_2$ values at ICU admission and on the following day. We defined $PaCO_2$ values of <35, 35–45, and ≥46 mmHg as hypocapnia, normocapnia, and hypercapnia, respectively.[4] Good $PaCO_2$ management was defined as normocapnia, whereas poor $PaCO_2$ management was defined as hypocapnia or hypercapnia. We classified patients into four groups based on their $PaCO_2$ management status on ICU admission and the following day: poor–poor (PP; poor management on both days), poor–good (PG;

poor management on ICU admission and good management on the following day), good–poor (GP; good management on ICU admission and poor management on the following day), and good–good (GG; good management on both days).

Outcomes and covariates

The primary outcome was a favorable neurological outcome, defined as CPC of 1–2 at 30 days after cardiac arrest. The secondary outcome was survival 30 days after cardiac arrest.

We selected covariates based on scientific knowledge[1–3,7–9,17] and clinical plausibility. The selected covariates were age, sex, activities of daily living and comorbidities (cardiac and chronic kidney diseases) before the arrest, location of the arrest (public space, private residence, road, and other), witness status, bystander CPR, first documented cardiac rhythm (ventricular fibrillation/ventricular tachycardia, pulseless electrical activity, and asystole), prehospital ROSC, and time from the emergency call to hospital arrival. We categorized patient ages into 20-year intervals: 18–39, 40–59, 60–79, and 80–99 years.[18,19] Activities of daily living before cardiac arrest assessed using performance status criteria were categorized as 0, 1, and ≥2. The time from the emergency call to hospital arrival was arbitrarily categorized into 20-min intervals: 0–19, 20–39, and ≥40 min.

Statistical analyses

Continuous variables are presented as either median with interquartile range (IQR) or mean with standard deviation (SD) and were compared using the Kruskal–Wallis test or paired *t*-test, as appropriate. Categorical variables are presented as numbers (percentages) and were compared using the chi-squared test. We performed multivariable logistic regression analysis with predetermined covariates and calculated adjusted odds ratios (ORs) and 95% confidence intervals (CIs) to determine the association between $PaCO_2$ management and outcomes. In addition, we evaluated the association between $PaCO_2$ change (difference between $PaCO_2$ values at ICU admission and ICU day 2) and outcomes in the GP group using a generalized additive model.

Sensitivity analysis

We performed different types of sensitivity analyses to assess the robustness of the results. First, we performed the same analysis but excluded patients who had fatal outcomes within 3 days after the arrest because the death may have been inevitable regardless of $PaCO_2$ management. Second, we performed the same analysis using a narrower definition of normocapnia, defined as a $PaCO_2$ value of 35–40 mmHg. Third, we analyzed the data with a wider definition of normocapnia, defined as a $PaCO_2$ value of 30–50 mmHg.

All statistical analyses were performed using the R software (version, 4.2.1; R Foundation for Statistical Computing, Vienna, Austria). All statistical tests were two-sided. Statistical significance was defined as a p-value <0.05 or assessed with the 95% CI.

RESULTS

A total of 1646 patients admitted to the ICU after receiving ECPR for OHCA of cardiac origin were registered in the SAVE-J II. After excluding 749 patients with missing $PaCO_2$ values and 12 patients with missing 30-day CPC scale values, 885 patients were eligible for analysis (Figure 1). Their median age was 60 (IQR: 48–67) years, and 754 (85.2%) patients were males. Targeted temperature management (TTM) was performed in 776 (87.7%) patients. At 30 days after the cardiac arrest, 352 (39.8%) patients survived and 176 (19.9%) had favorable neurological outcomes. The mean (SD) $PaCO_2$ levels at hospital arrival, ICU admission, and ICU day 2 were 68.2 (30.4), 34.8 (12.6), and 35.2 (8.1) mmHg, respectively (Figure 2). The $PaCO_2$ values between the time of hospital arrival and ICU admission differed significantly ($p<0.001$), while no significant difference was observed between the values at ICU admission and ICU day 2 ($p=0.353$).

Figure 3 shows the distribution of $PaCO_2$ values at ICU admission and on the following day. At ICU admission, 499 (56.4%) patients had hypocapnia, 293 (33.1%) had normocapnia, and 93 (10.5%) had hypercapnia, with mean (SD) $PaCO_2$ values of 27.7 (5.4), 39.6 (3.1), and 58.0 (21.3) mmHg, respectively. On the following day, 441 (49.8%) patients had hypocapnia, 369 (41.7%) had normocapnia, and 75 (8.5%) had hypercapnia, with mean (SD) $PaCO_2$ values of 29.1 (4.5), 39.3 (3.0), and 51.2 (6.4) mmHg, respectively. No significant association was observed between hypo- or hypercapnia on either day and favorable neurological outcomes or survival 30 days after the cardiac arrest (Tables S1 and S2).

Patients were classified into the PP ($n=361$, 40.8%), PG ($n=231$, 26.1%), GP ($n=155$, 17.5%), and GG ($n=138$, 15.6%) groups (Figure 4). Table 1 presents the baseline patient characteristics. There were no significant differences among the groups.

Outcome analysis

Table 2 shows the study outcomes of the PP, PG, GP, and GG groups. The GP group had the highest proportion of 30-day favorable neurological outcomes, followed by the GG group (PP group, 19.9%; PG group, 17.7%; GP group, 21.9%; GG group, 21.0%; $p=0.757$). After adjusting for confounding factors, no significant association was observed between the $PaCO_2$ management groups and 30-day favorable neurological outcomes. Relative to the PP

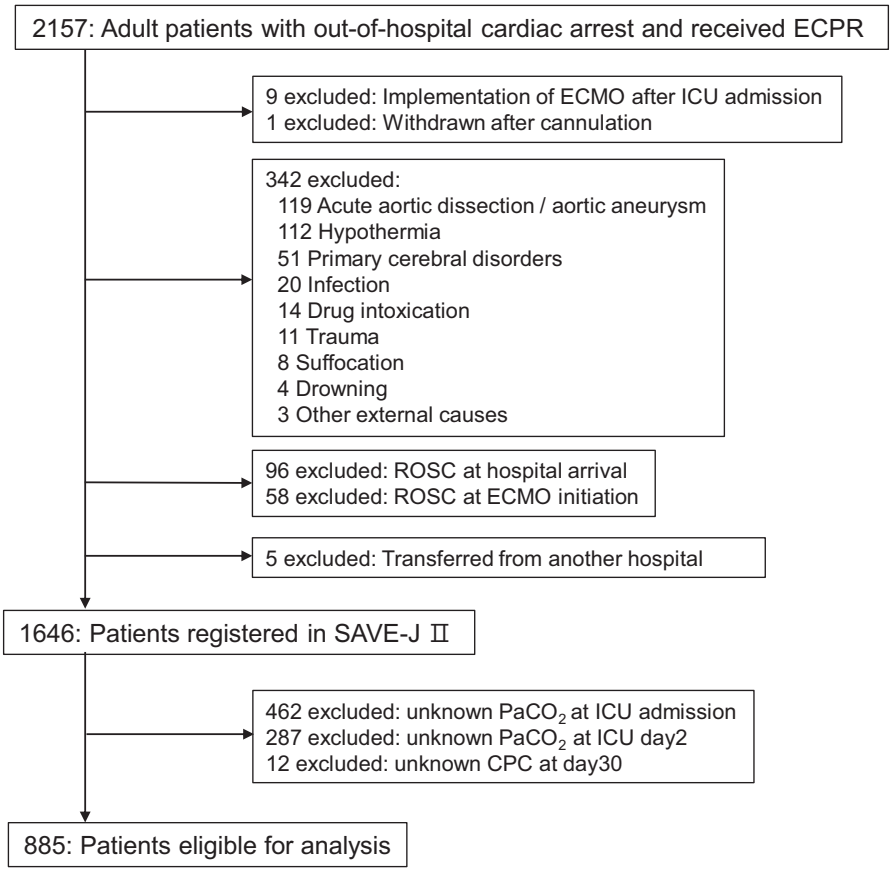

FIGURE 1 Study flow. CPC, cerebral performance category; ECMO, extracorporeal membrane oxygenation; ECPR, extracorporeal cardiopulmonary resuscitation; ICU, intensive care unit; $PaCO_2$, arterial partial pressure of CO_2; ROSC, return of spontaneous circulation.

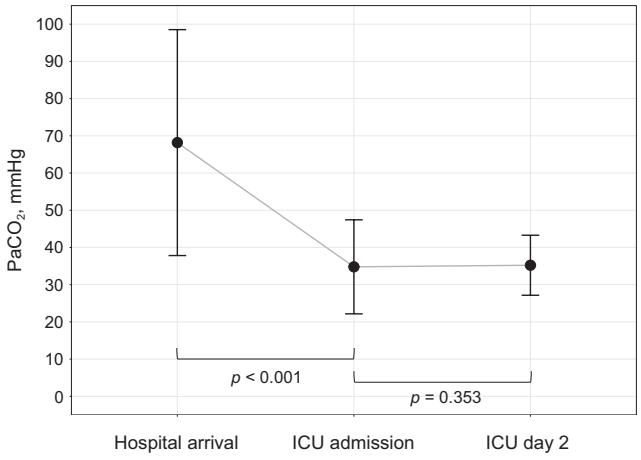

FIGURE 2 $PaCO_2$ values at hospital arrival, ICU admission, and ICU day 2. The black circle represents mean value, and error bars indicate standard deviation. ICU, intensive care unit; $PaCO_2$, arterial partial pressure of CO_2.

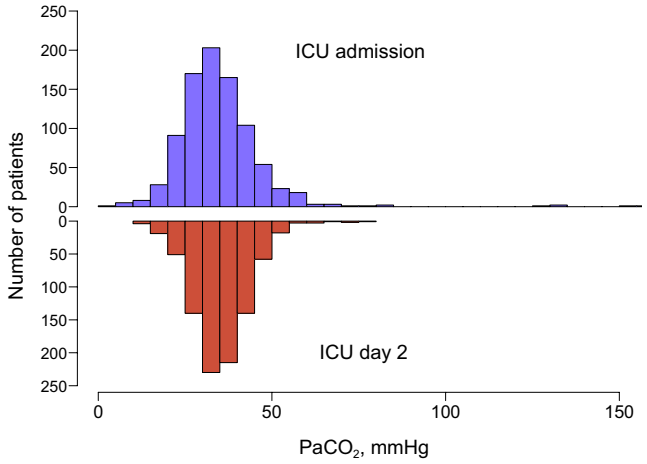

FIGURE 3 Distribution of $PaCO_2$ values at ICU admission and ICU day 2. ICU, intensive care unit; $PaCO_2$, arterial partial pressure of CO_2.

group, the PG, GP, and GG groups had adjusted ORs of 0.87 (95% CI, 0.52–1.44), 1.17 (95% CI, 0.65–2.05), and 0.95 (95% CI, 0.51–1.73), respectively. No significant difference was observed in the proportion of 30-day survival among the four groups (PP, 38.5%; PG, 39.4%; GP, 38.7%; and GG, 44.9%; $p = 0.602$). Relative to the PP group, the PG, GP, and GG groups had adjusted ORs of 1.01 (95% CI, 0.67–1.52), 0.92 (95% CI, 0.56–1.48), and 1.28 (95% CI, 0.78–2.09), respectively. In the GP group, no significant association existed between the change in $PaCO_2$ from ICU admission to ICU day 2 and the proportion of 30-day favorable neurological outcomes ($p = 0.500$) or survival ($p = 0.185$, Figure S1).

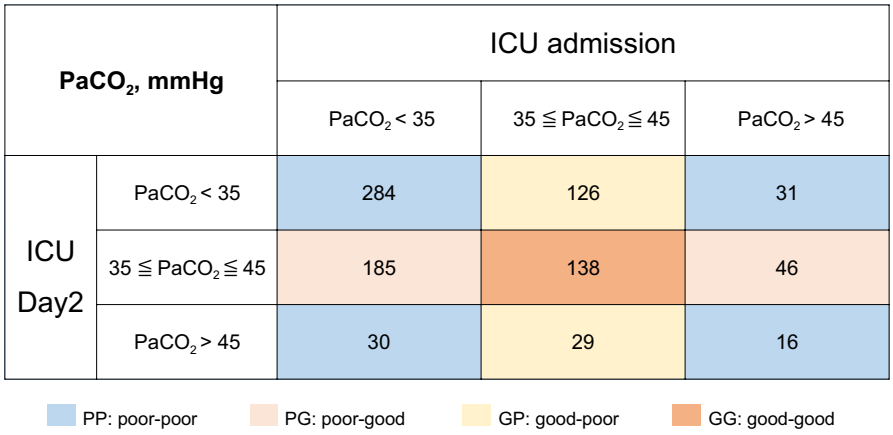

FIGURE 4 Patient classification based on $PaCO_2$ management. ICU, intensive care unit; $PaCO_2$, arterial partial pressure of CO_2.

Sensitivity analysis

After excluding 223 patients who had fatal outcomes within 3 days after the arrest, 662 patients (PP, $n=91$; PG, $n=173$; GP, $n=85$; and GG, $n=313$) were analyzed. The multivariable logistic regression analysis results were consistent with those of the main analysis; no significant association existed between the $PaCO_2$ management category and favorable neurological outcomes (adjusted ORs: PP, reference; PG, 1.08 [95% CI, 0.54–2.22]; GP, 1.02 [95% CI, 0.42–2.43]; and GG, 1.18 [95% CI, 0.63–2.31]) or survival 30 days after the cardiac arrest (adjusted ORs: PP, reference; PG, 1.33 [95% CI, 0.72–2.46]; GP, 1.17 [95% CI, 0.55–2.49]; and GG, 1.04 [95% CI, 0.59–1.83]). The sensitivity analyses using narrower or wider definitions of normocapnia had similar results with the primary analysis (Table 2).

DISCUSSION

In this study, we evaluated 885 patients after ECPR for OHCA and found no significant association between $PaCO_2$ levels and outcomes. The sensitivity analysis results were consistent with those of the primary analysis, indicating the robustness of the results.

In contrast to a previous study that evaluated patients resuscitated by conventional CPR,[17] this study found lower occurrence of hypercapnia (10.5% vs. 34.5%) and higher occurrence of hypocapnia (56.4% vs. 23.6%). Hypocapnia was far more frequent than hypercapnia, with about 50% of the patients experiencing hypocapnia on the following day of admission. These results can be attributed to several factors. First, blood gas levels can change rapidly and significantly when ECMO is initiated.[20] The excessive sweep gas flow rate set at the beginning of ECMO implementation may have caused the frequent occurrence of hypocapnia after ECPR. Second, patients receiving mechanical ventilation after resuscitation are prone to hypocapnia during TTM.[21] Notably, 87.7% of patients underwent TTM in this study, and this may have contributed to the frequency of hypocapnia. Third, maintaining normocapnia might be more difficult in patients who often have cerebral autoregulation disturbances due to hypoxic ischemic encephalopathy and post-cardiac arrest syndrome after ECPR.

The main finding of this study was the nonsignificant association between $PaCO_2$ levels and outcomes after ECPR for OHCA. Our results are consistent with those of some previous studies that evaluated a similar issue in patients resuscitated after conventional CPR,[10,15] although other studies have shown conflicting results.[7–9] Candidates for ECPR are patients with refractory cardiac arrest; thus, their outcomes are usually worse than those of patients who are successfully resuscitated from cardiac arrest with conventional CPR. Considering that the benefits of managing $PaCO_2$ are less apparent in severely injured patients, our results might be theoretically plausible.

In this study, normocapnia was defined according to international guidelines.[4] However, whether this range reflects the physiologically optimal threshold remains unclear, as experimental studies have shown a 2%–4% reduction in CBF for each mmHg decrease in $PaCO_2$ within the 25–55 mmHg range.[22] To this end, previous studies have used various definitions for normocapnia, ranging from 30 to 50 mmHg.[23] To address this, we conducted sensitivity analyses using different definitions of normocapnia. The results were consistent, suggesting the robustness of our findings across varying definitions of normocapnia.

This study had some limitations. First, it was a retrospective study. We adjusted for many potential confounders; however, unmeasured confounders may have biased the results. In more severe cases with poorer outcomes, intensivists may pursue stricter $PaCO_2$ management. Since severity affects both $PaCO_2$ management and outcomes, inadequate adjustment of such confounder may underestimate the benefits of proper $PaCO_2$ management, biasing results toward the null. Second, we excluded patients with missing $PaCO_2$ values or 30-day outcome data from the analysis. Missing data may be associated with particular intensive care practices, illness severity, and actual outcomes; therefore, this exclusion could have led to either an overestimation or underestimation of the relationship between $PaCO_2$ management and outcomes. In addition, excluding this subset may have reduced the generalizability of our findings. Third, some detailed information that could have enriched

TABLE 1 Baseline characteristics of the study population.

Variable	Overall ($n=885$)	$PaCO_2$ management[a]				p-Value
		Poor–poor ($n=361$)	Poor–good ($n=231$)	Good–poor ($n=155$)	Good–good ($n=138$)	
Age, years, median (IQR)	60 (48, 67)	60 (46, 68)	58 (48, 66)	61 (52, 67)	60 (50, 67)	0.158
Age, years, *n* (%)						
18–39	89 (10.1)	47 (13.0)	23 (10.0)	12 (7.7)	7 (5.1)	0.265
40–59	349 (39.4)	132 (36.6)	99 (42.9)	59 (38.1)	59 (42.8)	
60–79	429 (48.5)	173 (47.9)	106 (45.9)	81 (52.3)	69 (50.0)	
80–93	18 (2.0)	9 (2.5)	3 (1.3)	3 (1.9)	3 (2.2)	
Male sex, *n* (%)	754 (85.2)	297 (82.3)	202 (87.4)	134 (86.5)	121 (87.7)	0.236
Comorbidities, *n* (%)						
Hypertension	289 (32.7)	124 (34.3)	67 (29.0)	46 (29.7)	52 (37.7)	0.253
Diabetes mellitus	197 (22.3)	93 (25.8)	44 (19.0)	30 (19.4)	30 (21.7)	0.194
Dyslipidemia	125 (14.1)	52 (14.4)	23 (10.0)	23 (14.8)	27 (19.6)	0.080
Heart disease	225 (25.4)	90 (24.9)	60 (26.0)	45 (29.0)	30 (21.7)	0.545
Cerebrovascular disease	59 (6.7)	28 (7.8)	13 (5.6)	11 (7.1)	7 (5.1)	0.637
Chronic kidney disease	49 (5.5)	21 (5.8)	15 (6.5)	8 (5.2)	5 (3.6)	0.690
Dementia	3 (0.3)	2 (0.6)	0 (0.0)	1 (0.6)	0 (0.0)	0.536
Performance status, *n* (%)						
0	791 (90.8)	319 (89.4)	210 (92.1)	137 (91.9)	125 (91.2)	0.593
1	70 (8.0)	32 (9.0)	18 (7.9)	10 (6.7)	10 (7.3)	
≥2	10 (1.1)	6 (1.7)	0 (0.0)	2 (1.3)	2 (1.5)	
Location of cardiac arrest, *n* (%)						
Public space	156 (17.7)	63 (17.5)	42 (18.2)	23 (14.8)	28 (20.6)	0.472
Residence	329 (37.3)	145 (40.3)	86 (37.2)	59 (38.1)	39 (28.7)	
Road	137 (15.5)	49 (13.6)	33 (14.3)	29 (18.7)	26 (19.1)	
Others	260 (29.5)	103 (28.6)	70 (30.3)	44 (28.4)	43 (31.6)	
Initial cardiac rhythm, *n* (%)						
Asystole	50 (5.7)	19 (5.3)	10 (4.4)	11 (7.2)	10 (7.2)	0.802
Pulseless electrical activity	188 (21.4)	79 (22.1)	50 (21.8)	28 (18.3)	31 (22.5)	
Ventricular fibrillation/ventricular tachycardia	640 (72.9)	260 (72.6)	169 (73.8)	114 (74.5)	97 (70.3)	
Witness, *n* (%)	724 (82.2)	293 (81.6)	196 (85.2)	123 (79.4)	112 (81.8)	0.496
Bystander CPR, *n* (%)	539 (61.6)	217 (60.8)	141 (62.1)	93 (60.4)	88 (64.2)	0.891
ROSC before hospital arrival, *n* (%)	94 (10.8)	40 (11.2)	22 (9.6)	20 (13.3)	12 (9.1)	0.616
Emergency call to hospital arrival, min, median (IQR)	31 (25, 38)	31 (25, 38)	30 (25, 37)	30 (24, 39)	31 (26, 38)	0.348

Abbreviations: CPR, cardiopulmonary resuscitation; EMS, emergency medical services; IQR, interquartile range; $PaCO_2$, arterial partial pressure of CO_2; ROSC, return of spontaneous circulation.

[a]Good $PaCO_2$ management was defined as normocapnia ($PaCO_2$, 35–45 mmHg), whereas poor $PaCO_2$ management was defined as hypocapnia ($PaCO_2$, <35 mmHg) or hypercapnia ($PaCO_2$, ≥46 mmHg).

our understanding of the results, such as data on ventilator or ECMO settings (for example, blood and sweep gas flow rates) was unavailable in the dataset. Fourth, the small sample size may have weakened our analysis. Future studies with larger sample sizes are required to determine any clinically significant differences in outcomes based on target $PaCO_2$ values. Lastly, we classified patients based on $PaCO_2$ values from only two-time points. Since arterial blood gas is frequently evaluated to optimize $PaCO_2$ levels in the first several days after ECPR, our classification may not fully capture the relationship between $PaCO_2$ management and patient outcomes after ECPR.

CONCLUSIONS

This multicenter cohort study revealed no significant associations between $PaCO_2$ values and 30-day neurological outcomes or survival of patients with OHCA after

TABLE 2 Thirty-day favorable neurological outcomes and survival according to $PaCO_2$ management.

	$PaCO_2$ management			
	Poor–poor	**Poor–good**	**Good–poor**	**Good–good**
30-day favorable neurological outcomes				
n (%)	72 (19.9)	41 (17.7)	34 (21.9)	29 (21.0)
Crude odds ratio (95% CI)	Reference	0.87 (0.56–1.32)	1.13 (0.71–1.78)	1.07 (0.65–1.72)
Adjusted odds ratio (95% CI)				
Main analysis[a]	Reference	0.87 (0.52–1.44)	1.17 (0.65–2.05)	0.95 (0.51–1.73)
Sensitivity analysis 1[b]	Reference	1.08 (0.54–2.22)	1.02 (0.42–2.43)	1.18 (0.63–2.31)
Sensitivity analysis 2[c]	Reference	0.79 (0.45–1.36)	1.03 (0.56–1.82)	1.01 (0.38–2.41)
Sensitivity analysis 3[d]	Reference	1.07 (0.56–2.13)	0.88 (0.38–2.02)	1.17 (0.64–2.23)
30-day survival				
n (%)	139 (38.5)	91 (39.4)	60 (38.7)	62 (44.9)
Crude odds ratio (95% CI)	Reference	1.04 (0.74–1.46)	1.01 (0.68–1.48)	1.30 (0.87–1.94)
Adjusted odds ratio (95% CI)				
Main analysis[a]	Reference	1.01 (0.67–1.52)	0.92 (0.56–1.48)	1.28 (0.78–2.09)
Sensitivity analysis 1[b]	Reference	1.33 (0.72–2.46)	1.17 (0.55–2.49)	1.04 (0.59–1.83)
Sensitivity analysis 2[c]	Reference	1.11 (0.72–1.71)	0.90 (0.55–1.46)	1.34 (0.62–2.83)
Sensitivity analysis 3[d]	Reference	1.29 (0.76–2.22)	0.99 (0.51–1.90)	1.08 (0.66–1.80)

Abbreviation: CI, confidence interval.

[a]Good $PaCO_2$ management was defined as normocapnia ($PaCO_2$, 35–45 mmHg), whereas poor $PaCO_2$ management was defined as hypocapnia ($PaCO_2$, <35 mmHg) or hypercapnia ($PaCO_2$, ≥46 mmHg).

[b]Patients who had fatal outcome within 3 days after the arrest were excluded from the analysis.

[c]Narrower definition of normocapnia was applied ($PaCO_2$, 35–40 mmHg).

[d]Wider definition of normocapnia was applied ($PaCO_2$, 30–50 mmHg).

ECPR. Prospective studies are required to optimize post-resuscitation care after ECPR. Given the variability in patient conditions and responses to ECPR, an individualized approach based on continuous monitoring and assessment of the patient's physiological status is crucial.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data will be shared upon request to the author with permission from the SAVE-J II study group.

ETHICS STATEMENT

Approval of the research protocol: The study protocol was approved by the Institutional Ethics Committee of Metroporitan Bokuto Hospital (approval number 04-124; March 20, 2023).

Informed consent: The requirement for informed consent was waived as the data were anonymized before analysis.

Registry and the registration no. of the study/trial: The Study of Advanced Life Support for Ventricular Fibrillation with Extracorporeal Circulation in Japan was registered with the University Hospital Medical Information and Network Clinical Trials Registry and the Japanese Clinical Trial Registry (registration number: UMIN000036490)

Animal studies: This study did not involve any animal subjects.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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