Predictive Score for Survival After Percutaneous Cardiopulmonary Support in Cardiovascular Disease Patients

– Evaluation of Pre-Procedural Information –

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Background: The predictive factors for survival after percutaneous cardiopulmonary support (PCPS) are unknown.

Methods and Results: Data for 105 patients with cardiovascular disease requiring PCPS were analyzed. The patients were divided into a survivor ($n=21$) or a non-survivor group ($n=84$). The age was significantly lower, and there were more patients with fulminant myocarditis and PCPS attempted before cardiac arrest (CA) in the survivor group. Additionally, there were fewer cases of out-of-hospital CA, and the mean time from CA to PCPS was shorter in the survivor group. On multivariate logistic regression it was found that the age and the time from CA to PCPS were independently associated with survival. A predictive scoring system was constructed that included the following: (1) age <50 years; (2) diagnosis of fulminant myocarditis; (3) no out-of-hospital CA; (4) PCPS attempted before CA; and (5) time from CA to PCPS <45 min. The predictive score was significantly higher in the survivor than in the non-survivor group (2.33 ± 1.32 vs. 1.06 ± 1.02). The sensitivity and specificity for survival were 85.7% and 66.7% when the score was ≥ 2 . Kaplan-Meier survival analysis showed that any-cause death was significantly higher in patients with PCPS survival score ≤ 1 than in those with a score ≥ 2 .

Conclusions: PCPS survival score is suitable for clinically predicting survival in patients with cardiovascular disease undergoing PCPS. (*Circ J* 2013; **77**: 2064–2072)

Key Words: Emergency care; Mortality; Out-of-hospital cardiac arrest; Shock

Percutaneous cardiopulmonary support (PCPS) has recently become a common procedure because of its portability, rapid priming, and ease of handling. In 1992 the indications for PCPS were expanded to include medical emergency cases, based on the results of a multi-institutional study.¹ Therefore, PCPS has been used for severe cardiogenic shock or circulatory collapse complicating acute myocardial infarction, severe heart failure, fulminant myocarditis (FM), pulmonary thromboembolism, and refractory ventricular arrhythmia.² Several reports on emergency PCPS use have been published with relatively good results, showing a 20–60% survival rate.^{3,4} Despite major advances, however, in

the development of new devices and improvements in intensive care, a disappointingly high rate of short-term mortality is still observed. To date, there have been no guidelines established for the use of PCPS in patients with cardiovascular disease, although the American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care state that it should be used for patients with disease of class IIb and with evidence level C.⁵ Furthermore, the predictive factors for the survival of patients undergoing PCPS are also unclear. Because the extended use of this PCPS procedure, which requires highly specialized staff and equipment, might increase hospitals costs and affect resource utilization,

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	All (n=105)	Non-survivor (n=84)	Survivor (n=21)	P-value†
Age (years)	60.3±14.5	62.4±12.2	54.2±18.8	0.043
Gender (male)	82 (78.1)	67 (79.8)	15 (71.4)	
Past medical history				
Hypertension	56 (53.3)	47 (56.0)	9 (42.9)	0.333
Diabetes mellitus	35 (33.3)	28 (33.3)	7 (33.3)	1.000
Dyslipidemia	37 (35.2)	29 (34.5)	8 (38.1)	0.801
Smoking	66 (62.9)	51 (60.7)	15 (71.4)	0.453
CVA	10 (9.5)	7 (8.3)	3 (14.3)	0.415
Chronic kidney disease	41 (39.1)	35 (41.7)	6 (28.6)	0.324
Etiology				
Acute coronary syndrome	67 (63.8)	55 (65.5)	12 (57.1)	0.612
Fulminant myocarditis	7 (6.7)	3 (3.6)	4 (19.5)	0.028
Pulmonary thromboembolism	9 (8.6)	6 (7.1)	3 (14.3)	0.379
ICM/Prior MI	9 (8.6)	7 (8.3)	2 (9.5)	1.000
Non-ischemic cardiomyopathy	3 (2.9)	3 (3.6)	0 (0.0)	1.000
Aortic disease	3 (2.9)	3 (3.6)	0 (0.0)	1.000
Other	7 (6.7)	7 (8.3)	0 (0.0)	0.340

Data given as mean±SD or n (%). †Between-group comparisons. CVA, cerebrovascular accident; ICM, ischemic cardiomyopathy; MI, myocardial infarction.

the early identification of factors associated with a better survival and detailed analysis of the long-term outcomes of survivors are urgently needed. We therefore retrospectively evaluated the patients who needed emergency PCPS for cardiovascular disease, and conducted this study to determine the predictive factors for survival related to undergoing the PCPS procedure.

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Methods

Subjects

We analyzed the data for 105 patients in whom PCPS was used for cardiovascular disease, who were admitted to the intensive

care unit (ICU) of Chiba Hokusoh Hospital, Nippon Medical School between February 2005 and December 2012. The indications for and the timing of PCPS initiation were determined by the experienced interventional cardiologist in charge, according to the following criteria: (1) severe intractable cardiogenic shock with imminent cardiac arrest (CA) refractory to catecholamine and intra-aortic balloon pumping (IABP) after correcting both hypovolemia, hypoxemia and acidemia; (2) in-hospital CA with cardiovascular disease; and (3) out-of-hospital CA with admission to the emergency department within 45 min and no response to the usual advanced cardiovascular life support (ACLS). PCPS was initiated in the catheter laboratory, ICU or emergency department, and was considered to be contraindicated in patients with previous irreversible brain damage or severe comorbidities such as the terminal stage of

Table 2. PCPS and Patient Data vs. Outcome

	All (n=105)	Non-survivor (n=84)	Survivor (n=21)	P-value†
PCPS attempt before cardiac arrest	9 (8.6)	4 (4.8)	5 (23.8)	0.015
PCPS attempt after cardiac arrest				
VT/VF	53 (50.5)	42 (50.0)	11 (52.4)	1.000
PEA/Asystole	43 (41.0)	38 (45.2)	5 (23.8)	0.087
Cardiac arrest location				
Out-of-hospital cardiac arrest	50 (47.6)	45 (53.6)	5 (23.8)	0.016
Admission time				
Daytime PCPS procedure (8:00–20:00 hours)	62 (59.1)	51 (60.7)	11 (52.4)	0.621
Ambulance system				
Air ambulance	26 (24.8)	22 (26.2)	4 (19.1)	0.583
Duration of cannulation (min)	33.8±24.8	34.8±26.5	28.8±13.3	0.378
Duration from cardiac arrest to PCPS (min)	51.3±33.3	55.8±33.4	33.4±26.8	0.005
Arterial blood gas				
pH	7.16±0.25	7.13±0.23	7.24±0.28	0.244
PCO ₂ (mmHg)	43.0±22.0	44.5±23.0	39.0±19.0	0.389
PO ₂ (mmHg)	175.0±139.9	180.1±147.9	161.0±117.8	0.701
HCO ₃ (mmol/L)	14.7±6.8	14.0±6.5	16.6±7.4	0.175
SaO ₂ (%)	88.4±21.2	86.9±22.3	92.4±17.5	0.351
Lactate (mmol/L)	9.45±5.41	7.56±6.21	7.56±6.21	0.133
Laboratory data				
BUN (mg/dl)	22.6±12.6	22.5±11.5	22.9±15.7	0.889
Creatinine (mg/dl)	1.30±0.59	1.31±0.54	1.28±0.72	0.831
Total bilirubin (mg/dl)	0.63±0.47	0.61±0.47	0.69±0.49	0.509
CRP (mg/dl)	2.50±4.08	2.15±3.68	3.53±5.04	0.232
Hemoglobin (g/dl)	12.9±2.6	13.0±2.5	12.9±2.9	0.948
PCPS duration (h)	66.1±60.6	71.0±45.6	62.1±71.3	0.658
Mechanical device				
IABP	92 (87.6)	74 (88.1)	18 (85.7)	0.721
CHDF	76 (72.4)	58 (69.1)	18 (85.7)	0.175
Pacing	23 (21.9)	20 (23.8)	3 (14.3)	0.555
Complication				
Limb ischemia	40 (38.1)	31 (36.9)	9 (42.9)	0.624
Pneumonia	18 (17.1)	10 (11.9)	8 (38.1)	0.009
Sepsis	19 (18.1)	9 (10.7)	10 (47.6)	<0.001
Stroke	7 (6.7)	3 (3.6)	4 (19.1)	0.028
Bleeding	65 (61.9)	48 (57.1)	17 (81.0)	0.049
Success of treatment for primary disease	50 (48.1)	29 (35.0)	21 (100)	<0.001
Neurological recovery before discharge				
CPC 1–2	18 (17.1)	0 (0)	18 (85.7)	<0.001
CPC 3–4	3 (2.9)	0 (0)	3 (14.3)	0.007
CPC 5	84 (80.8)	83 (100)	0 (0)	<0.001
Weaned from PCPS	38 (36.2)	17 (20.2)	21 (100.0)	<0.001
Cause of death				
Not weaned	67 (73.8)	67 (79.8)	0 (0.0)	<0.001
Sepsis	6 (5.7)	6 (7.1)	0 (0.0)	0.597
VT/VF	2 (1.9)	2 (2.4)	0 (0.0)	1.000
Heart failure	2 (1.9)	2 (2.4)	0 (0.0)	1.000
Brain death	2 (1.9)	2 (2.4)	0 (0.0)	1.000
Bleeding	2 (1.9)	2 (2.4)	0 (0.0)	1.000
Others	2 (1.9)	2 (2.4)	0 (0.0)	1.000

Data given as mean±SD or n (%). †Between-group comparisons. PCPS duration in the non-survivor group is given as time to wean from PCPS. BUN, blood urea nitrogen; CHDF, continuous hemodiafiltration; CPC, cerebral performance category; CPR, cardiopulmonary resuscitation; CRP, C-reactive protein; IABP, intra-aortic balloon pump; PCPS, percutaneous cardiopulmonary support; PEA, pulseless electrical activity; VT/VF, ventricular tachycardia/ventricular fibrillation.

Table 3. Factors Affecting Survival After PCPS (Multivariate Analysis)

Information	In-hospital mortality		
	OR	95% CI	P-value
Age (<50 years old)	5.591	1.742–17.946	0.004
Time from cardiac arrest to PCPS (<45 min)	5.136	1.660–15.887	0.005

CI, confidence interval; OR, odds ratio; PCPS, percutaneous cardiopulmonary support.

a malignant disease or cerebral hemorrhage. Pediatric patients and patients with CA caused by non-cardiovascular disease were excluded from this study. The patients in whom PCPS was attempted after 7 days from admission to the ICU were also excluded in this study. All data were retrospectively retrieved from hospital medical records.

PCPS System

We use a heparin-coated PCPS circuit system (Senko Medical Instrument Mfg, Tokyo, Japan) consisting of a hollow-fiber microporous membrane oxygenator, a heart exchanger, centrifugal pump, and cannulae. Venous drainage was performed using a 20-Fr Venous cannula in the right atrium. Oxygenated blood was returned by a 16-Fr arterial cannula.

Procedures

The patients were assigned to 2 groups based on their in-hospital mortality: a survivor group (n=21), and a non-survivor group (n=84).

All variables on admission, including age, gender, past medical history, etiology, timing of PCPS attempt (before CA or after CA), first documented electrocardiogram after CA, the location of CA, the time from CA to the PCPS procedure, ambulance system, arterial blood gas levels and laboratory data, were compared between the 2 groups. All blood samples were collected within 30 min after performing the PCPS procedure. The factors that were significantly different between the 2 groups on univariate analysis were selected for inclusion in a multivariate logistic regression model. The continuous variables were evaluated by dividing the patients into 2 groups using a cut-off. Receiver operating characteristic (ROC) curves were calculated to predict the optimal cut-offs. We established a predictive score for survival of PCPS (PCPS survival score) by clarifying which information was specific for the survival of PCPS. We then scored the total number of indices specific to PCPS survival for each patient. We determined the PCPS survival score in each patient, and evaluated the sensitivity, specificity and the positive and negative predictive value for differentiating survivors and non-survivors. We also investigated the efficacy of the PCPS survival score by evaluating mid-term prognosis. The mid-term prognosis was evaluated with regard to any-cause death, including non-cardiac death, sudden death and cardiac death (other than sudden death) during the first 180 days after presentation. The patients were clinically followed up in a routine outpatient clinic. For the patients followed up at other institutes, their final prognoses were determined by telephone contact. The survival rates were analyzed using Kaplan-Meier curves according to PCPS survival score. We also evaluated the cerebral performance category class at discharge.

Statistical Analysis

All data were statistically analyzed using SPSS 16.0 J (SPSS Japan Institute, Tokyo, Japan). All numerical data are expressed as mean±SD. Unpaired Student's t-test or Mann-Whitney U-

test were used to compare the 2 groups. Comparisons of all proportions were performed with chi-squared analysis. ROC curves were calculated to predict the cut-off, and the sensitivity, specificity, and area under the ROC curves (AUC) were determined. The significant factors indicating survival after PCPS were determined using a multivariate logistic regression model. $P<0.05$ was considered to be statistically significant. The survival rates were analyzed between groups based on the PCPS survival score using Kaplan-Meier curves, and significant differences were calculated using log-rank test.

Results

Patient Characteristics

The distribution of PCPS patients according to the year of admission is shown in Figure 1. Twenty-one of the 105 patients (20.0%) survived after 2005.

PCPS score	Non-survivor	Survivor
≥2 (n)	28	18
≤1 (n)	56	3
Sensitivity (%)		85.7
Specificity (%)		66.7
PPV (%)		39.1
NPV (%)		94.9

PCPS, percutaneous cardiopulmonary support; PPV, positive predictive value; NPV, negative predictive value.

The patient cohort consisted of 78.1% men, with a mean age of 60.3±14.5 years. Sixty-seven (63.8%) of the patients had acute coronary syndrome (ACS; including ACS due to coronary spasm in 1 patient, and type A aortic dissection in 3 patients), 7 (6.7%) had FM, 9 (8.6%) had pulmonary thromboembolism, 9 (8.6%) had ischemic cardiomyopathy or prior myocardial infarction, 3 (2.9%) had non-ischemic cardiomyopathy (including 1 case of dilated cardiomyopathy and 1 case of alcoholic cardiomyopathy), 3 (2.9%) had acute aortic dissection, and 7 (6.7%) had unknown etiology (Table 1).

The relationships among patient characteristics, including the background of the PCPS procedure, arterial blood gas levels, and laboratory data, are shown in Table 2. The patients in whom PCPS was attempted before CA were significantly more likely to be in the survivor group (23.8%) than in the non-survivor group (4.8%). The first documented cardiac rhythm after CA was not significantly different between the 2 groups. There were fewer patients with out-of-hospital CA in the survivor group (23.8%) than in the non-survivor group (53.6%), but the time of admission and the ambulance system were similar between the groups. The time from CA to PCPS was significantly shorter in the survivor group (33.4±26.8 min) than in the non-survivor group (55.8±33.4 min). The arterial blood gas levels and laboratory data were not significantly different between the 2 groups. Furthermore, the use of mechanical support with PCPS was not different between the groups. Three patients (14.3%) in the survivor group were in cerebral

performance category class 3 and the remaining 18 patients (85.7%) were in class 1.

PCPS Survival Score

On multivariate logistic regression analysis for the survival group it was found that the specific predictive factors were age <50 years ($P=0.004$, odds ratio [OR], 5.591; 95% confidence interval (CI): 1.742–17.946) and time from CA to PCPS ≤45 min ($P=0.005$, OR, 5.136; 95% CI: 1.660–15.887; Table 3). Using the age of 50 years as a cut-off produced the optimal balance for ROC curve analysis (sensitivity, 86.7%; specificity, 42.9%; AUC, 0.649; $P=0.036$), and selecting 45 min as the cut-off for the time from CA to PCPS produced the optimal balance for this factor (sensitivity, 63.1%; specificity, 71.4%; AUC, 0.697; $P=0.005$; Figure 2).

On the basis of these results, we selected the following indices to calculate the predictive score for PCPS-related survival (PCPS survival score): (1) age <50 years old; (2) diagnosis of FM; (3) no out-of-hospital CA; (4) PCPS attempted before CA; and (5) time from CA to PCPS <45 min. The PCPS survival score was significantly higher in survivors than non-survivors (2.33±1.32 vs. 1.06±1.02; Figure 3). The sensitivity and specificity for survival after PCPS were 85.7% and 66.7% (AUC, 0.781), respectively, for a PCPS score ≥2 (Figure 2; Table 4). The positive and negative predictive value were 39.1% and 94.9%, respectively (Table 4).

The Kaplan-Meier survival curves showed that the prognosis, including any-cause death, was significantly poorer in the patients with a PCPS survival score ≤1 than in the patients with a PCPS survival score ≥2 (Figure 4).

Discussion

PCPS Survival Score

We constructed the PCPS survival score by giving 1 point each for the following: (1) age <50 years; (2) diagnosis of FM; (3) no out-of-hospital CA; (4) PCPS attempted before CA; and (5) time from CA to PCPS ≤45 min. The patients with a PCPS survival score ≤1 had a poorer outcome, including mid-term prognosis, with high sensitivity (85.7%) and specificity (66.7%). For these 5 factors, age <50 years and time from CA to PCPS

Figure 4. Kaplan-Meier survival curves for the percutaneous cardiopulmonary support (PCPS) survival score. Any-cause death was significantly more common in the patients with a PCPS survival score ≤ 1 ($n=59$) than in those with a PCPS survival score ≥ 2 ($n=46$).

≤ 45 min were the specific predictive factors identified on the multivariate logistic regression model. We therefore constructed another PCPS survival score system in which more points were allocated to the “age” and “time” factors, but the sensitivity and specificity were not improved in comparison with the original PCPS score. The original PCPS score, in which each factor was allocated a score of 1 point, could be calculated quickly and used precisely in the emergency department. We therefore used the original PCPS score, in which 1 point was allocated to each factor.

We also examined the other factors that affected survival in detail. The other factors, that is, the cannulation time, the physician’s experience and the degree of obesity, were not significantly different between the survival group and non-survival group.

Some previous reports have indicated that age >75 years is considered a contraindication for PCPS,⁶ but the majority of studies indicated that there were no associations between survival or weaning from PCPS and age.^{7,8} We therefore have proactively used PCPS, and did not consider age alone to be a contraindication. The older patients in the present study, however, had a poorer survival rate, and age was therefore included as a factor in the PCPS survival score. PCPS survival score consists of 5 factors. If the patients do not have other factors predicting poor prognosis, they should still undergo the PCPS procedure.

The patients diagnosed with FM were more likely to be weaned from PCPS compared with patients diagnosed with other diseases. The AUC for FM, however, was unsatisfactory in the present study (AUC, 0.694; 19.0% sensitivity and 97.0% specificity; $P=0.075$), so we could not predict the survival based only on diagnosis of FM. Shinn et al suggested that the rapid application of PCPS helps resuscitate patients with myocarditis.² The bridging use of PCPS for FM contributes to the recovery of systolic contraction of the left ventricle from cardio-

genic shock; furthermore, the long-term survival of FM appears to be favorable in the chronic phase.^{9,10} It is difficult to diagnose FM before the PCPS procedure, especially for CA patients. The clinical history, first documented rhythm on electrocardiogram, echocardiography and circulation were all important factors for the CA patients,¹¹ meanwhile, the changes in echocardiography, electrocardiogram and cardiac troponin¹² were important factors for the severe intractable shock patients. Because there is not sufficient time to diagnose FM in CA patients, we therefore diagnose FM in CA patients before PCPS based on the following criteria: (1) cold symptoms preceding CA; (2) severely reduced left ventricular function (diffuse hypokinesia) with hypertrophy observed at echocardiography; (3) high troponin-T; (4) atrioventricular block and repeat ventricular fibrillation after the return of spontaneous circulation (ROSC); and (5) ST-T changes or abnormal Q wave or poor R regression after ROSC on electrocardiogram. Previous reports have suggested that the mortality in the acute phase of FM was approximately 40% lower than that found with the bridging use of PCPS or a left ventricular assist device in the acute phase.^{9,11} The PCPS procedure is necessary to treat FM, but the outcome in patients who were treated using the PCPS has not yet been satisfactory. This survival rate was similar to that of patients requiring extracorporeal cardiopulmonary support during the treatment of acute myocardial infarction, which was approximately 30–40%.⁸ In the present study, 4 of the 7 patients with FM survived (57.1%), which was better than previous reports. The survival rate of ACS patients, however, was low, at only 17.9%. As a result, the patients with FM were more likely to be in the survival group in the present study, so this was selected as a factor predicting survival after PCPS. The low survival rate of ACS patients was due to the increased number of out-of-hospital CA in that group. It was previously reported that out-of-hospital CA patients have a low survival rate of approximately 3–20%.^{13,14} We could not calculate the

PCPS survival score for each of the patients with FM and ACS, because the number of patients with each diagnosis was small. Future prospective studies from a larger number of patients might allow for the calculation of the PCPS survival scores for patients with FM and ACS.

In the present study, PCPS was attempted for refractory cardiogenic shock in 9 patients, so that the PCPS procedure was performed before CA. The in-hospital mortality rate was relatively low, at 44.4%, for these patients. This mortality rate was similar to that in previous reports.^{8,15} The AUC for the use of PCPS before CA were unsatisfactory (AUC, 0.694; 55.6% sensitivity and 83.3% specificity; $P=0.052$), so we could not predict the survival based only on the timing of the PCPS procedure. In the present study, the mortality of the CA patients was low at 17.7% (only 17 of 96 patients survived). This may be because it is difficult to establish the correct timing for PCPS in emergency situations. The mortality of the patients with refractory cardiogenic shock was also not satisfactory, but the mortality was better in these patients than in the CA patients in the present study. The earlier introduction of PCPS might be helpful to improve the survival.

There were fewer patients with out-of-hospital CA in the survivor group than in the non-survivor group, but the AUC for the patients with out-of-hospital CA was unsatisfactory, at 0.595 (29.1% sensitivity and 90.0% specificity, $P=0.092$), so we could not predict the survival based only the location where the CA occurred. The survival rate of patients who experienced in-hospital CA was higher in comparison with those who had out-of-hospital CA. The overall survival rate of patients who experienced in-hospital CA, however, remains unsatisfactory.¹⁶ It was reported that cardiopulmonary resuscitation (CPR) assisted with ACLS improved the survival rate of in-hospital CA patients.^{7,15} Based on the present findings, we recommend that immediate PCPS should be considered when in-hospital CA patients with cardiovascular disease do not respond to ACLS. Rescuer actions, which are termed a "chain of survival" based on the participation of rescuers, including family members, bystanders, emergency medical service dispatchers, pre-hospital care providers, and hospital-based personnel, have been improved every year, although each group of rescuers has different skills. The survival rate of the patients in whom resuscitation is attempted is also increasing year by year, from below 3% to 5–20% for out-of-hospital CA patients.^{13,14} The survival rate of out-of-hospital CA patients was unsatisfactory in the present study, but is expected to improve. There were only 50 patients (47.6%) with out-of-hospital CA in the present study, therefore bystander CPR and witnessed CPR might not have been sufficiently reflected in the present PCPS score. If the PCPS survival score for patients with out-of-hospital CA can be calculated in the future, these factors might be included by improving the chain of survival. To further improve survival, PCPS support for out-of-hospital CA patients should be considered, especially for the patients who have a PCPS survival score of ≥ 2 .

Shinn et al reported that PCPS can extend the CPR time to 60 min with an acceptable survival rate, and CPR duration was not significantly different between weaned and non-weaned patients.² Meanwhile, in other reports both the survival-to-discharge rate and the 6-month survival rates were better in patients with a CPR duration <35 min than in those with a CPR duration >35 min,⁷ and <35 min for the recovery of circulation was the optimal period for achieving a favorable recovery, with a sensitivity of 68% and a specificity of 73%.¹⁷ These durations were different from the present study conclusion, and there are currently no definitive guidelines for when PCPS

should be utilized. Therefore, the cut-off for CPR duration is still controversial. Furthermore, the sensitivity and specificity were unsatisfactory to predict the survival or a favorable recovery when using only the time factor. Rapid stabilization of hemodynamic status and rapid restoration of cerebral and coronary perfusion in CA patients, however, are critical for survival.⁷ The present study has confirmed that early attempts at PCPS could improve these factors, and help to improve the chances of survival. Therefore, the duration of time from CA to PCPS was included in the PCPS survival score in the present study.

Survival After PCPS With PCPS Survival Score ≤ 1

Three patients who survived after PCPS had scores of 0 points. Two patients were in cerebral performance category class 3 and the other patient was in class 1 at discharge. Two patients survived from the PCPS in 2012.

A 58-year-old man was admitted to the emergency room after ventricular fibrillation in August 2012. Forty min earlier, he had suddenly collapsed, and ventricular fibrillation was documented at the first contact with the emergency medical system. He arrived at Chiba Hokusoh Hospital, Nippon Medical School with pulseless electrical activity after the complete chain of survival, and PCPS was immediately started 22 min after arrival. Coronary angiograms showed total occlusion at the mid-circumflex. A bare metal stent was successfully implanted, and Thrombolysis In Myocardial Infarction (TIMI) flow grade 3 was obtained. After intensive care, he was successfully weaned from PCPS after 18 h, and was finally discharged with cerebral performance category class 1 after 35 days.

In the present study, the aforementioned case was the only one involving survival with a cerebral performance category class 1 and a PCPS score of 0 points. Therefore it is possible that the other patients with a score of 0 points may have survived, but we could not rescue such patients due to the development of PCPS-related complications (ie, bleeding, sepsis), and hypoxic brain damage, brain bleeding and the ventricular fibrillation storm after weaning from PCPS. The complete chain of survival was required to rescue the patient who underwent PCPS for out-of-hospital CA. The rescuer actions (ie, the chain of survival), including ACLS, the physician's skill in deploying PCPS, the specific device used and the level of intensive care have been dramatically improving year by year, so the future may see an increase in successful cases involving a score of 0.

Other Potential Factors Predicting Survival After PCPS

The first documented cardiac rhythm might be another factor that can be used to predict survival after PCPS. It was reported that ventricular tachycardia/ventricular fibrillation was independently associated with survival to hospital discharge in patients with in-hospital and out-of-hospital CA.¹⁶ In the present study, however, the first documented rhythm was not associated with survival. This might have been due to the relatively small number of patients ($n=50$, 47.6%) with out-of-hospital CA in the present study.

IABP can generate pulsatile flow, increase the coronary blood flow, might decrease the left ventricular afterload in patients with ACS,¹⁸ and might inhibit the remodeling of an inflamed left ventricle by reducing the preload and afterload during the acute phase of FM.¹⁰ IABP might therefore facilitate weaning from PCPS. A total of 92 patients (87.6%) were supported with IABP in addition to PCPS in the present study, but we did not find any association between IABP use and PCPS survival.

The efficacy of continuous hemodiafiltration (CHDF) has rarely been reported in patients receiving PCPS, but it was reported that CHDF improved the clinical parameters and survival in intensive care patients, especially those with multiple organ failure, sepsis and heart failure.^{19,20} The majority of patients who receive PCPS eventually develop multi-organ failure, sepsis and heart failure either before or after weaning from PCPS, and they also often suffer from acute kidney injury. We therefore use CHDF from the early stage to prevent these complications when the patients have recovered from a shock state, have a preserved blood pressure and do not have major bleeding.

APACHE II score was a strong independent predictor of unfavorable in-hospital outcome for patients with profound cardiogenic shock undergoing extracorporeal membrane oxygenation.²¹ It is difficult to calculate the APACHE II score for CA patients, the timing of the blood sampling was not the same, and it takes time to calculate this complicated score in the clinical situation. We therefore did not evaluate APACHE II score in the present study; nevertheless, the presence of organ failure might be a factor affecting PCPS survival.

In a previous report, a lower final TIMI flow grade was identified in patients with IABP/PCPS than in those without IABP/PCPS for ACS.²² Therefore, the TIMI grade might predict survival after percutaneous coronary intervention (PCI) in patients with ACS receiving PCPS, but final TIMI grade was not independently associated with the in-hospital mortality for these patients in a previous study.²² In the present study, the final TIMI grade was also not significantly different between the survivor group and non-survivor group; furthermore, the door to reperfusion time and the rate of primary PCI were also not significantly different.

Treatment of Primary Disease in Patients Receiving PCPS

In patients with ACS, early reperfusion is the most important factor predicting outcome. The patients who received PCPS had unstable circulation. We therefore performed PCI for all ACS patients. Two of the patients who survived suffered from heart failure caused by mitral regurgitation after weaning from PCPS, therefore they needed mitral replacement to compensate for the heart failure. One patient who required PCPS had experienced refractory vasospasm. Kobayashi et al reported that coronary vasospasm was one of the major causes of out-of-hospital CA.²³ We successfully treated and weaned this patient from PCPS using 3 types of Ca blockers.

One surviving patient with FM was treated with high-dose (2 g/kg) i.v. immunoglobulin. Acute inflammation was identified in these patients on pathology of the myocardium, which indicated varying nuclear size and edematous extracellular matrix. Furthermore, 1 surviving patient with a pulmonary thromboembolism underwent pulmonary thromboendarterectomy, and percutaneous catheter embolus fragmentation and/or thrombectomy were undertaken in 2 other patients who survived. One patient with ventricular fibrillation caused by a prior myocardial infarction successfully underwent PCI for chronic total occlusion on PCPS, and he was weaned from PCPS after his ejection fraction was improved.

Benefits of Using PCPS

Using the PCPS procedure allows for PCI to be performed under stable circulation in patients with CA and cardiogenic shock. The reperfusion time was faster when the PCPS procedure was used for these patients, and it might therefore lead to good outcomes in patients with ACS.

Therapeutic hypothermia increased the rate of a favorable

neurologic outcome and reduced mortality,²⁴ while a faster decrease in body temperature to the 34°C target appears to predict unfavorable neurological outcome.²⁵ It is difficult, however, to rapidly decrease the body temperature. It was possible to shorten this time by using the PCPS procedure, and this might have led to a favorable neurologic outcome. In the present study, only 3 patients (14.3%) in the survivor group were in cerebral performance category class 3, while the remaining 18 patients (85.7%) were in class 1.

Study Limitations

The present study had several limitations. First, it is difficult to diagnose FM before the PCPS procedure, therefore we have recommended some markers with which to diagnose FM, but they are not perfect. In which case, when physicians suspect FM based on these factors, they should allocate 1 point in the PCPS survival score for FM. Second, this survival score was calculated for all cardiovascular patients, therefore the primary disease of the patients who needed PCPS support was mixed. Therefore, we also examined the predictive factors based on the different primary diseases but, because of the relatively small number of patients studied, we could not identify the predictive factors in patients with ACS, FM, pulmonary thromboembolism, ischemic cardiomyopathy or prior myocardial infarction. Further study is needed to determine PCPS survival score for patients with each type of primary disease. Furthermore, we also could not determine the PCPS survival score for each patient category, that is, the patients with out-of-hospital CA or intractable cardiogenic shock. Third, the sensitivity of the PCPS survival score was not 100%, therefore 3 patients survived even though they all had scores of 0 points. This PCPS score should therefore be used carefully when considering these patients in the emergency department.

Conclusions

The PCPS survival score, based on (1) age <50 years old; (2) diagnosis of FM; (3) no out-of-hospital CA; (4) PCPS attempted before CA; and (5) time from CA to PCPS <45 min, is suitable for clinically predicting short-term and mid-term survival after PCPS in patients with cardiovascular disease. The sensitivity and specificity for survival were high at 85.7% and 66.7%, when the PCPS survival score was ≥ 2 . The patients with a PCPS survival score ≤ 1 had poor mid-term prognosis. Therefore, if the PCPS survival score is ≤ 1 , the emergency use of PCPS should be prudently considered for patients with cardiovascular disease.

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