허혈성 심질환으로 인해 병원 내에서 발생한 심정지 혹은 심인성 쇼크에 있어서의 경피적 심폐 보조장치의 치료 경험

이 일* · 권성욱* · 성기익* · 조성우* · 권현철* · 이영탁* · 박표원* · 박계현* · 이상훈*

Experiences with Emergency Percutaneous Cardiopulmonary Support in In-hospital Cardiac Arrest or Cardiogenic Shock due to the Ischemic Heart Disease

Il Rhee, M.D.*, Sung-Uk Kwon, M.D.*, Kiick Sung, M.D.*, Sung Woo Cho, M.D.*, Hyeon-Cheol Gwon, M.D.*
Young Tak Lee, M.D.*, Pyo Won Park, M.D.*, Kay-Hyun Park, M.D.*, Sang Hoon Lee, M.D.*

Background: Percutaneous cardiopulmonary support (PCPS) provides passive support of gas exchange and perfusion, allowing the use of other methods of care for organ recovery, and saves lives of patients with severe cardiopulmonary failure in a wide variety of clinical settings with a minimal risk of bleeding and need for chest re-exploration. We summarized a single center's experiences with PCPS in patients with cardiogenic shock or cardiac arrest due to the ischemic heart disease. ***Material and Method:*** Among the 20 consecutive patients with cardiogenic shock or cardiac arrest from May 1999 to June 2005, Biopump® (Medtronic, Inc, Minneapolis, MN) was used in 7 patients and the self-priming, heparin-coated circuit of EBS® (Terumo, Japan) was applied to remaining 13 patients. Most of cannulations were performed percutaneously via femoral arteries and veins. The long venous cannulas of DLP® (Medtronic inc. Minneapolis, MN) or the RMI® (Edwards's lifescience LLC, Irvine, CA) were used with the arterial cannulae from 17 Fr to 21 Fr and the venous cannula from 21 Fr to 28 Fr. ***Result:*** The 20 consecutive patients who were severely compromised and received PCPS for the purpose of resuscitation were comprised of 13 cardiac arrests and 7 cardiogenic shocks in which by-pass surgery was performed in 11 patients and 9 ongoing PCIs under the cardiopulmonary support. The mean support time on the PCPS was 38±42 hours. Of the 20 patients implanted with PCPS, 11 patients (55%) have had the PCPS removed successfully; overall, 8 of these patients (40%) were discharged from the hospital in an average surviving time for 27±17 days after removing the PCPS and survived well with 31±30 months of follow-up after the procedure. ***Conclusion:*** The use of PCPS appears to provide the hemodynamic restoration, allowing the survival of patients in cardiac arrest or cardiogenic shock who would otherwise not survive, and patients receiving PCPS had a relatively long-term survival.

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Key words: 1. Percutaneous bypass
2. Cardiac arrest
3. Cardiogenic shock
4. Ischemic heart disease

*성균관대학교 의과대학 삼성서울병원 심혈관센터
Cardiac and Vascular Center, Samsung Medical Center Sungkyunkwan University School of Medicine
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책임저자 : 성기익 (135-230) 서울시 강남구 일원동 50, 삼성서울병원 심혈관 센터
(Tel) 02-3410-6541, (Fax) 02-3410-0089, E-mail: kiick.sung@samsung.com

BACKGROUND

Percutaneous cardiopulmonary support (PCPS) has been proven to be a support system of value for patients with profound cardiogenic shock or impending cardiac arrest and some of these patients need the PCPS as an emergency procedure to support revascularization. PCPS has been a therapeutic option in a variety of the clinical settings with varying degrees of success, including heart failure, high-risk angioplasty and elective coronary interventions[1-3]. We report our clinical experiences with PCPS as the emergency procedure in cardiac arrest or cardiogenic shock due to ischemic heart disease (IHD).

MATERIAL AND METHOD

Between May 1999 and June 2005, the hemodynamic compromise requiring emergency PCPS has occurred in 20 patients who were treated with coronary revascularization before or after the procedure. When hemodynamic collapse occurred during a percutaneous coronary intervention (PCI), PCPS was instituted in the catheterization laboratory, coronary interventions were performed simultaneously and the patients were placed on PCPS till the procedures were completed or the patients were transferred to the operation room for coronary artery bypass graft (CABG) in some cases. PCPS apparatus and the well-trained team are ready for the emergency use in the room near to this laboratory to make the patient put into pump within minutes. The patients with postbypass cardiogenic shock or cardiac arrest who received PCPS for transient circulatory support in the intensive care unit were also included in this study.

Two types of centrifugal pumps and membrane oxygenators were utilized as PCPS systems. We initially used a Biopump® (Medtronic Inc, Minneapolis, MN, USA), a system in which pump and an oxygenator were separate, and it took time to assemble the system occasionally. Since November 2003, we have been using a Capiox Emergency Bypass System® (Terumo, Inc., Tokyo, Japan) in which the pump, oxygenator, and circuit are preassemble. The entire blood contacting surface of the PCPS system is coated by heparin bonded materials. The console has a fully automatic priming function, and it takes only several minutes to prepare to use. Therefore, this system has the advantages of allowing the quick insertion of PCPS with convenience, especially in patients with cardiopulmonary arrest.

The tip of the arterial cannula was advanced and positioned in the common iliac artery, and the tip of the venous one was placed at the junction of the right atrium and superior vena cava through a rigid backup guidewire and under fluoroscopy, using the percutaneous technique. Long venous cannulas of DLP® (Medtronic inc. Minneapolis, MN) from 21 Fr to 28 Fr and RMI® (Edwards's lifescience LLC, Irvine, CA) from 17 Fr to 21 Fr were used for venous and arterial circulation, respectively. If percutaneous cannulation failed, a direct surgical cut down to the femoral vessels was performed, and cannulas were inserted under the direct visualization.

The patients were fully heparinized by the continuous infusion at the rate of 3 mg/kg/min to maintain the activated clotting time at greater than 200 sec. After the pump and canulae were purged, the extracorporeal circulation was initiated and the used pump provides nonpulsatile flow at rate between 1 and 5 L/min. The pump flow could be increased or decreased with the indication of inotropics or fluids as needed during the procedure. The perfusion catheter is inserted distally into the femoral artery for the prevention of leg ischemia. When the pump was weaning, both canulae were clamped and the pump was interrupted. There were no cases of using protamin to reverse circulating heparin in our patients, as indicated in other papers[4], and cannula removal is performed surgically.

1) Follow-up

All survivors were followed up closely by telephone calls and were clinically reevaluated ever it was necessary. The mean clinical follow-up time was 31 ± 30 months.

2) Statistical study

All values are expressed as the mean $\pm$ SD. Comparison between quantitative data was performed by the student's t-test. A $p < 0.05$ was considered to be statistically significant.

Table 1. Summary of the cases

Pts	Sex	Age	Diagnosis	Type	Method	Outcome	PCPS time
1	M	50	3VD, Post-CABG shock	Bio-pump®	Percut.	Died of renal failure	16 h
2	M	77	LM, Cardiogenic shock	Bio-pump®	Percut.	OPCAB but died of heart failure	16 h
3	M	47	LM+2VD, Arrest at OPD	Bio-pump®	Open	PCI but died (lower limb ischemia)	80 h
4	M	63	LM+3VD, Cardiac arrest	Bio-pump®	Open	Weaning after Redo-CABG & discharged	4 h
5	F	60	3VD, Cardiac arrest	Bio-pump®	Percut.	Weaning after PCI but died of renal failure	4 h
6	M	61	3VD, Post-CABG arrest during HD	Bio-pump®	Open	Weaning after OPCAB but died of hypoxic brain damage	3 h
7	M	67	LM+3VD, Post-CABG arrest	Bio-pump®	Percut.	Died of heart failure	15 h
8	M	46	LM+2VD, Cardiac arrest during PCI	EBS®	Percut.	Weaning & discharged	24 h
9	M	48	3VD, Post-CABG shock	EBS®	Open	Weaning & discharged	63 h
10	F	59	LM+2VD, Shock	EBS®	Open	Weaning after PCI but died of hypoxic brain damage	21 h
11	F	70	1VD, Arrest during PCI	EBS®	Percut.	Weaning after CABG, Discharged	2 h
12	M	68	3VD, Post-CABG arrest	EBS®	Percut.	Weaning after CABG but died of VF	86 h
13	F	69	2VD, Cardiogenic shock during PCI	EBS®	Percut.	Died of MOF	148 h
14	F	63	LM+2VD, Arrest during PCI	EBS®	Percut.	Weaning after PCI & discharged	7 h
15	M	68	LM+2VD, Post-OPCAB arrest	EBS®	Percut.	Weaning & discharged	25 h
16	M	55	3VD, Post-OPCAB arrest	EBS®	Percut.	Died of heart failure	10 h
17	M	71	3VD, Arrest during PCI	EBS®	Percut.	Died of MOF	23 h
18	F	84	2VD, Arrest during PCI	EBS®	Percut.	Died of heart failure	3 h
19	M	68	2VD, Cardiogenic shock during PCI	EBS®	Percut.	Weaning after PCI & discharged	72 h
20	M	57	2VD, Cardiogenic shock during PCI	EBS®	Percut.	Weaning after PCI & discharged	48 h

PCPS=Percutaneous cardiopulmonary support; M=Male; VD=Vessel disease; percu.=Percutaneous; LM=Left main; OPCAB=Off-pump coronary artery bypass; OPD=Out-patient department; PCI=Percutnaeous coronary intervention; CABG=Coronary artery bypass graft; F=Female; HD=Hemodialysis; MOF=Multiorgan failure.

RESULTS

A summary of the cases is shown in Table 1. Biopump® (Medtronic) was used in 7 patients and the self-priming, heparin-coated circuit of EBS® (Terumo) was applied to remaining 13 patients. The percutaneous approach was applied in 15 patients, and the open surgical technique was done in remaining 5 patients. The mean time from the onset of cardiogenic shock or cardiac arrest to the initiation of PCPS was 28±35 min (range 10~170 min). The mean pump flow rate of PCPS was in the range of 3.0 to 5.2 L/min/m^2, and the most patients showed the clinical and hemodynamic improvement at those flow rates. Eleven of the 20 patients (55%) in this series could be weaned from PCPS or cardiopulmonary bypass initially, however, only 8 patients (40%) survived and they were discharged from the hospital 27±17 days after medical treatment with survival rates of 36% for CABG, 44% for PCI. All 8 patients were long-term survivors, 3 of 8 patients with cardiogenic shock vs. remaining 5 patients with cardiac arrest and maintained the good quality of life at a 6 month follow-up. In the nonrecovered who were unable to wean from the PCPS, however, postoperative cardiac contraction did not improve and finally the patients died on PCPS. The procedure was also performed under refractory ventricular fibrillation after CABG in 2 patients who could be initially weaned from PCPS, however, an abrupt deterioration of cardiac function occurred and died of refractory ventricular arrhythmia.

Table 2 shows the baseline characteristics of the 20 patients placed on the PCPS. There were 15 males and 5 females whose ages ranged from 46 to 84 years with an

Table 2. Baseline characteristics of patients requiring emergency PCPS

Age (years)	63±10
Cardiac history	
Myocardial infarction	10
Unstable Angina	8
Stable Angina	2
Extent of disease	
One vessel	2
Two vessels	4
Three vessels	9
Left main disease	5
Procedure	
CABG	11
Preoperative cardiac arrest	5
Postoperative cardiogenic shock	6
PCI	9
Pre-LVEF (mean)	41±18%
Intraaortic balloon pump	16

PCPS=Percutaneous cardiopulmonary support; CABG=Coronary artery bypass graft; PCI=Percutaneous coronary intervention; LVEF=Left ventricular ejection fraction.

Table 3. Complications of elective PCI warranting PCPS

Left main dissection	1
No reflow	4
Abrupt vessel closure	6
Intra-procedural thrombus	4
Subacute thrombosis	2

PCI=Percutaneous coronary intervention; PCPS=Percutaneous cardiopulmonary support.

Table 4. Major complications in PCPS patients (n=20)

Procedural success	20
Acute renal failure	8
Bleeding	4
Cerebrovascular accident	2
Limb ischemia	1
Infection	1
Vascular injury	1

PCPS=Percutaneous cardiopulmonary support.

average of 63±10 years. The etiology of shock in 7 patients was the acute coronary syndrome related to the left main coronary artery or multiple coronary artery diseases with the severe left ventricular (LV) dysfunction not responding to inotropics adequately. Thirteen patients with cardiopulmonary arrest required aggressive resuscitation and circulatory support prior to the institution of PCPS. The mean left ventricular end-diastolic pressure (LVEDP) was 27±7 mmHg. The mean ejection fraction (EF) was 41±18% on the preprocedural 2D echocardiography, and in 5 patients the EF was <20%. The intraaortic balloon pump (IABP) was inserted in 16 of the 20 (80%) patients prior to PCPS.

All 14 patients required the PCPS used as an emergency procedure to resuscitate and stabilize patients with circulatory collapse in order to attempt the urgent coronary revascularization. In 9 of the 14 cases, the PCI was carried out in the catheterization laboratory on PCPS with the complete revascularization in 6 patients (67%). A total of 15 lesions were treated in these patients and we implanted 1.3±0.7 stents per patient. Two patients were treated with bailout stents for the left main dissection. Out of the 20 patients, 11 (55%) were weaned from PCPS. The mean running time of PCPS was 49±52 hours. In 5 of the 14 cases undergoing emergency PCPS, CABG was performed with 30±31 hours. The complications of elective PCI resulted in hemodynamic collapse are listed in Table 3. In addition, occlusive maneuvers in complex procedures such as kissing balloon technique for the left main bifurcated lesions, combined debulking procedures or prolonged manipulation of IVUS, frequently originated circulatory collapse, malignant arrhythmias, or cardiac arrest in our series.

The procedural success was initially achieved in all patients (Table 4). There were peri-procedural problems in 11 patients. They were the acute renal failure (ARF) requiring hemodialysis in 8 (40%), critical bleeding in 4 (20%), stroke in 2 (10%), and catheter-related infection in 1 (5%). A cannulation-related laceration of femoral artery was observed in 1 patient and surgically repaired. Mild, transient ischemic injury of the leg was found in one patient (5%) before the distal leg perfusion was not used.

During the period of this study there were a total of 12 deaths, thus the in-hospital mortality rate of patients placed on PCPS was 60%. Three patients were unlikely to have the

Table 5. Deaths in patients instituted with emergency PCPS

Number of patients	12
No resuscitation order at time of death	2
Causes of death	
Multiorgan failure and sepsis	2
Heart failure with low cardiac output	4
Respiratory failure	2
Refractory ventricular arrhythmia	2

PCPS=Percutaneous cardiopulmonary support.

benefit from PCPS due to the noncardiac causes, uaually not reversible. Two of these patients died of multiorgan failure (MOF). One of these patients died of respiratory failure, while on mechanical ventilation in hospital day 6. Data on these 12 patients are presented in Table 5. The survivors were followed through 31±30 months after the procedure. During this period, no major adverse cardiac events occurred and 8 patients remained at present in functional class I~II. The statistical significance was not found in several variables between the survivors and the nonsurvivors (Table 6).

Table 6. A comparison of preprocedural factors between the patients who died in hospital (nonsurvivors) and those discharged from hospital (survivors)

Factors	Nonsurvivors (n=12)	Survivors (n=8)	p value
Gender male/female	8/4	6/2	0.690
Age>70 years	3	1	0.371
LVEF<30%	4	2	0.307
Use of intraaortic balloon pump	9	7	0.495
Time from shock to PCPS (min)	16±4	35±45	0.079
PCPS running time (hr)	31±27	43±50	0.558
Initial mean PCPS flow ($L/min/m^2$)	4.0±0.7	3.8±0.9	0.624
Initial cardiac index ($L/min/m^2$)	2.3±0.3	2.4±0.3	0.532
Initial 24 h urine volume (L)	1.2±1.8	2.6±1.9	0.158
24 h serum creatinine later (mg/dL)	2.4±1.1	1.9±1.2	0.354

LVEF=Left ventricular ejection fraction; PCPS=Percutaneous cardiopulmonary support.

DISCUSSION

PCPS has been employed widely to provide support to the patient's vital organs such as the brain and the kidney during the episodes of circulatory compromise unresponsive to conventional cardiopulmonary resuscitation. In these patients, the PCPS preserves systemic perfusion pressures and cardiac arrests or malignant arrhythmias are well tolerated under PCPS. In addition, the PCPS decreases markedly the myocardial oxygen consumption, maintaining the favorable hemodynamic status for the ongoing ischemia.

Several studies have demonstrated the effectiveness of PCPS in critical coronary patients with prolonged cardiac arrest or cardiogenic shock undergoing revascularization and the weaning rates for PCPS and the survival rates are vary over a wide range. Reichman et al reported a series of 38 cardiac arrest patients and 7 patients underwent CABG in their series[5]. Seven were early survivors and 3 of those who underwent CABG were long-term survivors. Matsuwaka et al reported the results of PCPS for severe cardiogenic shock after acute myocardial infarction[6]. In their series of 16 patients, 13 underwent emergency surgery, CABG in 4 and closure of LV rupture in 9. One patient who underwent CABG and another patient who underwent closure of LV rupture were hospital survivors. Suarez de Lezo et al reported a series of 24 acute myocardial infarction and circulatory collapse needing PCI. Ten were early survivors and 9 of these patients remain at present[7]. The survival rates in these reports were 25~43% (3 of 7, 1 of 4, 1 of 3 and 9 of 24) for CABG or PCI. The large variations at outcomes may be caused by various reasons such as, the variable delay until the onset of PCPS and the varying degree of experience with the techniques; however, the most important factor responsible for the marked differences in survival is the patient selection[8]. In our series 14 of 20 patients, treated by PCPS for cardiac arrest or cardiogenic shock, underwent emergency coronary revascularizations, CABG in 5 and PCI in 9. Our rate of weaning from PCPS (55%, 11/20) and survival rate (57%, 8/14) were somewhat better than the rates previously reported. The duration of PCPS ranged from 3 to 148 hours

(mean, 38±42 hour).

The cause of death in our patients who were unable to be weaned from PCPS was the MOF, complicated with respiratory failure, and deterioration of heart failure whereas three patients who could be weaned from PCPS died from MOF due to prolonged low cardiac output, deterioration of heart failure, and refractory ventricular fibrillation which persists postoperative period of CABG. In one case of acute MI with LV rupture, we performed the LV repair and the additional bypass grafting, however, this did not have caused the hemodynamic amelioration or recovery of LV function.

It has been suggested that patients with IHD should undergo coronary intervention even if hemodynamic stability has been achieved by PCPS, because myocardial recovery is affected by the duration of ischemia. Although PCPS provides stable hemodynamic conditions, the malperfusion of the infarction related coronary arteries persists[9]. As the intervals from the onset of the shock to PCPS institution increased, the mortality generally increased[10]. Therefore, to minimize the impairment of cardiac function, it is important to make the initiation of PCPS achieved as quickly as possible and shortens the time interval in addition to prompt and complete coronary revascularization. In our series the interval from the onset of cardiogenic shock to the institution of PCPS was almost always less than 3 h, and the mean interval was 27±35 min.

IABP may be also the useful method of protection for coronary revascularization or in conditions of low cardiac output. However, IABP in diastole is not equivalent to the favorable conditions with strong output provided by PCPS, it cannot support in extreme conditions such as cardiac arrest or malignant arrhythmia, which appear frequently in cardiogenic shock[7]. On the other hand, PCPS itself has unphysiological directional circulation leading to increased afterload of LV, LV distension and myocardial injury, it is less likely to promote the recovery of LV function unless the left atrium is decompressed[11]. Therefore, for the optimal clinical results, the concomitant use of IABP would be required for the recovery of cardiac function during the PCPS operation[12]. IABP was used concomitantly in 16 of the 20 (80%) patients in our study.

Several complications related to PCPS have been reported, including limb ischemia, thromboembolism, and bleeding[13], but they are relatively infrequent. We have encountered some of these major complications like major bleeding, stroke, limb ischemia and ARF, but major bleeding and ARF were the problems predominately contributing to the significant morbidity associated with PCPS. However, most of the complications developed before the institution of PCPS due to the result of aggressive cardiopulmonary resuscitation or prolonged low cardiac output. Although the effect of bleeding on mortality remains controversial, Yamashita et al.[14] identified the bleeding and the consecutive MOF as one of the main causes of death in his study, 2 of 4 patients with substantial bleeding were long term survivors in our study population. We found a lower rate of femoral vessel injury or leg ischemia, with only 1 patient needing surgical intervention (Table 4).

CONCLUSION

Over 5 year periods, 20 patients of IHD were placed on emergency PCPS for cardiogenic shock or cardiac arrest and eight survived in our institution (40%). This retrospective analysis demonstrated the effectiveness of PCPS for the treatment of hemodynamic collapse before or after the coronary interventions, allowing the last opportunity for salvage of patients with a predicted mortality of around 100%, and most of the patients receiving PCPS had a relatively long- term survival.

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=국문 초록=

배경: 경피적 심폐 보조장치(PCPS)는 체내의 가스교환과 혈액의 관류를 간접적으로 도와줌으로써, 장기를 회복시키기 위한 다른 치료법의 사용을 용이하게 하고, 여러 다양한 임상 상황에서 출혈의 위험성을 최소화하면서 심각한 심폐부전에 빠진 환자의 생명을 구해준다. 본 저자들은 허혈성 심질환자들에서 발생한 심인성 쇼크 혹은 심정지를 PCPS로 치료한 경험을 보고하고자 한다. **대상 및 방법**: 1999년 5월부터 2005년 6월까지 발생한 심정지 혹은 심인성 쇼크 환자들을 대상으로 연구가 진행되었고, 환자들 중 7명에서 원심펌프인 Biopump® (Medtronic inc., Minneapolis, MN), 나머지 13명에게는 자가 priming이 되는 헤파린-코팅된 EBS® (Terumo, Japan)를 사용하였다. 삽관은 모든 환자에서 대퇴동맥과 대퇴 정맥을 통해서 이루어졌으며, 동맥용 케눌라는 17 Fr에서 21 Fr까지, 정맥용은 21 Fr에서 28 Fr까지의 DLP® (Medtronic inc., Minneapolis, MN) 또는 RMI® (Edwards lifescienc LLC, Irvine, CA)의 비교적 긴 정맥용 케눌라를 사용하였다. **결과**: 소생을 목적으로 PCPS가 시도되었던 총 20명의 환자들 중에서 심정지가 13명이었으며, 심인성 쇼크였던 환자가 7명이었다. 이들 중 11명에서 관동맥 우회술이 시행되었고, 나머지 9명의 환자에서 PCPS한 상태에서 경피적 관동맥 중재술이 시도되었다. 평균 PCPS가동 시간은 38±42시간이었으며, 총 20명의 환자들 중 PCPS 이탈이 가능하였던 11명(55%)의 환자 중 총 8명(40%)의 환자가 특별한 합병증 없이 평균 27±17일만에 퇴원하였다. 퇴원한 환자는 현재 모두 생존하여 최장 31개월째 외래 추적관찰 중이다. **결론**: PCPS를 시행함으로써 혈역학적 회복을 가져옴으로써 다른 방법으로는 살리기 힘들었던 심정지 또는 심인성 쇼크로부터 환자를 구할 수 있고, 일단 회복된 환자들은 장기 생존율을 보인다.

중심 단어 : 1. 경피적 체외순환
2. 심인성 쇼크
3. 심정지
4. 허혈성 심질환