Original Article

Clinical Effects of Percutaneous Cardiopulmonary Support in Severe Heart Failure: Early Results and Analysis of Complications

Shigeru Sakamoto, MD, Junichi Matsubara, MD, Toshiaki Matsubara, MD, Yasuhiro Nagayoshi, MD, Shinji Shono, MD, Hisateru Nishizawa, MD, Masaaki Kanno, MD, Katsunori Takeuchi, MD, Toshimichi Nonaka, MD, and Jun Kyosawa, MD

Between January 1993 and December 2001, we employed percutaneous cardiopulmonary support (PCPS) in 35 patients. PCPS was used for postcardiotomy in 25 of these patients who could not be weaned from cardiopulmonary bypass (CPB) because of severe cardiogenic shock. In the other 10 patients, PCPS was used for a non-surgical disease. Twenty-nine patients (82.9%) were weaned from PCPS, and 28 (80.0%) survived. The other 7 patients (20.0%) died due to postoperative complications. The causes of death were multiple organ failure (MOF) due to wound bleeding, low cardiac output syndrome (LOS), myonephropathic metabolic syndrome (MNMS) with severe lower limbs ischemia, cerebrovascular accident (CVA), and sepsis. The first cause for the complications was postoperative sustained severe heart failure. To improve the survival rate, it was necessary to prevent bleeding and begin PCPS at an earlier stage. (Ann Thorac Cardiovasc Surg 2003; 9: 105–10)

Key words: percutaneous cardiopulmonary support (PCPS), bleeding, multiple organ failure (MOF), myonephropathic metabolic syndrome (MNMS), low cardiac output syndrome (LOS)

Introduction

The percutaneous cardiopulmonary support (PCPS) has been employed widely for severe heart failure. Many investigators have reported its efficacy in patients suffering from postcardiotomy shock or profound cardiogenic shock.[1-5] However, in spite of this assistance, the rates of morbidity and mortality in these patients have still been high and PCPS has presented various clinical problems such as sustained ventricular failure, limbs ischemia, decrease in platelet count, bleeding, and multiple organ failure (MOF). At our institute, in this retrospective study, we evaluated the outcome of PCPS for severe heart failure.

From Department of Thoracic and Cardiovascular Surgery, Kanazawa Medical University, Ishikawa, Japan

Received August 15, 2002; accepted for publication October 16, 2002.

Address reprint requests to Shigeru Sakamoto, MD: Department of Thoracic and Cardiovascular Surgery, Kanazawa Medical University, 1-1, Kahokugun, Uchinada, Ishikawa 921-0293, Japan.

Patients and Methods

Between January 1993 and December 2001, we employed PCPS in 35 patients. Twenty-five were males and 10 females with a mean age of 60.9±13.0 years (range, 44 to 76 years). The diagnosis of these 35 patients was acute myocardial infarction (AMI) in 8, AMI with ventricular septal rupture (VSR) in 2, AMI with mitral valve regurgitation (MR) in 4, AMI with mitral valve stenosis (MS) in 1, failed percutaneous transluminal coronary angioplasty (PTCA) in 2, old myocardial infarction (OMI) in 2, perioperative myocardial infarction (PMI) in 1, prosthetic valve dysfunction (PVD) in 2, prosthetic valve endocarditis (PVE) in 2, type A dissecting aneurysm in 1, myocarditis in 7, and fetal arrhythmia in 3. An intraaortic balloon pumping (IABP) was inserted in 19 of the 35 patients prior to PCPS. PCPS was applied in 25 patients with surgical procedure when they could not be weaned

Table 1. Patient characteristics: diagnosis, procedure, and type of support

Diagnosis	Operative procedure	Type of support		No. of patients
IHD		Preoperative	Postoperative	(20)
RVMI with RHF	CABG	IABP+PCPS	IABP+PCPS	4
AMI with HF	CABG	IABP	IABP+PCPS	4
AMI with VSR	VSR patch closure	IABP+PCPS	IABP+PCPS	2
PTCA failure	CABG	IABP	IABP+PCPS	2
AMI with MR	CABG with MAP	IABP	IABP+PCPS	4
AMI with MS	CABG with MVR	IABP	IABP+PCPS	1
PMI	MIDCAB		PCPS	1
OMI with HF	CABG	IABP	IABP+PCPS	2
VHD				(4)
PVD	Re-MVR	PCPS	PCPS	2
PVE	Re-MVR	PCPS	PCPS	1
	Re-AVR	PCPS	PCPS	1
Thoracic aortic aneurysm				(1)
HF during type A dissection	Total arch replacement		PCPS	1
Others				(10)
Myocarditis	No surgical procedure		PCPS	5
			IABP+PCPS	2
Arrhythmia	No surgical procedure		PCPS	3
Total				35

IHD, ischemic heart disease; RVMI, right ventricular myocardial infarction; RHF, right heart failure; AMI, acute myocardial infarction; HF, heart failure; VSR, ventricular septal rupture; PTCA, percutaneous transluminal coronary angioplasty; MR, mitral valve regurgitation; MS, mitral valve stenosis; PMI, perioperative myocardial infarction; OMI, old myocardial infarction; VHD, valvular heart disease; PVD, prosthetic valve dysfunction; PVE, prosthetic valve endocarditis; CABG, coronary artery bypass grafting; MAP, mitral valve anuloplasty; MVR, mitral valve replacement; MIDCAB, minimal invasive coronary artery bypass; AVR, aortic valve replacement; IABP, intraaortic balloon pumping; PCPS, percutaneous cardiopulmonary support.

from cardiopulmonary bypass (CPB) because of profound postcardiotomy ventricular failure. PCPS was used preoperatively in 10 patients with profound cardiogenic shock after AMI, PVD, and deterioration of heart failure due to PVE. Furthermore, PCPS was employed in 10 patients without surgical procedure who fell into severe heart failure due to myocarditis and ventricular arrhythmia (VA) (Table 1).

All causes of PCPS are summarized in Table 2. In 25 patients with surgical procedures, PCPS was used after cardiotomy. These patients could not be weaned from CPB due to profound postcardiotomy ventricular failure. The mean CPB time was 195±60 min (range, 40 to 240 min). PCPS was used preoperatively in 10 patients for profound cardiogenic shock developing after AMI, PVD, and deterioration of heart failure due to PVE. The four of these 6 patients with AMI presented with severe right ventricular failure due to right ventricular myocardial infarction (RVMI). In 10 patients without surgical procedures, PCPS was also used for profound cardiogenic shock developing after myocarditis and arrhyhmia.

A membrane oxygenator (Model Cameda MAXIMA® CB 1380, Medtronic, Inc., Eden Prairie, MN, U.S.A.) and a centrifugal pump (Model BP-80, Medtronic, Inc., Eden Prairie, MN, U.S.A.) were utilized (Fig. 1). The membrane oxygenator was changed when PCPS was used for more than 4 to 6 days. When PCPS was used during postcardiotomy, heparin was at first neutralized completely by protamine sulfate. Then, heparin administration was started when there was no bleeding from the chest drainage tubes. The activated coagulation time was maintained at 200 sec with a low dose of heparin, and it was increased when the bypass flow decreased to 2.0 L/min. During PCPS, hemodynamics was evaluated by a Swan-Ganz catheter. These 35 patients were divided into the surgical group (Group I) and non-surgical group (Group II), and the causes of death and complications were analysed.

Table 2. Causes of percutaneous cardiopulmonary support (PCPS)

Causes	Diagnosis	Number of patients
Postoperative cardiogenic shock not weaned from CPB		
CPB time: 40-240 min (mean, 195±60 min)	IHD	20
	VHD	4
	Thoracic aneurysm	1
Total		25
Preoperative cardiogenic shock	AMI (RVMI)	6 (4)
	PVD	2
	PVE	2
Total		10
Cardiogenic shock (others)	Myocarditis	7
	Arrhythmia	3
Total		10

CPB, cardiopulmonary bypass; IHD, ischemic heart disease; VHD, valvular heart disease; AMI, acute myocardial infarction; RVMI, right ventricular myocardial infarction; PVD, prosthetic valve dysfunction; PVE, prosthetic valve endocarditis.

Results

Out of the 25 surgical patients (Group I), 19 (76%) were weaned from PCPS. The mean duration of PCPS was 82.5±55.4 hours (range, 42 to 144 hours). IABP was used in 19 patients (76%). The complications that developed during PCPS were acute renal failure (ARF) in 5 (20%), massive bleeding in 4 (16%), cerebrovascular accident (CVA) in 2 (8%), limbs ischemia in 2 (8%), and infection in 2 (8%). The mean blood transfusion volume was 1,689.6±3,795.5 mL (range, 250 to 19,600 mL). In the 4 patients with massive bleeding, the CPB time exceeded 3 to 4 hours, and 2 of the 4 patients were put into deep hypothermia. These 2 patients had massive blood transfusion for hemostasis, but bleeding did not subside because of coagulopathy. The 5 patients with ARF underwent renal support (continuous venovenous hemofiltration: CVVH). In Group I, the survival rate was 76%, and the mortality rate was 24%. The causes of death were MOF in 2 (8%), myonephropathic metabolic syndrome (MNMS) in 2 (8%), CVA in 1 (4%), and sepsis due to methicillin-resistant staphylococcus aureus

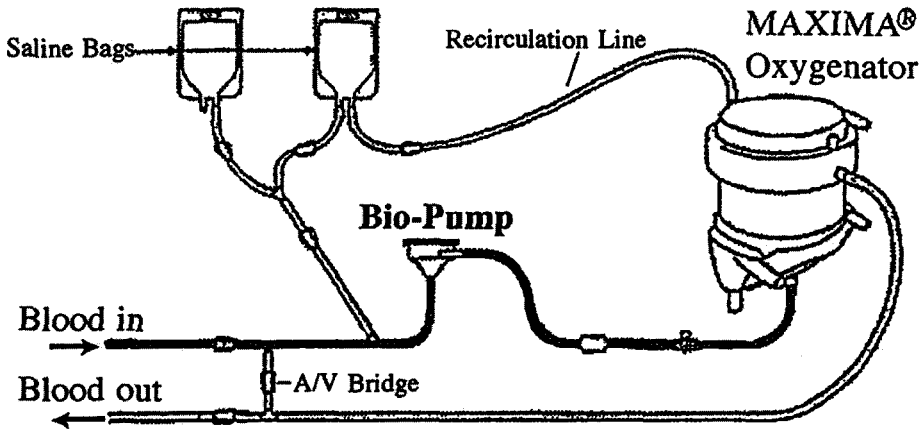

Fig. 1. Schematic diagram of the percutaneous cardiopulmonary support (PCPS) and instrumentation used in this series. A/V, arterial/venous.

Table 3. Results of the patients with PCPS in Group I

No. of patients	PCPS time (hrs)	Weaning (%)	IABP support (%)	Renal support (%)	BTF (mL)	Complications: Bleeding (%)	Complications: ARF (%)	Complications: CVA (%)	Complications: Limb ischemia (%)	Complications: Infection (%)	Results (%)	Causes of death (%)
25	42-144	19 (76)	19 (76)	CVVH 5 (20)	250-19,600	4 (16)	5 (20)	2 (8)	2 (8)	2* (8)	Survival 19 (76)	MOF 2 (8)
	(82.5±55.4)				(1,689.6±3,795.5)						Death 6 (24)	MNMS 2 (8)
												CVA 1 (4)
												Sepsis 1 (4)

No., number; PCPS, percutaneous cardiopulmonary support; hrs, hours; IABP, intraaortic balloon pumping; BTF, blood transfusion; ARF, acute renal failure; CVA, cerebrovascular accident; CVVH, continuous venovenous hemofiltration; MOF, multiple organ failure; MNMS, myonephropathic metabolic syndrome.
*: mediastinitis=1, **: pneumonia=1.

Table 4. Results of the patients with PCPS in Group II

No. of patients	PCPS time (hrs)	Weaning (%)	IABP support (%)	Renal support (%)	BTF (mL)	Complications: ARF (%)	Complications: CVA (%)	Complications: Limb ischemia (%)	Complications: Infection (%)	Results (%)	Causes of death (%)
10	14-120	10 (100)	2 (20)	CVVH 1 (10)	200-1,000	1 (10)	1 (10)	–	1 (10)	Survival 9 (90)	CVA
	(80.0±39.4)				(320±342.5)					Death 1 (10)	1 (10)

No., number; PCPS, percutaneous cardiopulmonary support; hrs, hours; IABP, intraaortic balloon pumping; BTF, blood transfusion; ARF, acute renal failure; CVA, cerebrovascular accident; CVVH, continuous venovenous hemofiltration.

(MRSA) in 1 (4%) (Table 3).

All of the 10 non-surgical patients (Group II) were weaned from PCPS. The mean duration of PCPS was 80.0±39.4 hours (range, 14 to 120 hours). An IABP was used in 2 patients (20%). The complications that developed during PCPS were ARF, CVA, and infection in 1 patient (10%), respectively. There were no complications such as massive bleeding for part of PCPS canullation and MNMS due to limb ischemia. The amount of blood transfusion was 320±342.5 mL (range, 200 to 1,000 mL). One patient with ARF underwent renal support with CVVH. The survival rate was 90%, and mortality rate was 10%. One patient died of CVA (Table 4).

Discussion

PCPS using a centrifugal pump and a membrane oxygenator has been widely applied because of convenience and quick insertion.[6,7] On the other hand, a ventricular assist system (VAS) insertion takes from one to several hours.[8,9] Management or maintenance of PCPS is easy, and it can be used not only in the operation room but also in the intensive care unit for patients in a state of severe cardiogenic shock. However, for patients requiring mechanical circulatory support, the rates of morbidity and mortality are high.[10-12] The indications for PCPS in our institute are as follows: unresponsiveness to IABP with a support of maximal inotropic drug, failure of weaning from CPB even under IABP after cardiotomy, right ventricular heart failure due to right ventricular myocardial infarction (RVMI), fatal VA which is refractory to the antiarrhythmic agent, and other miscellaneous reasons. In Group I, the main causes of ventricular failure were extensive AMI and low cardiac output syndrome (LOS) after cardiotomy. In these patients, emergency cardiopulmonary support was often necessary for prevention of the acute deterioration in the hemodynamic state. An IABP was used in 19 patients (76%), but it could not provide a stable hemodynamic state. The effect of IABP was mainly pressure support, and so flow support by PCPS was necessary for recovering from severe cardiogenic shock. In Group I, the general condition whilst the patient was in shock was very poor. Furthermore, invasive stress was added by other surgical procedures. Therefore, the duration of PCPS was prolonged and the complications increased after cardiac operations. The coagulopathy arose,

and a massive blood transfusion was necessary due to the bleeding from chest tube drainage. In Group II, the main cause of ventricular failure in myocarditis was unresponsiveness to IABP, and another cause was hemodynamic deterioration due to VA. In these patients, surgical stress was less than the patients in Group I, and so the duration of PCPS was short and fatal complications reduced during PCPS.

Weaning from PCPS is a very difficult problem. The duration of PCPS ranged from 42 to 144 hours (mean, 82.5±55.4 hours) in Group I, and from 14 to 120 hours (mean, 80.0±39.4 hours) in Group II. In 6 patients of Group I, PCPS was used for more than 6 days. These patients could not be weaned from PCPS, and in one of these 6 patients, the circulatory assist was changed from PCPS to left ventricular assist system (LVAS). The other 5 patients died from severe complications (MOF, MNMS, CVA, and sepsis). In one patient of Group II, PCPS was used for 5 days. All of patients in Group II were able to be weaned from PCPS.

In our series, 76% of the patients in Group I, and 100% of the patients in Group II were able to be weaned from PCPS, and the survival rate was 76% and 90%, respectively. The survival rates in recent reports were 24-88%.[13,14] The results of PCPS depend on myocardial recovery, which is affected by the duration of ischemia. We had such good results because of the complete coronary revascularization and the rapid institution of PCPS in both groups.

Postoperative complications in our series were bleeding (16%), CVA (8%), MNMS (8%), ARF (20%), and infection (8%). The complications frequently reported were bleeding, ARF, neurological disorders, and sepsis.[15-17] Causes of postoperative deaths in our series were MOF (8%), MNMS (8%), CVA (4%), and sepsis (4%). To improve the results under PCPS, the prevention of bleeding and avoidance of non-cardiac complications are important.

Bleeding during mechanical support is the most frequent complication. Therefore, complete hemostasis and neutralization of heparin after surgery are mandatory. We have recently used heparin coated cardiopulmonary equipment. Heparin coated cardiopulmonary equipment improved thromboresistance and platelet preservation.[15,16]

MOF is another severe fatal complication. In Group I, 5 patients were subjected to CVVH. Patients with improved heart failure could be weaned from CVVH. Two patients died of MOF with heart failure. The cause of MOF was prolonged low cardiac output following cardiac surgery.[18-20] On the other hand, in Group II, only one patient was subjected to CVVH. There was no surgically invasive stress in Group II. Therefore, the rate of MOF was lower than that of Group I.

Ischemia of the lower limbs due to femoral arterial cannulation (FAC) was a serious complication during PCPS or IABP.[16,21] In our series, 2 patients with MNMS died. Therefore, in recent years, an FAC has been inserted via a prosthetic vascular graft to prevent ischemia of the lower limbs, and MNMS has not been experienced.

References

1. Phillips SJ, Ballentine B, Slonine D, et al. Percutaneous initiation of cardiopulmonary bypass. *Ann Thorac Surg* 1983; **36**: 223–5.
2. Ree MR, Browen T, Sivananthan UM, et al. Cardiac resuscitation with percutaneous cardiopulmonary support. *Lancet* 1992; **34**: 513–4.
3. Phillips SJ, Zeff RH, Kongtahworn C, et al. Percutaneous cardiopulmonary bypass: application and indication for use. *Ann Thorac Surg* 1989; **47**: 121–3.
4. Mooney MR, Arom KV, Joyce LD, et al. Emergency cardiopulmonary bypass support in patients with cardiac arrest. *Thorac Cardiovasc Surg* 1991; **101**: 450–4.
5. Hill JG, Bruhn PS, Cohen SE, et al. Emergency application of cardiopulmonary support: a multi-institutional experience. *Ann Thorac Surg* 1992; **54**: 699–704.
6. Banosy A, Posival H, Minami K, et al. Seven years of experience with the centrifugal pump in patients with cardiogenic shock. *Thorac Cardiovasc Surg* 1995; **43**: 347–51.
7. Paolini G, Triggiani M, Credico G, et al. Assist circulation in postcardiotomy heart failure: experience with the BioMedicus centrifugal pump in ten patients. *Cardiovasc Surg* 1994; **2**: 630–3.
8. Pae WE, Miller CA, Matthews Y, et al. Ventricular assist device for postcardiotomy cardiogenic shock. *J Thorac Cardiovasc Surg* 1992; **104**: 541–53.
9. Noon GP, Ball JW. Postcardiotomy mechanical ventricular support: decreasing morbidity and mortality. *Ann Thorac Surg* 1996; **1**: 15–20.
10. Nakata K, Shiono M, Orime Y, et al. The influence of percutaneous cardiopulmonary support for the circulation of major organs. *Ann Thorac Cardiovasc Surg* 1997; **3**: 113–20.
11. Reichman RT, Joyo CI, Dembitsky WP, et al. Improved patient survival after cardiac arrest using a cardiopulmonary support system. *Ann Thorac Surg* 1990; **49**: 101–5.
12. Matsuwaka R, Sakakibara T, Shintani H, et al. Emergency cardiopulmonary bypass support in patients with severe cardiogenic shock after acute myocardial infarction. *Heart Vessels* 1996; **11**: 27–9.

13. Mitsui N, Koyama T, Marui A, et al. Experience with emergency cardiac surgery following institution of percutaneous cardiopulmonary support. *Artif Organs* 1999; **23**: 496–9.
14. Korfer R, el-Banayosy A, Posibal H, et al. Mechanical circulatory support: the Bad Oeynhausen experience. *Ann Thorac Surg* 1995; **59** (Suppl 2): S56–62.
15. Segesser LK. Heparin-bonded surface in extracorporeal membrane oxygenation for cardiac support. *Ann Thorac Surg* 1996; **61**: 330–5.
16. Muehrcke DD, McCarthy PM, Stewart RW, et al. Complication of extracorporeal life support system using heparin-bounded surfaces. The risk of intracardiac clot formation. *J Thorac Cardiovasc Surg* 1995; **110**: 842–51.
17. Orime Y, Hasegawa T, Kitamura S, et al. Clinical application of left ventricular assist device: retrospective evaluation of multiple organ failure. *Artif Organs* 1990; **14** (Suppl 1): 115–8.
18. Yagura A, Takano H, Taenaka Y, et al. Profiles of renal function during management of left ventricular assist device recipients. *Artif Organs* 1990; **14** (Suppl 1): 131–4.
19. Vasku J, Dolezel J, Vasku M, et al. Liver damage in total artificial heart bearers, and its prevention. *Artif Organs* 1990; **14** (Suppl 1): 73–8.
20. Furuhara K, Ohteki H, Sakai M, et al. Usefulness of percutaneous cardiopulmonary bypass support in patients with difficulties in weaning from cardiopulmonary bypass. *Kyobu Geka* 1998; **51**: 981–8. (in Japanese)
21. Hata M, Shiono M, Orime Y, et al. Strategy of circulatory support with percutaneous cardiopulmonary support. *Artif Organs* 2000; **24**: 636–9.