Recent Advances in Assisted Circulation Using Centrifugal Pump in Surgical and Non-Surgical Patients with Acute Heart Failure or Related Conditions

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During the last 3 years, left or bi-ventricular support using a centrifugal pump as a ventricular assistance device was performed in 10 patients after open heart surgery. The basic lesions were coronary heart disease in 8 and valvular disease in 2 patients. Bypass support ranged in time from 33 to 240 h (average 114 h), and 3 patients received biventricular support. Six patients have survived in this group. Other supportive methods, in the form of emergency or elective use of portable cardiopulmonary bypass support, were used in 8 patients; 4 with cardiogenic shock and 4 for supported percutaneous coronary angioplasty. These assisted circulations appear to be useful and promising in the management of the critical cardiac patient. (Jpn Circ J 1992; 56: 111–116)

The role of mechanical circulatory support has become very important in acute as well as chronic heart failure in recent treatment of patients with advanced cardiac lesions.1,2 Assisted circulation using ventricular assist devices (VAD) started as a supportive method for acute heart failure mainly for patients after they had undergone open heart surgery, and this is still a major target for mechanical assisted circulation in cardiac surgery.2,3 The centrifugal pump (CFP) has been utilized as a VAD for short-term use in patients with postcardiotomy shock. This device has advantages such as simple handling and low cost, although it has limitations in durability and antithrombogenicity, precluding long-term use. In addition, short-term use of a portable cardiopulmonary bypass support with CFP and a membrane oxygenator is used for emergency cardiopulmonary resuscitation or electively in critical patients who have been subjected to interventional cardiac catheterization.4 In Japan, the latter modality has, so far, not been well accepted. In this report, we have analyzed the recent advances and results using mechanical circulatory assistance for acute heart failure or its elective use for supported coronary angioplasty.

PATIENTS AND METHODS

In our mechanical circulatory assistance program in collaboration with the affiliated hospitals, 2 support systems have been employed; one is a circulatory support using VAD for perioperative patients receiving open heart surgery, and the other is a temporary circulatory support using a portable cardiopulmonary bypass support (PCPS) for acute cardiogenic shock or elective coronary bypass.
angioplasty. During the last 3 years, a total of 18 adult patients were treated with these support systems. Ten patients received left or biventricular support using VAD after open heart surgery. In the remaining patients, PCPS support was performed for cardiopulmonary resuscitation following acute circulatory failure in 4 and for elective supported percutaneous coronary angioplasty (PTCA) in 4 patients.

1) Left or Bi-ventricular Bypass Support after Open Heart Surgery  
   a) Device and Method

   All patients were supported by centrifugal pumps (CFP: Bio-medicus, BP-80 and Sarns 5700). CFP was exchanged electively every 2 to 3 days. Left and bi-ventricular bypasses (LVB/BVB) were performed through the same median sternotomy. For LVB, drainage was performed from the left atrium with cannulation, and arterial return was performed through a conduit anastomosed to the ascending aorta. Right ventricular bypass (RVB) was performed between the right atrium and the pulmonary artery. An intra-aortic balloon pump (IABP) was combined in 8 patients. Activated clotting time was controlled between 150—200 seconds with continuous infusion of heparin.

   b) Patients (Table I)

   A total of 10 patients received this type of support, the age ranged from 15 to 67 years and all except one were over 44 years old. Two patients required VAD support because of profound low cardiac output and shock with arrhythmia at an early postoperative stage following open heart surgery. The others went into cardiopulmonary bypass (CPB) dependent state from severe pump failure during surgery and the circulatory support was switched to VAD from regular

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TABLE III CLINICAL PROFILES OF THE PATIENTS FOR SUPPORTED PTCA

<table>
<thead>
<tr>
<th>Patients: 4, age: 55-77 years (average 68)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnosis:</td>
</tr>
<tr>
<td>Impending MI with poor LV function</td>
</tr>
<tr>
<td>Unstable angina with poor LV function</td>
</tr>
<tr>
<td>Unstable angina and high age (77 yrs)</td>
</tr>
<tr>
<td>Effort angina (gastric sarcoma)</td>
</tr>
<tr>
<td>LMT lesion: 4 patients</td>
</tr>
<tr>
<td>LVEF: 20–63% (average 37%, &lt;40%: 3)</td>
</tr>
<tr>
<td>IABP: 2 patients</td>
</tr>
</tbody>
</table>

MI: myocardial infarction, LV: left ventricle, LMT: left main trunk lesion, EF: ejection fraction, IABP: intraaortic balloon pumping

CPB system. The surgical procedures employed in these 10 patients are listed in Table I. Coronary bypass grafting (CABG) was the main procedure in 7 and complex valve replacement in 2 patients. All except 1 with septal perforation were elective surgeries. The heart failure necessitating VAD support appeared to be related to prolonged aortic cross-clamp or inadequate myocardial protection in most of the patients. Maximum inotropic support and IABP were ineffective.

2) Portable CPB Support (PCPS)

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a) Method

We used our own system using Sarns membrane oxygenator and Sarns centrifugal pump in a closed system allowing femoral approach for venous drainage and arterial return to femoral artery (Fig. 1). This system was designed to incorporate a battery and heat exchanger and to be compact, allowing easy handling and transport. The patients were heparinized (3 mg/dl) and the femoral artery and venous cannulations were performed either surgically or percutaneously. The size of the cannulas were 18 or 21 french for arterial and 22 or 24 for venous drainage.

b) Patients

i) Emergency support for shock (Table II)

Four patients received this support for resuscitation or emergency support for profound shock. The causes of shock are listed in Table II. Ages ranged from 39 to 74 years, and all patients received cardiac massage before starting PCPS support.

ii) Supported angioplasty (Table III)

In our program 4 patients were assigned to undergo supported PTCA in 2 cardiac centers. Two patients had unstable angina, 1 with impending myocardial infarction, and 1 with stable angina and malignant disease of
TABLE IV SUMMARY OF THE RESULTS IN 10 PATIENTS WITH LEFT OR BIVENTRICULAR SUPPORT

<table>
<thead>
<tr>
<th>Indication/Procedure</th>
<th>Patients</th>
<th>Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postoperative shock</td>
<td>2</td>
<td>2 (100%)</td>
</tr>
<tr>
<td>CPB-dependent</td>
<td>8</td>
<td>4 (50%)</td>
</tr>
<tr>
<td>CABG</td>
<td>4</td>
<td>3 (75%)</td>
</tr>
<tr>
<td>CABG + others</td>
<td>3</td>
<td>1 (33%)</td>
</tr>
<tr>
<td>VSP</td>
<td>1</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Valve replacement</td>
<td>2</td>
<td>2 (100%)</td>
</tr>
</tbody>
</table>

the stomach who refused surgical intervention. All had left main trunk disease and 3 patients had poor left ventricular function with left ventricular ejection fraction of 29 to 38%. Two patients had been on IABP. One patient had also received support using a perfusion catheter during dilatation of the left main coronary trunk.

RESULTS

1) Left or Biventricular Bypass Support

The bypass support period ranged from 33 to 240 h with an average of 114 h. Two patients who required LVB during the early postoperative period were weaned from LVB, and both patients have survived. Out of the other 8 patients who required LVB for profound left heart failure resulting in "CPB-dependence", 6 patients were weaned from bypass and 4 have survived. In these 8 patients, 3 had BVB for 42 to 120 h and 2 have survived. The causes of death were multorgan failure from persisting heart failure unresponsive to the assisted circulation in 2, and infection in 2 (Table I). The salvage rate was 60% over all and 50% in those with CPB-dependence. Those who had valve replacement or CABG alone showed satisfactory results (Table IV). Regarding complications during LVB or BVB support, cerebral infarction occurred in 2, bleeding in 2, and renal failure in 4 patients. Two patients with cerebral infarction were discharged with minimum symptoms.

2) Emergency CPB Support

In 4 patients, PCPS support was given for 110 to 250 min. One patient had been on IABP from the onset of preceding shock. PCPS flow was maintained at 2.0 to 2.9 L/min/m² with an average flow in each patient of around 2.0 L/min/m². Surgery was performed following PCPB support in all patients (Table II) who tolerated surgery and were weaned from CPB after switched from PCPS in the operating room. Early death occurred in 1 patient, 2 patients died during the late postoperative period, and there was 1 long-term survivor.

3) Supported PTCA

All patients had successful PTCA with PCPS support (Table V). The PCPS duration was 60 to 160 min, and CPB flow ranged from 0.8 to 2.3 L/min/m². Aortic pressure was maintained at a mean of 60 to 90 mmHg. The maximum inflation time of the balloon was 60 to 140 min. The extent of the stenotic lesions was reduced in degree from 90% to 25% or 50% overall. Two patients were discharged with improved symptoms. One patient with poor ventricular function showed some improvement in symptoms, but died from arrhythmia about 1 month later. The last patient required subsequent CABG, and died from heart failure unresponsive to surgery.

DISCUSSION

In this report, two systems of assisted circulation utilizing CFP were described: 1) left or biventricular support in acute cardiogenic shock or heart failure in patients underwent open heart surgery using CFP as VAD, and 2) cardiopulmonary support for venaarterial bypass with CFP and membrane oxygenator for emergency cardiopulmonary support in patients with shock or for elective use in supported coronary angioplasty. The former
has been widely used abroad, but has only recently been adopted in our country as a practical method. The latter method is relatively new method of circulatory support for emergency use as well as for angioplasty support.

1) Left and Biventricular Support

In open heart surgery, it has been reported that circulatory support using VAD is required in 0.1–1.3% of patients who undergo open heart surgery. In this subset of heart failure resulting in CPB dependence, the causes of heart failure are complex, with a combination of inadequate myocardial protection, pre-existing poor ventricular function, and perioperative myocardial infarction. A severe low cardiac output state after surgery is also an indication for VAD support. In these situations the depressed ventricular function is often reversible when the heart is supported for some period of time.

As a device for ventricular assistance (VAD), the pneumatic or electrically driven pulsatile pump has become available and provided satisfactory results elsewhere. CFP is also widely utilized as a VAD because of its advantage of easy availability and management although it was originally developed for short-term use as a pump for CPB in open heart surgery. We have used the pneumatic device in a limited number of patients during a cooperative clinical study. In this series, this pneumatic device was not available, so we utilized a CFP. Therefore, selection of the pump for VAD has become a practical necessity for the immediate future.

In this report, the over-all salvage rate was 60%, which seemed satisfactory in this critical condition compared with the previous reports of average salvage rates ranging from 23 to 37%. The interval between the onset of heart failure and start of LVB was as little as under 4 h in the surviving patients compared with the others who were in irreversible heart failure or multiorgan failure. As a complication, thromboembolism appeared to be the most serious problem, particularly in CFP. Two patients developed cerebral infarction during the weaning process when bypass flow was reduced. However, both patients recovered well and were discharged with minimum symptoms. Other complications were multiorgan failure and infection; these are potentially lethal problems in assisted circulation. Early-instituted LVB is crucial, as is the importance of combining right ventricular support when right failure persists.

2) Emergency Use of Portable Cardiopulmonary Support

This circulatory support system is a modification of conventional venoarterial bypass which is an extension of CPB used in the operating room. This system is also applicable using the percutaneous approach if the body size and cannulation are suitable. In this series, there were 4 patients who required emergency support mainly due to cardiogenic shock in the catheterization room. This experience proved its usefulness in a patient with cardiac-free wall rupture after acute myocardial infarction that had been almost lethal when we didn’t have a chance to bring the patients to the operating room in a stable condition. Although our limited experience showed a poor ultimate result, this method of emergency support appears to be very useful in the management of the critical patient in the cardiac catheterization room and in the intensive coronary care unit.

3) Cardiopulmonary Support for PTCA

Recently, supported angioplasty is of interest to cardiologists who are engaged in percutaneous coronary angioplasty, and its successful results have been reported, although the number is limited. This supported PTCA is indicated for critical patients who are unstable in hemodynamics or unsuitable for surgical intervention. Indication of this method for left main trunk lesion appears to be controversial because of the risk of restenosis and of surgical indication. In this series our cardiologists performed successful angioplasty in patients with left main trunk lesions as an initial trial.

SUMMARY

In this clinical experience, surgical patients with acute heart failure unresponsive to conventional therapies appeared to have a good chance of being treated using an assisted ventricular device. A portable CPB support system was applied in critical patients in the emergency situation or in elective PTCA, and was shown to be useful in cardiac
surgery and interventional cardiology.

REFERENCES


