Balloon Counterpulsation Together with Bio-Medicus Pump Closed Circuit Membrane Oxygenation for Left Ventricular Assist: A Case Report

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Abstract

A 23-year old male was admitted at 1,093 days post cardiac transplantation in cardiac failure. Despite inotropic support and later intra-aortic balloon pumping there was a slow continued fall in cardiac output, renal function and a worsening metabolic state. The patient was then placed on extracorporeal membrane oxygenation (ECMO), consisting of a Bio-Medicus pump and Kolobow membrane oxygenator in a closed circuit configuration (without reservoir). Vascular access was by femoral artery and vein using a non-obstructive technique. Anticoagulation management consisted of a heparin infusion of 2,000 Iu/hour into a peripheral line to an ACT of 170 seconds and a prostacyclin infusion of 3ng/Kg/min. into the venous line.

Induction of ECMO was followed by a rapid hemodynamic and metabolic improvement allowing the patient to sit up, talk and eat normally. One hundred and one hours later a new donor organ was located and transplanted.

This system has much to recommend it. The equipment forms a compact module. The device functions safely with minimal perfusionist supervision. The system produces excellent hemodynamic function and offers effective short and medium term support for a range of cardiac and pulmonary disorders.

Introduction

Extracorporeal membrane oxygenation (ECMO) has been used for the treatment of acute respiratory distress syndrome (ARDS), massive pulmonary thromboembolism and ventricular failure. The extracorporeal approach assumes that dysfunction is a reversible short lived state in ARDS, and that in chronic ventricular failure ECMO support can be an effective interim measure until cardiac transplantation can be carried out. This case report examines primarily one of severe cardiac failure in the transplanted heart and the support system used. It also looks briefly at the whole Papworth support perfusion experience.

Pre-1983 Experience

By 1979 there had been many cases reported of the use of ECMO in ARDS, cardiac failure leading to transplantation, as well as its effective use as a ventricular assist device for post-cardiac surgery patients in cardiogenic shock.1,2,3,4,5,6

In 1979 a 15-year old male was admitted to Papworth Hospital with ARDS, right ventricular and renal failure, following a partial drowning accident and 17 days of ineffective intermittent positive pressure ventilation (IPPV). The patient was placed on veno-veno support...
perfusion using a basic membrane lung circuit (2.5 m² Kolobow with 500 ml reservoir). A hollow fiber dialyser was added to the circuit via a shunt line (Figure 1). There followed an improvement in the patient’s biochemical, hemodynamic, and central nervous state. The system was run at a flow of 1.0-1.6 L/min. Dialysis produced a fall in serum potassium from 7.0 to 5.5 mmol/l. A modest hypothermia level of 35°C was maintained. However, after 38.5 hours of perfusion, it became clear that the patient’s cardiopulmonary system had been irreversibly damaged in the first 17 days of care and ECMO support was therefore discontinued.

The second case was a soldier who had inhaled toxic gas during a military exercise. He was admitted to Papworth Hospital ICU with ARDS, where after a short period of ineffective IPPV he was placed on ECMO support perfusion. After 18 hours his lung function had recovered sufficiently to allow conventional ventilatory management. Adequate arterial pO₂ was produced on 60 percent inspired oxygen. This patient was eventually discharged from hospital.

The support system used on these two patients, although it functioned adequately, required round-the-clock perfusionist control, producing many logistical problems in a busy cardiothoracic unit. It proved to be a heavy load on the perfusion resources at Papworth and consequently could not be adopted for routine use in the treatment of ARDS or cardiac failure.

Case Report

A 25-year old 70 kilogram male was admitted 1,093 days post-cardiac transplantation in severe cardiac failure. His postoperative course during the first six to nine months following his transplant on June 4, 1980, had been characterized by recurrent rejection episodes which were difficult to control. He had bilateral pneumothoraces and an aspergillus infection of the right lung which were successfully treated. One month following organ grafting he had a series of grand-mal convulsions which were also subsequently controlled. He experienced episodes of epilepsy for the next three years. At eight months post-transplant he was fitted with a programmable pacemaker for sinus node dysfunction. Thereafter he recovered satisfactorily and had a good quality of life, returning to full employment.

Selective coronary angiograms at two years showed the presence of moderately extensive coronary arterial disease. There were 70 percent marginal, 50 percent left anterior descending and 20 percent right coronary artery stenoses. However he remained well until the middle of May 1983 when he was admitted to Papworth with a short history of fluid retention. This responded to diuretic therapy. As the possibility of left ventricular dysfunction form coronary artery atherosclerosis was considered, a nuclear left ventricular gated study was carried out which showed reduced left ventricular function. Cardiac biopsy showed no evidence of acute rejection so he was discharged to be re-admitted two weeks later for his three-year follow up study.

Eleven days later, on May 31, 1983, he was re-admitted to Papworth as an emergency with a four-day history of vomiting and being generally unwell. On examination he had generalized edema, a tachycardia, and a blood pressure of only 80/50 mm.Hg., with a central venous pressure (CVP) of 12 mm. Hg. He was confused, hypoxemic and oliguric with a severe metabolic acidosis.

Very soon after admission inotropic support was started, but despite increasing doses there was no improvement. Intra-aortic balloon pump (IABP) counterpulsation was started on the next day, after a percutaneous balloon had been inserted through the right femoral artery. This also failed to improve his circulation satisfactorily. He remained with a low cardiac index.

A radionuclide (Technetium 99 m bound to human serum albumin) is injected into the patient’s blood stream. A collimated N° I scintillation gamma camera takes counts, for up to 5 minutes, in 20 millisecond counts up to 600 times, triggered by the R wave of the EKG. By use of a computer, these ‘gated’ counts are built up to form a picture. Commonly 22 pictures are built up to observe different stages of the cardiac cycle. Regional wall motions can be accurately examined, as well as ejection and regional ejection fractions and blood transit times.

This technique can provide data safely which is very difficult or impossible to obtain by other diagnostic means, such as angiography.11

*Note: The Nuclear Gated Study: Radionuclide Ventriculography.
output, a blood pressure of 70/45 mmHg., a CVP of 28 mmHg., and a persistent acidosis with a base deficit of -15 mEq/L. His PaO₂ was only 80 mmHg. on an FiO₂ of .50. Swan-Ganz thermal dilution determinations showed a cardiac output of under 2.0 liters/minute. At this stage he was anuric and semicomatose. It was therefore decided that supportive perfusion should be instituted while urgent efforts were made to locate a new heart.

Methods and Materials

A closed ECMO (without reservoir) system was set up, comprising a 2.5 m² Kolobow SciMed® membrane lung with integral heat exchanger, a Bio-Medicus® model 600 centrifugal blood pump with its control electromagnetic flow meter, and a 1/8 inch polyvinyl chloride tubing sash (Figure 2).

![Figure 2: Papworth Support Perfusion Circuit.](image)

The circuit was primed with 400 ml of 5 percent albumin (to coat internal surfaces), followed by 500 ml Hartmann’s solution and 3,000 Iu of heparin. A CO₂/vacuum method was used for priming.

The ECMO system together with a small water circulator (used to supply thermal control via the integral heat exchanger), was mounted on a small trolley so that the pump and oxygenator were close to ground level to aid gravity drainage.

The patient was moved to the operating room. A transverse cut down incision was made in the left groin down to the femoral artery and vein at the junction of the great sapheno-femoral vein (Figure 3). The patient was given a bolus of 12,000 Iu heparin. The arterial cannulation consisted of a 14 French Bard cannula passed through a purse string in a manner so as not to obstruct distal perfusion. A 24 French USCI wire reinforced cannula was then introduced via the femoral-saphenous junction for venous drainage. Both cannulae were then tunnelled out some 5 centimeters below the primary incision in order to reduce the risk of infection, the cannulae were then secured to the skin. Both cannulae were then connected to the support perfusion circuit. Hemostasis was achieved, the skin closed and the system was then run at a blood flow of 2.0 liters/minute as measured by the Bio-Medicus flow probe. The IABP was maintained as a counterpulsation device.

The patient was returned to the ICU where anticoagulation therapy was a combination of heparin at a rate of 2,000 Iu/hour into a peripheral line, plus an infusion of prostacyclin at 270 ng/min. into a membrane luer port. Activated clotting times (ACT) of about 200 seconds were aimed for. In order to achieve this, the levels of prostacyclin/heparin infusions had to be increased to 800 ng/min. and 4,000 Iu/hr. respectively, plus boluses of heparin at 8, 24, 40 and 50 hours. Moderate hypothermia of 35°C was maintained.

Results

Hemodynamically and biochemically the system proved to be a great success in that there was a dramatic improvement in the patient's hemodynamic status. The cardiac output increased significantly, as did the arterial blood pressure. The patient's oxygenation improved, as evidenced by an increase in the SaO₂ and a decrease in the PaCO₂. The patient's acid-base status improved, and the base deficit decreased to -9 mEq/L. The patient's urine output returned to normal, and the patient's mental status improved. The patient was weaned from cardiopulmonary bypass and successfully discharged from the hospital.

a Bio-Medicus, Minnetonka, MN 55343
b SciMed Life Systems Inc., Minneapolis, MN 55441
improvement in the patient's status within a very short time. Anticoagulation was less well managed, producing problems of increasing thrombocytopenia and a reduction in oxygenator efficiency due to the deposition of fibrin. However this was not a major problem and was managed by increasing heparin and prostacyclin infusions and by the transfusion of 2 units of platelets. There were no hemorrhagic problems that are often associated with ECMO support.  

The patient's PaO₂ was 210 torr on ECMO. He was then taken off 60 percent oxygen and was allowed to breathe room air (he had never been intubated). The O₂ flow delivered to the membrane lung had to be increased from 1.5 up to 7.0 liters/minute over the 5 days due to the fibrin information in the blood pathways (Figure 4).  

Systolic blood pressure rose from 70 mmHg. to 120 mmHg. with an average dynamic blood pressure of 100/60 mmHg. At the same time the CVP fell from 28 down to 3 mmHg. with an average mean CVP of 10 mmHg. Renal function was restored to a urine output of 300 ml/hour, stabilizing at 120 ml/hour for most of the five days. His cerebral function improved to a normal state, he was able to sit out of bed, eat and drink normally, talk lucidly, read and even play a game of chess (Table 1). At the same time inotropic support with adrenalin and dopamine was reduced and eventually discontinued.

Figure 4: Fibrin build-up in the blood pathways of the membrane lung after 101 hours use.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Effect of ECMO</th>
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<tbody>
<tr>
<td>Before ECMO</td>
<td>On ECMO</td>
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<tr>
<td>1. Cardiac Index</td>
<td>Less than 2.0 L/min.</td>
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<tr>
<td>2. Urine Output</td>
<td>0-8 ml/hr.</td>
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<tr>
<td>3. Blood Pressures</td>
<td>70/45 mmHg.</td>
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<tr>
<td>Arterial</td>
<td>28 mmHg.</td>
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<tr>
<td>CVP</td>
<td>−15 mE/L.</td>
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<tr>
<td>4. Acid Base</td>
<td>80 torr (on 60% O₂)</td>
</tr>
<tr>
<td>5. Arterial PaO₂</td>
<td>Semi Comatose</td>
</tr>
<tr>
<td>6. CNS</td>
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</table>
Retransplantation

During the first four days after the induction of ECMO support, the patient's condition remained relatively stable; however we were anxious not to prolong the support perfusion unduly, primarily due to the fear of massive infection in the immunosuppressed patient.

On the evening of June 5th, a compatible donor heart became available and the patient was retransplanted. After 101 hours of ECMO support, the patient was put on conventional cardiopulmonary bypass. However, when loaded, the new transplanted heart would not take over full circulatory support without the re-use of the ECMO support. This was effective and after nine hours support, cardiac function had improved to an extent where only inotropic support was needed for the rest of the recovery period.

Discussion

The experience gained with this patient demonstrated that this system could provide an effective circulatory support system. There are a number of important elements. A closed system provides important advantages with regard to safety and reduced thrombogenicity. In a closed system the patient acts as his own reservoir which together with the action of the Biomedicus pump, which is both preload and afterload sensitive, provides a useful degree of self regulation and reduces the operator control required to a minimum.

The cannulation technique is important since it is designed to minimize infection while maintaining peripheral blood flow to the lower limb. However, in the case of total cardiac failure, as was experienced in a later case, this cannulation site is inadequate to facilitate total support and an internal jugular/carotid cannulation would be superior.'

Previous reports have suggested that heparinization is unnecessary using the centrifugal pump. However, it must be noted that in the report quoted, the animal undergoing support for 14 days using this pump died from a large renal infarct caused by thrombus from the circuit. The ideal anticoagulation protocol would seem to consist of a single loading dose of heparin to the patient of 3 mg/Kg prior to cannulation, a prostacyclin infusion of 2.4 ng/Kg/min. into the venous line, and the use of heparin bonded tubing and cannula. This regimen was shown on a later case to result in the ACT stabilizing at around twice normal with very little additional heparin.

The rationale for the use of prostacyclin is threefold. First, this drug has a very short half life so that the effects are declining quite rapidly in the blood being returned to the patient. Secondly, the drug has been shown to exhibit protective effects on platelets so minimizing thrombocytopenia. And thirdly, the vasodilatory effects are more pronounced on the pulmonary vasculature so overcoming another common problem encountered during ECMO, that of thrombotic occlusion of the microvasculature. ECMO in this patient was lifesaving until a second heart could be obtained, and produced a dramatic improvement in the patient's condition.

This system offers an effective medium term method to support the circulation in patients who may be expected to recover from temporary organ dysfunction or until transplantation of terminally damaged organs can take place.

References