Case Report

Conversion of Percutaneous Cardiopulmonary Bypass to Total Cardiopulmonary Bypass to Repair an Acute Ventricular Septal Defect

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ABSTRACT

This case report describes techniques involved in the conversion of femoral-femoral percutaneous cardiopulmonary bypass to femoral/superior vena cava-femoral cardiopulmonary bypass with integrated cardiotomy suckers and cardioplegia delivery system. The conversion was instituted in order to repair an acute ventricular septal defect secondary to a myocardial infarction without switching to a traditional heart-lung machine set-up.

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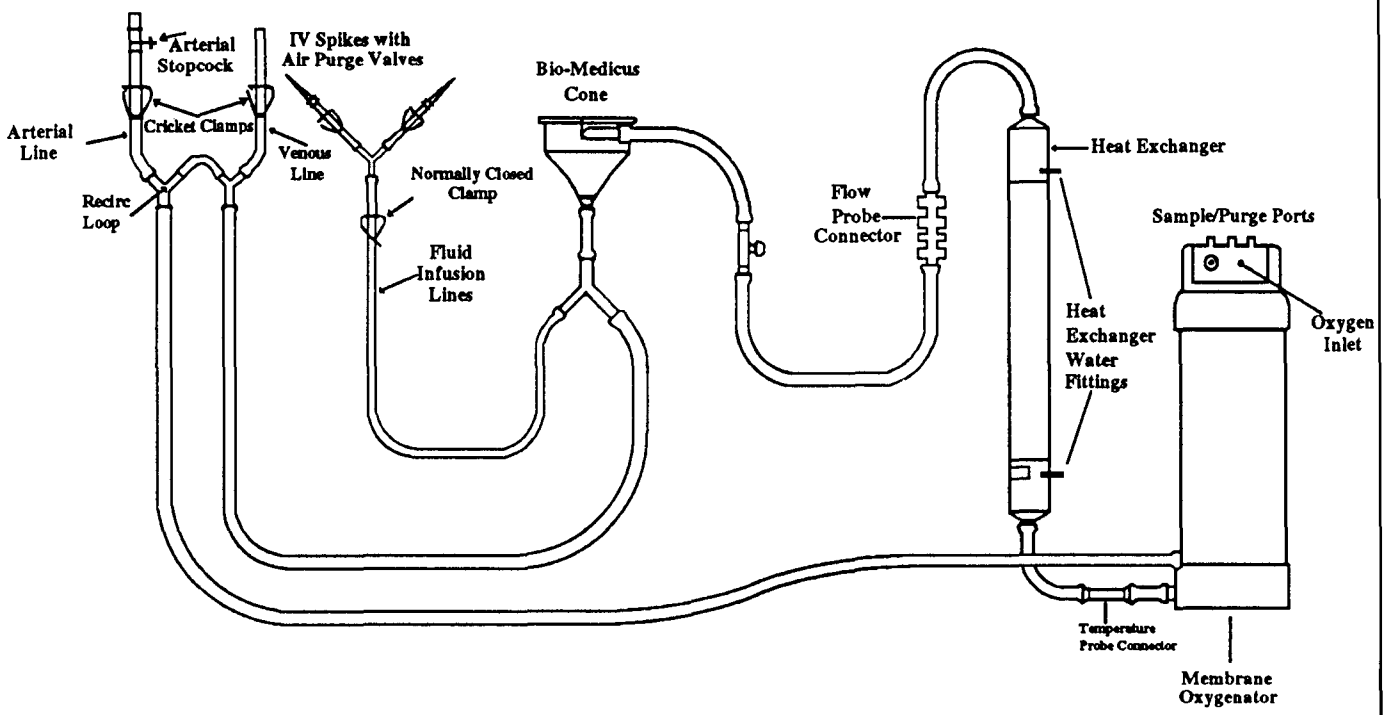
Figure 1
Standard CPS circuit.



INTRODUCTION

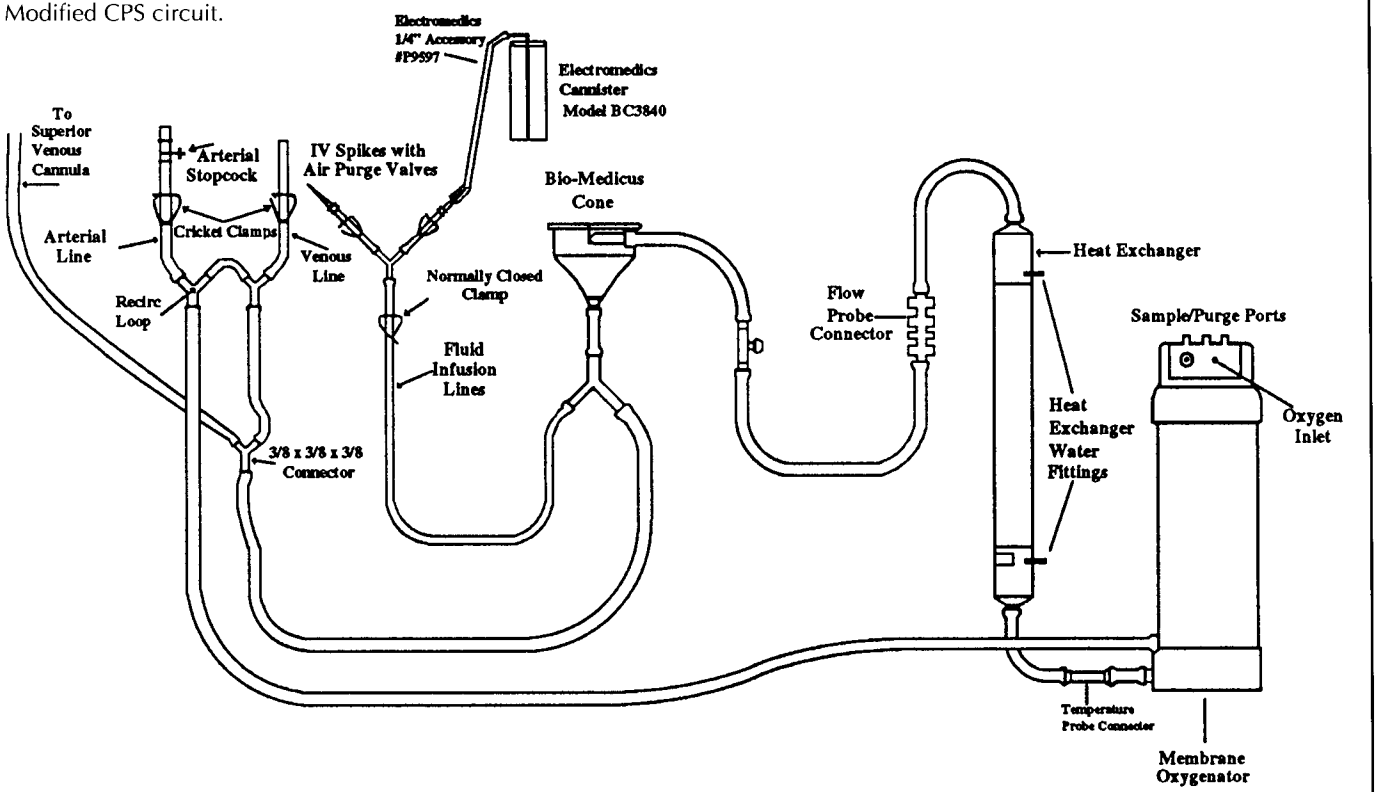
Percutaneous cardiopulmonary bypass (PCPB) was developed as a means to provide emergent and portable cardiopulmonary support (1). PCPB became practical when the design of thin-walled, non-collapsible femoral venous cannulae allowed the negative pressure development on the inlet or venous side of a centrifugal pump to unload the heart and achieve systemic flows as high as 6 L/min. Additionally, these new venous as well as arterial cannulae were designed to be inserted emergently using the Seldinger technique. PCPB has been used to support patients suffering from a variety of pathologies including refractory cardiac arrest, cardiogenic shock, accidental hypothermia, and pulmonary embolism (2-7).

PCPB has also been widely utilized as an elective support technique during high risk percutaneous transluminal coronary angioplasty (PTCA) (8-14). In recent years, this application has apparently become reserved for only the most hemodynamically unstable patients because of the high associated morbidity (15). Consequently, PCPB has been increasingly used to resuscitate patients in hemodynamic collapse refractory to advanced cardiac life support (ACLS) techniques.

Among those patients to whom PCPB has been applied, a percentage have required immediate transfer to the operating room for corrective surgery. Most of the published accounts documenting such transfers suggest that the patient was weaned from PCPB and then placed on cardiopulmonary bypass (CPB) using a standard bypass circuit (2,3,5,16,17). The common rationale behind such a changeover was that the highly negative central venous pressure (CVP) generated by the centrifugal pump, which allowed the use of a small femoral venous cannula, constituted a potential source of gaseous emboli should venous luminal integrity be compromised. This danger was particularly acute in procedures requiring the right side of the heart to be opened, such as the repair of a ventricular septal defect (VSD). The switch to standard CPB is not without potential disadvantages. These include increased hemodilution frequently requiring commensurate homologous blood transfusion, possible aortic cannulation, and increased cost to the patient. Gil et al (18) described a laboratory tested convertible and customized system which obviated the switch from PCPB to standard CPB. Our case report describes techniques that achieved the gaseous emboli free conversion of femoral-femoral PCPB to femoral/superior vena cava (SVC)-femoral CPB with integrated cardiotomy suckers and cardioplegia delivery system using a commercially available PCPB system[a] (Figure 1). The conversion allowed the safe repair of an acute VSD secondary to a myocardial infarction (MI) without exposing the patient to the disadvantages of switching to standard CPB.

a CPS, Bard Cardiopulmonary Division, Billerica, MA 01821

Figure 2
Modified CPS circuit.



CASE REPORT

A 56 year old female presented to the Riverside Methodist Hospital emergency department complaining of nocturnal angina and sharp back pain. Her history revealed insulin dependent diabetes mellitus and medically controlled hypertension. She was diagnosed as having congestive heart failure and unstable angina secondary to a MI less than 24 hours old. Shortly following the administration of tissue plasminogen activator (tPA), the patient's condition degenerated into cardiogenic shock. When the patient's condition was found to be refractory to ACLS techniques, the decision to place the patient on PCPB was made immediately before irreversible organ dysfunction ensued.

The patient's left groin area was anesthetized with a subcutaneous injection of 1% lidocaine. The patient was anticoagulated with the intravenous (IV) injection of 40,000 units of porcine-mucosal heparin resulting in an activated clotting time (ACT) of 1822 seconds. The left femoral artery and vein access was accomplished using a modified Seldinger technique with 17 Fr arterial and 17 Fr venous cannulae[b]. The cannulae were connected to the PCPB system which was retrieved, assembled, and primed in less than 5 minutes with 1600 ml Plasmalyte A[c]. Just as the patient went into ventricular fibrillation, PCPB was established at 6 L/min, 1:1 gas-to-blood flow ratio, and 37°C. Sodium bicarbonate was administered to correct metabolic acidosis.

The patient was immediately transported to the cardiac catheterization laboratory. Cineangiography revealed high grade lesions of both the left anterior descending (LAD) and right coronary arteries (RCA) and a VSD secondary to a posterior MI. Emergent coronary revascularization and VSD closure were deemed necessary, and the patient was transported to the operating room.

As the patient was being prepped and draped, the decision not to switch to standard CPB was made. Accordingly, while the heart was being exposed, the heat exchanger of the PCPB system was connected to a cooler/heater unit[d], and patient cooling was initiated. During cooling, two tandem high-flow roller pumps[e] on a mobile base were brought in to provide suction and crystalloid cardioplegia delivery. The sucker line was attached to a cardiotomy reservoir[f], which was connected to the PCPB circuit via one of the IV spikes with purge valves (Figure 2). Volumetric additions were made by opening the rapid infusion line whereupon the negative pressure on the venous side of the centrifugal pump aspirated fluid from the cardiotomy reservoir. Packed red blood cells and Plasmalyte A[c] were added while on bypass. A

b Medtronic Bio-Medicus, Minneapolis, MN 55344
c Baxter Healthcare Corp., Deerfield, IL 60015
d Cincinnati Sub-Zero, Cincinnati, OH 45241
e Travenol Corp., Morton Grove, IL 60053
f Electromedics Inc., Englewood, CO 80112

constant volume was kept in the cardiotomy reservoir to avoid the generation of air emboli when volumetric additions were made.

When the patient had been cooled to a bladder temperature of 27°C, circulatory arrest was instituted by clamping the arterial and venous lines. Another clamp was placed beside the one on the venous line. The tubing was cleansed with alcohol and subsequently cut using sterile scissors. A 3/8 inch polycarbonate Y connector was inserted. A second 3/8 inch venous line was passed off, connected to the Y connector, and then filled with sterile saline by the scrub nurse. At the same time, the surgeon pulled back the femoral vein cannula until it was palpably in the inferior vena cava (IVC). The IVC was then snared shut with a caval tape proximal to the cannula. The SVC was cannulated with a 32 Fr bullet tipped cannula[g] inserted through the right atrial appendage. The SVC was then snared shut around the cannula proximal to the tip. Care was taken to remove all air from the modified circuit during the cannulation. Total CPB was established after 3 minutes of circulatory arrest. No gaseous emboli were apparent despite the negative pressure generated by the centrifugal pump.

The aorta was subsequently cross-clamped, and 800 ml of crystalloid cardioplegia solution was delivered antegrade using a recirculating cardioplegia system with an integral heat exchange coil set in a slush bath[g]. A saphenous vein graft from aorta to the LAD was made, and the VSD closed. No graft to the posterior descending branch of the RCA was attempted because the myocardial tissue was poor. Warming of the patient was then initiated. Furosemide and mannitol were administered to encourage urine output. The heart was debubbled, and the cross-clamp removed after 87 minutes. The SVC caval tape was loosened, and the SVC cannula was pulled back into the right atrium. The femoral venous line was clamped and removed. The femoral vein was closed, and the IVC caval tape removed.

When the patient was fully rewarmed, volume was transferred from the cardiotomy reservoir to the patient, and the pump flow rate was gradually lowered. When the patient began ejecting adequately, CPB was terminated by clamping the arterial and then venous lines. The total pump time was 298 minutes. Although the patient had an initial arterial blood pressure of 85/58 mmHg, the posterior wall of both ventricles was completely akinetic and unable to contribute to the generation of an adequate cardiac output. As a result, the patient expired before leaving the operating room.

DISCUSSION

This case study shows that the conversion of femoral-femoral PCPB to femoral/SVC-femoral CPB with integrated cardiotomy suckers and cardioplegia delivery system can be safely and easily accomplished. Accordingly, switching to a traditional heart-lung machine set-up is not the only alternative for the perfusionist bringing a patient on PCPB into the operating for open-heart surgery. Such a switch can result in profound hemodilution requiring volume control techniques, such as hemofiltration and autotransfusion, and multiple homologous blood product transfusions. Profound hemodilution can compromise oxygen delivery to a patient while on CPB. Profound hemodilution can also contribute to intra-operative morbidity, such as post-CPB coagulopathies resulting from excessive dilution of platelets, fibrinogen, and clotting factors (19). Multiple homologous blood transfusions increase the patient's chances of a transfusion reaction and exposure to hepatitis, AIDS, and foreign antigens. The switch to a traditional bypass system may also require aortic cannulation which is not without risk. Lastly, the switch increases the cost of the procedure to the patient in a climate where burgeoning health care costs have become a national concern. It follows then that switching to a traditional heart-lung machine set-up may not always be necessary or prudent.

The converted PCPB system, on the other hand, can have potential drawbacks when compared to a traditional heart-lung machine set-up. Unfamiliarity with any new system, for instance, can increase the possibility of operator error; however, studious preparation and teamwork can usually eliminate such untoward occurrences. Both the unconverted (Figure 1) and converted (Figure 2) PCPB systems do not incorporate the safety mechanisms, which can include high pressure, low level, and air bubble alarms as well as an arterial line filter/bubble trap (ALFBT), listed in the suggested pre-bypass perfusion checklist of the American Society of Extracorporeal Technology (20).

The incorporation of safety alarms into the traditional heart-lung machine set-up helps ensure the uncomplicated conduct of CPB. Accordingly, the incorporation of high pressure, low level, and air bubble alarms into the PCPB systems described above constitutes a prudent measure. Unlike a roller pump, a centrifugal pump is afterload dependent and will not cause catastrophic overpressurization in the event of partial or total occlusion of the arterial line. The perfusionist could diagnose such an event by noting a high line pressure, normal centrifugal pump RPM, and little or no forward flow as measured by the electromagnetic flow probe in the arterial line. Nevertheless, the inclusion of a high pressure alarm would alert the perfusionist in a timely manner. A commercially available pressure monitoring/high pressure alarm system[h] can be connected to a sideport provided on the arterial line distal to the centrifugal pump (Figures 1 and 2) in lieu of the pressure monitoring line provided. The interface of a commercially available air bubble and low level detector[i] with the centrifugal pump console can be readily accomplished by a qualified factory or in-house biomedical engineer. The two sites of the converted PCPB system that have the highest potential for the generation of gaseous emboli are the venous cannulation site and the cardiotomy reservoir. Therefore, the air bubble detector should be placed on the venous line, and the low level detector on the minimum safe operating level of the

g Cobe Cardiovascular Inc., Arvada, CO 80004
h DLP Pressure Display 6000, Grand Rapids, MI 49501
i Sarns, 3M Health Care, Ann Arbor, MI 48103

cardiotomy reservoir. For optimal safety, the air bubble and low level detectors should be set to turn off the centrifugal pump when triggered. The use of the low level detector would not be necessary with the unconverted CPB system. The inclusion of these safety devices would not affect the set-up speed of the PCPB system in the event of the need for emergent cardiopulmonary resuscitation.

Most traditional heart-lung machine set-ups utilize ALFBTs to remove possible particulate and gaseous emboli (21). Numerous studies have reported conflicting results with respect to the efficacy of ALFBTs in reducing the incidence of neurological damage, particularly in circuits utilizing membrane oxygenators and filtered cardiotomy suction (22-24). Such scientific ambivalence with respect to the efficacy of ALFBT has lead to their exclusion from circuits used in special applications of CPB where the benefits of their exclusion have outweighed those of their inclusion. For example, ALFBTs are not incorporated into extracorporeal membrane oxygenation (ECMO) circuits because the low ACT times, maintained to avoid hemorrhagic complications, make ALFBTs a site of likely thrombus formation (24). Similarly, since one of the principle applications of PCPB is emergent cardiopulmonary resuscitation, ALFBTs are apparently not incorporated into commercially available PCPB systems because they inordinately extend the amount of time necessary to prime and debubble the circuit. Additionally, the PCPB circuit functions as an effective bubble trap. While the centrifugal pump will pass small air bubbles, a large bolus of air simply deprimes the pump and is not passed downstream. Any small bubbles passed downstream are trapped and vented by the membrane oxygenator used in the circuit (2,26-28).

The only potentially significant compromise involved with the use of a converted PCPB circuit that incorporates high pressure, air bubble, and low level alarms during an open or closed heart repair is the absence of an ALFBT. Clearly, it is incumbent upon the perfusionist to contemplate alternatives to switching patients on PCPB requiring emergent surgery to a traditional heart and lung machine set-up. This case study presents such an alternative.

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